Laboratory of Animal Nutrition and Animal Product Quality
Faculty of Bioscience Engineering

Laboratory of Animal Nutrition
Faculty of Veterinary Medicine

Ghent University

TECHNICAL REPORT submitted to EFSA

Selected trace and ultratrace elements: Biological role, content in feed and requirements in animal nutrition – Elements for risk assessment [1]

Prepared by Marleen VAN PAEMEL, Noël DIERICK, Geert JANSSENS, Veerle FIEVEZ, Stefaan DE SMET

Abstract

Up-to-date information on the authorisations granted in the EU and in relevant countries outside the EU, for human and/or animal nutrition for 27 selected trace and ultratrace elements is reported. Descriptive information is summarized on the biological role, bioavailability, metabolism and human toxicity for these elements. Numerical data from assessments by scientific bodies including animal requirements, maximum tolerable levels and upper intake levels are compiled. In addition, background concentrations of these elements in feed materials and complete feedingstuffs, and use levels are given. Data on these element concentrations in edible tissues and products as well as their concentrations in edible tissues and products linked with the dietary intake of the elements are also provided. Finally, where available, toxicological risks for user/worker and environment are indicated.

Key words: trace and ultratrace elements, feed, food, aluminium, arsenic, cadmium, cerium, chromium, cobalt, copper, boron, bromine, fluorine, iodine, iron, lanthanum, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silicon, silver, strontium, tin, vanadium, zinc

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Background

Regulation (EC) 1831/2003[2] establishes the rules governing the Community authorisation of additives for use in animal nutrition. In particular, recital number 14 of the mentioned regulation sets that "*In order to ensure a harmonised scientific assessment of feed additives, such assessment should be carried out by the European Food Safety Authority, established by Regulation (EC) 178/2002. [...]*". Article 7 of the above mentioned Regulation foresees that the applicant shall send to the EFSA the technical dossier supporting an application of a feed additive; and article 8 establishes that EFSA shall give an opinion for each valid application. The opinion shall account for the efficacy and the safety –for the target species, the consumer of the animal derived products, the worker/user (persons handling the additives), and the environment- of the feed additive. In Regulation (EC) 1831/2003, 5 categories of feed additives have been set, 4 of which are further subdivided into functional groups (see Art. 6 and Annex 1 of the above-mentioned Regulation). One of the feed additive categories is the "Nutritional additives" which includes the "Compounds of trace elements" as one functional group. In order to perform a risk assessment of any (ultra)trace element as a nutritional additive, either presently authorised and used or to be potentially used in the future (i.e. not being authorised yet), and in the context of this call for proposals, data on its function, metabolism and deposition, content in feed (straight feedingstuffs and compound feedingstuffs), animal requirements (including allowances and their use in practice) and some elements of risk assessment are needed.

Terms of reference

The objective of the call was for EFSA to acquire a document in which the scientific data and information on 27 selected trace and ultratrace elements in animal nutrition is collected and synthesized. The trace and ultratrace elements which were selected are aluminium, arsenic, cadmium, cerium, chromium, cobalt, copper, boron, bromine, fluorine, iodine, iron, lanthanum, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silicon, silver, strontium, tin, vanadium and zinc. More specifically the information request of the call comprised:

[2] OJ L 268, 18.10.2003, p.29

A. Collecting up-to-date information on the authorisations granted for 27 selected trace and ultratrace elements and their forms/sources, in the EU and relevant countries outside the EU (e.g., USA, Canada, Mexico, Australia, New-Zealand, Japan, China, India, Turkey, Russia, Brazil, Argentina, Thailand, Philippines),

B. Collecting up-to-date information on the biological role of 27 selected trace and ultratrace elements,

C. Collecting data on the background content of 27 selected trace and ultratrace elements in feed materials and in animal feed. If available, information on the analytical method used shall be included,

D. Collecting data on the requirements, including the allowances and use levels, of 27 selected trace and ultratrace elements for animal nutrition and

E. Collecting data on tolerance, metabolism and toxicology of the 27 selected trace and ultratrace elements.

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Preliminary to the report

Contents

Introduction to the preliminary and the sources that were consulted

For each of the chapters an identical methodology to collect data was applied. Firstly, available EFSA's, SCAN's and SCF's Opinions and reports were consulted. For the chapters 1 – 15, which are mainly a demand for information linked to livestock, relevant reports from the following established bodies and textbooks were consulted: NRC Nutrient Requirement Series; NRC Mineral Tolerance of Livestock, Gesellschaft für Ernährungsphysiologie Nutrient Requirement Series; INRA (2004); CVB Feed Table (2007); Underwood & Suttle (1999) and McDowell (2003). For the chapters 16 – 25 which are mainly a request for information on human toxicology, reports from the following established bodies and textbooks were consulted: Toxicological Profiles from the Agency for Toxic Substances and Disease Registry (ATSDR); Federal Institute for Risk Assessment (BfR); Expert Group on Vitamins and Minerals of the Food Standards Agency (EVM); Institute of Medicine (IOM); Nordberg *et al*. (2007).

This is a non restrictive list of information sources and data bases which have been included. In case no information was found it was verified that in the most recent reports published by these bodies there was no relevant information available. In the monographs it is then reported that no information was found in 'principal literature sources'. Consequently, it is thereby communicated to what extent the literature search was restricted.

The objective of this introduction is to give a concise summary of the followed methodology. For many chapters an effort was made to search and report on recent and relevant peer reviewed articles.

In this preliminary to the report it is firstly, more substantiated in detail which information sources have been used for each chapter and secondly, the policy in reporting the required information is clarified if considered necessary. The structure of this preliminary is identical to the format of the reports of the individual elements.

1 Forms/Sources of the element of importance in human and animal nutrition

Element compounds of importance as described in principal literature sources are reported.

2 Information on the authorization of use of the element –and which specific form or source– in human/animal nutrition

The authorization of use of the element compounds in human and animal nutrition are given for the EU and the US and for animal nutrition for Canada. For the US, the AAFCO 2010 Official Publication was used as information source (AAFCO, 2010). The provided information on authorization of use is restricted to these three countries due to difficulties in getting the information.

3 Essential functions

With the exception of cerium and lanthanum, NRC (2005) classified all elements object of the call into three possible categories namely, essential, non essential or possibly essential. With possibly essential NRC (2005) indicated that there are circumstantial data which suggest that the element might be essential but any mechanistic information is lacking. For each of these elements this NRC (2005) classification is reported in the monographs. Other principal literature sources were consulted to verify whether essentiality was beyond discussion. Essential trace elements often exert the majority of their functions in association with enzymes. If this mechanistic information is available, all or the most important enzymes or proteins are reported.

4 Other functions

Data available in principal literature sources are reported.

5 Antimicrobial properties

Reports from scientific bodies were screened for information on antimicrobial properties. If no antimicrobial properties of compounds of the element relevant for animal nutrition and/or used in animal husbandry are described in these reports, it is stated in the monograph that no information was found in principal literature sources. Hence, it cannot be excluded that there are indications to be found in peer reviewed literature on antimicrobial properties. It was reasoned that if no information is available in recent reports of scientific bodies that there might not be a substantial body of evidence.

6 Typical deficiency symptoms

For essential elements deficiency symptoms are given for several livestock species.

7 Animal requirements, allowances and use levels

For the essential elements Co, Cu, Fe, I, Mn, Se and Zn, requirements are established for livestock species (categories) by several scientific bodies. These data are collected in Annex 3. The species categories are given as defined/described by the respective scientific bodies which implies that the 'template Annex 3' as part of the call was slightly modified.

The data sources include: CVB (2007 b), GfE (1995), GfE (1999), GfE (2003), GfE (2008), NRC (1993), NRC (1994), NRC (1998), NRC (2000), NRC (2001), NRC (2006), NRC (2007), NRC (2007 b), Meschy (2007). For the other elements object of this call there is no Annex 3 included in the report.

The remaining elements include elements which are essential, possibly essential and non essential. For essential and possibly essential elements any requirements found in reports from established bodies and peer reviewed articles are reported in the monograph.

The above mentioned scientific bodies did not publish any animal allowances for trace elements except for dogs and cats (NRC, 2007). All the available data on animal allowances are included in Annex 3.

For the elements allowed as feed additives in the EU information on use levels was requested. Use levels should give an idea of the total concentration of the element in complete animal feeds and diets. Three sources contribute to the total content of an element in complete feed, i.e. feed materials (background levels), the premix and possibly an additional supplementation of a specific element. The information on use levels had to be acquired from the industry. Three major premix companies were contacted. All three companies have a similar methodology to develop supplementation recommendations and their premix compositions. It can be summarized as follows:

- A trace element composition table of feed materials is used to calculate background levels in compound feeds. These feed material element composition tables are primarily based on data published by an established body, e.g., CVB. The CVB values are updated, on a regular basis, using data from own monitoring analysis of feed materials.
- Once a background level range for a compound feed is simulated based on the element composition data of the composing feed materials, recommendations for supplementation by the premix are issued taking into account a safety margin to stay within the maximum legally allowed concentrations.

The contacted companies all have contracts with CVB and could for IP reasons not provide the feed material trace element composition data. The companies were willing to deliver their own analysis data, but extracting these data from the tables would be very time consuming. In addition, it is unclear how many data are available from own analysis. One premix company provided their background level calculations and their supplementation recommendations. Use levels were calculated as the sum of the maximum background level and the supplementation recommendation. These values are presented and compared to the maximum legally allowed amounts in Annex 3.2.

Although the calculated use levels are probably reliable estimates, it is clear from the made inquiries that actual ‘use levels’ are not well known. The premix companies and compounders did not have any monitoring data of the trace element composition of complete compound feeds. There was no information obtained on the actual supplementation by the compounders. The extent to which the supplementation recommendations issued by the premixers are actually followed by the compounders remains unknown.

8 Concentration of the element in feed materials

For the elements Co, Cu, Fe, I, Mn, Mo, Se and Zn, data published in the feed material composition tables of CVB (2007) and INRA (2004), are collected in Annex 4. The feed material descriptions used by these bodies are given which implies that the ‘template Annex 4’ as part of the call was slightly modified. CVB (2007) and INRA (2004) used spectroscopic methods adapted for each element to determine element concentrations in feed materials.

For the other elements data available in principal literature sources are listed in the monograph.

9 Concentration of the element in complete feedingstuffs

For the elements Co, Cu, Fe, I, Mn, Mo, Se and Zn background levels were calculated for a list of species categories as requested in Annex 5. Background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. Hence, a background level simulation implies combining data of trace element composition tables of feed materials with complete feedingstuff composition data. The simulations were done using one representative complete feedingstuff for each species category. These representative complete feedingstuff composition data were acquired from the feed industry or were taken from peer reviewed articles. Two background level simulations were done for each representative complete feedingstuff using two different feed material composition tables, namely CVB (2007) and INRA (2004). It has to be stressed that these tables do not contain trace element concentrations for all composing feed materials of the complete feedingstuffs. These tables do also not contain element concentrations for mineral sources. For the mineral sources element concentrations were used from Batal and Dale (2008).

The following data are reported in Annex 5:

- # Feed materials: number of feed materials in the complete feedingstuff;
- Mass with element concentration (%): the mass percent of the complete feedingstuff for which an element concentration is available in the trace element composition table;
- # Feed materials with element concentration: the number of feed materials in the complete feedingstuff for which an element concentration is available in the trace element composition table;
- Element concentration (mg/kg): the calculated background levels.

Differences between the two simulated background level values for the same complete feedingstuff are due to differences in the feed material element composition data (CVB (2007) vs. INRA (2004)) and to differences in the availability of data between these two tables. It is pointed out that, in accordance with the above given definition, premixes are not included as trace element sources in the background level calculations.

For the elements Co, Cu, Fe, I, Mn, Mo, Se and Zn the Addendum to the monograph substantiates the data reported in Annex 5. They provide the following information for each calculated background level:

- The element concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008);
- The feed material composition of the complete feedingstuff;
- The contribution of each of the composing feed materials to the total calculated element content of the complete feedingstuff.

Hence, the Addenda to the monographs contain one sheet for each calculated background level reported in Annex 5.

For the other elements object of this call background levels found in peer reviewed articles are reported.

10 Tolerance of animal species and Maximum Tolerable levels (MTL)

The NRC established, or attempted to establish, MTL values for the elements object of this call with the exception of cerium and lanthanum (NRC, 2005). These MTL values are listed in this chapter together with the conjoint remarks. Additionally, information on differences in sensitivity for the element between species is given.

11 Typical symptoms of toxicosis

Descriptive information on toxicosis symptoms in livestock reported on in principal literature sources is given.

12 Bioavailability

12.1 General

Quantitative data on the absorbability of various element compounds are reported. Information is primarily taken from review reports and textbooks. For the elements Co, Cu, Fe, I, Mn, Mo, Se and Zn a compilation of the information available in Jongbloed *et al*. (2002) is given. Generally, this includes assessments of the relative biological value of various element compounds for pigs, poultry and ruminants.

12.2 Indicators of element status

For the elements Co, Cu, Fe, I, Mn, Mo, Se and Zn the ranking of adequacy of several response criterions for assessing relative biological value of the element is given as reported by Jongbloed *et al*. (2002). If any compound of the element has been evaluated by the FEEDAP Panel, it is reported which status indicators have been used in the described animal experiments in the FEEDAP Opinions.

13 Metabolism

Descriptive and quantitative information is given for absorption, transport, distribution, deposition and excretion of the element. The metabolism of specific element compounds is described when relevant, i.e., in case of nonmetallic and metalloid elements. For quantitative information on absorbability the reader is referred to Chapter 12 Bioavailability.

14 Distribution in the animal body

If available, information is given on how the total amount of the element present in the body is distributed between various tissues. For tissue concentrations the reader is referred to Chapter 15.

15 Deposition (typical concentration) in edible tissues and products

Knowledge on typical concentrations and accumulation in edible tissues and products of the element is an important tool for risk assessment and consumer protection. For the majority of the elements two additional annexes were prepared in which data were collected. Annex 1 contains data from peer reviewed articles on typical concentrations of the element in meat, liver, kidney, muscle, milk, eggs and honey. The peer reviewed articles are mainly monitoring studies and total diet studies. Annex 2 contains data from peer reviewed articles on concentrations in edible tissues and products linked with dietary concentrations of various compounds of the element. The peer reviewed articles are principally feed trials. The following trial parameters of these studies are reported in Annex 2: species category, element compound, supplementation level, background level in the control feed, duration of the trial, element concentration in edible tissues and products.

16 Acute toxicity

Acute toxicity symptoms are reported. Furthermore, oral LD_{50} values for various element compounds from animal experiments are given.

17 Genotoxicity and Mutagenicity

Summarized results from *in vitro* assays on genotoxicity and mutagenicity of element compounds are reported. As far as available in the consulted toxicology reports, the test system, the element compounds and the result of the assay are given.

18 Subchronic toxicity

Often the available data on subchronic toxicity are not as 'subchronic' reported on in toxicological reports. The ATSDR published Toxicological Profiles for a series of elements object of the call. These very comprehensive reports organized the available toxicological data according to route of exposure (oral, inhalation, dermal) and affected organ system. It was considered opportune in these cases to refer to the toxicological report and not to reclassify some of the data as subchronic toxicity.

19 Chronic toxicity, including carcinogenicity

Data available in principal literature sources are reported.

20 Reproduction toxicity

Data available in principal literature sources are reported.

21 Non observed adverse effect level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

The following scientific bodies and reports were consulted: BfR (2006), EFSA / SCF, EVM (2003), IOM (2001). If an assessment was done by these bodies it is included in the monograph. The following items are reported if an UL was established: critical toxicological endpoint, NOAEL / LOAEL, uncertainty factor, UL for several live stage categories. If a scientific body considered the available data insufficient for the setting of an UL it is also mentioned in the report.

23 Toxicological risks for user/workers

It was considered that the main route of exposure in occupational settings is by inhalation. Hence, the reported information on toxicological risks for users and workers was primarily extracted from inhalation exposure chapters found in toxicology reports, e.g., ATSDR.

24 Toxicological risks for the environment

Reported information is restricted to risks or consequences for the environment linked to the use of compounds of the element as a feed additive. Principal literature sources were consulted. Available monitoring data on concentrations of the element in manure are given.

25 References for The preliminary to the report

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Aluminium

Executive summary of the monograph for aluminium

Numerous aluminium compounds are presently authorized in the EU as food and feed additives.
NRC did not classify aluminium as a required nutrient and did not find any conclusive evidence that aluminium is essential for growth, reproduction or survival of animals. Contrarily, in a limited number of studies the induction of deficiency symptoms provoked by aluminium deprivation has been described. Natural dietary aluminium intake in livestock is high. Aluminium concentrations in compound feed are reported to generally vary between 100 – 600 mg/kg DM. For grazing animals the ingestion of soil may lead to an aluminium consumption as high as 1.5 % of their dry matter intake.
NRC established a maximum tolerable level (MTL) of 1000 mg Al/kg DM for livestock species. Fish species have been reported to be sensitive to aluminium, especially in acidic water. Though, the NRC considered the available data to be insufficient to set a MTL for fish. In livestock toxicosis caused by a chronic excessive aluminium intake is primarily manifested by a reduced phosphorus and fluoride utilization. Toxicity of ingested aluminium is rarely a matter of concern as long as gut and kidney functions are normal.
The gastrointestinal tract is an excellent barrier to the entry of aluminium in the body. In humans the absorbability of orally ingested aluminium generally varies between 0.05 and 0.3%.
Ingested aluminium is absorbed in the upper intestine. Plasma aluminium is mainly associated with transferrin. Aluminium may enter the brain through the blood brain barrier. Approximately 95 % of the absorbed aluminium is excreted by the kidneys. Retained aluminium accumulates primarily in bone.
The acute toxicity of various aluminium compounds is low with reported oral LD_{50} values ranging between 162 – 980 mg Al/ kg bw in mice and rats. In most short term mutagenic assays aluminium compounds have produced negative results. In a recent EFSA Opinion it was considered unlikely that aluminium is a human carcinogen at exposure levels relevant to dietary intake. Toxicity studies have identified the nervous system as the most sensitive target of aluminium toxicity. Encephalopathy associated with long term dialysis and Alzheimer's Disease are pathologies for which there is a well documented link with the neurotoxicity of aluminium. EFSA and WHO established a tolerable weekly intake of 1 mg Al/(kg bw.week). Inhalation exposure to aluminium compounds was reported to have resulted in pulmonary fibrosis and astma. There were no indications that the use of aluminium compounds as feed additives would have an impact on the environment.

Aluminium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

The aluminium compounds authorized in human and animal nutrition are considered those of importance in human and animal nutrition (Chapter 2).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal nutrition

Aluminium compounds presently authorized in the EU as feed additives (Council Directive 70/524/EEC[1]) and as feedingstuffs intended for the reduction of milk fever (Commission Directive 2008/4/EC[2]) are listed in Table 1.

Table 1 Aluminium compounds authorized as feed additives (subclassification: binders, anticaking agents and coagulants) according to Council Directive 70/524/EEC[1] and Commission Directive 2008/4/EC[2]

EC No	Additive	Species or category of animal : Maximum content mg/kg of complete feedingstuff
E 554	Sodium aluminosilicate, synthetic	All species or categories of animals
E 558	Bentonite-montmorillonite	All species or categories of animals: 20000
E 559	Kaolinitic clays, free of asbestos	All species or categories of animals
E 560	Natural mixtures of steatites and chlorite	All species or categories of animals
E 561	Vermiculite	All species or categories of animals
E 566	Natrolite-phonolite	All species or categories of animals : 25000
E 598	Synthetic calcium aluminates	Poultry, rabbits, pigs: 20000 Dairy cows, cattle for fattening, calves, lambs, kids: 8000
E 599	Perlite	All species or categories of animals
	Zeolite (synthetic sodium aluminium silicate)	Dairy cows

In the US, the AAFCO adopted from the Code of Federal Regulations the following aluminium compounds its Official Publication: Aluminium ammonium sulphate (582.1127), Aluminium potassium sulphate (582.1129), Aluminium sodium sulphate (582.1131), Aluminium calcium silicate (582.2122), Hydrated

[1] OJ C 50, 25.2.2004, p. 1

[2] OJ L 6, 10.1.2008, p. 4

sodium calcium aluminosilicate (582.2729). These compounds are not specifically defined by AAFCO. They are listed in the Code of Federal Regulations as Substances Generally Recognized as Safe in Animal Feeds, Subpart B: General Purpose Food Additives and Subpart C: Anticaking Agents. Aluminium sulphate (582.1125) is allowed as 'Special Purpose Product' without quantitative restrictions (AAFCO, 2010).

2.2 *Human nutrition*

Aluminium compounds are presently authorized in the EU:

- As food additives other than colours and sweeteners (Council Directive 95/2/EC[3]). The authorized aluminium compounds are: E 520 aluminium sulphate; E 521 aluminium sodium sulphate; E 522 aluminium potassium sulphate; E 523 aluminium ammonium sulphate; E 541 sodium aluminium phosphate, acidic; E 554 sodium aluminium silicate, E 555 potassium aluminium silicate, E 556 calcium aluminium silicate, E 559 aluminium silicate.

- Aluminium, E173, is presently authorized as colour for use in foodstuffs (Council Directive 94/36/EC[4]).

In the US the Code of Federal Regulations grants the generally recognized as safe status to various aluminium compounds for their use as food additives, namely: General Purpose Food Additives: aluminium sulphate (582-1125), aluminium ammonium sulphate (582.1127), aluminium potassium sulphate (582.1129), aluminium sodium sulphate (582.1131); Anticaking Agents: aluminium calcium silicate (582.2122), sodium aluminosilicate (582.2727).

3 Essential functions

The NRC (2005) classified aluminium as not required and did not find any conclusive evidence that suggested that aluminium is essential for growth, reproduction, or survival of animals. No biological function has yet been assigned to aluminium (Kawahara *et al*., 2007; Verstraeten *et al*., 2008).

4 Other functions or effects

The FEEDAP Panel concluded in its assessment that zeolite (sodium aluminosilicate, synthethic) is effective in reducing the risk of milk fever (EFSA, 2007).

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[3] OJ L 61, 18.3.1995, p.1

[4] OJ L 237, 10.9.1994, p.13

5 Antimicrobial properties

There were no data available in principal literature sources.

6 Typical deficiency symptoms

Although NRC (2005) classified aluminium as non essential, apparent deficiency signs have been found in animal studies. Depressed growth was observed in chicks. Increased spontaneous abortions, depressed growth, incoordination and weakness in hind legs, and decreased life expectancy were observed in goats (Anke *et al*., 2005; Nielsen, 1996).

7 Animal requirements, allowances and use levels

Anke *et al*. (2005) published a normative dietary requirement of animals : < 10 mg Al/(kg DM). Additionally, these authors concluded that the aluminium requirement of animals and man is satisfied by the natural aluminium offer.

8 Concentration of the element in feed materials

SCAN (2003) compiled data on aluminium concentrations in feed materials (Table 2). Normally in pastures aluminium concentrations are lower than 100 mg/(kg DM). Under unfavorable conditions values can be much more than 1000 mg/(kg DM). Grazing animals ingest considerable amounts of soil, sometimes over 10 percent of their total dry matter intake. This could result in an aluminium consumption as high as 1.5 % of the diet dry matter (SCAN, 2003).

Table 2 Aluminium concentrations (mg/kg) in feed materials (SCAN, 2003)

Feed material	**Al concentration**
Grain products	5 – 68 DM
Sugar beet pulp and mollasses	115 – 550 DM
Meat and bone meal	100 – 500 DM
Fish meal	35 – 350 DM
Soft phosphates	15000

9 Concentration of the element in complete feedingstuffs

Aluminium concentrations in complete feed of dairy cattle, fattening bulls, sheep and horses was reported to vary between 100 – 600 mg/kg DM (SCAN, 2003). More data on aluminium concentrations in complete feedingstuffs are compiled in Table 3

Table 3 Aluminium concentrations (mg/kg) in complete feeds of various livestock species

Species	**Major feed components**	**Al concentration**	**Reference**
Lambs	Ground corn, cotton seed hulls, corn starch	370 DM	Felix *et al*. (2008)
Lambs	Ground corn, cotton seed hulls, corn starch	168 DM	Valdivia *et al*. (1982)
Calves	Milk replacer	117	Turner *et al*. (2008)
Steers	Ground corn, cotton seed hulls, soybean seeds	210 DM	
Laying hens	Ground corn, soybean meal	260	Wisser *et al*. (1990)

10 Tolerance of animal species and Maximum Tolerable levels (MTL)

MTL values for aluminium established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels (MTL) (mg/kg DM) for aluminium (NRC, 2005)

Species	**MTL**	**Additional remarks**
Rodents,	200	
Poultry, cattle, sheep	1000	
Swine, horses	1000	Value derived from interspecies extrapolation
Fish	-	Data were insufficient to set a MTL

11 Typical symptoms of toxicosis

Toxic effects of chronic (> 2 weeks) oral exposure to aluminium appear to be related to aluminium effects on general growth, longevity or on the utilization of essential elements. Excessive chronic dietary aluminium intake might reduce phosphorus and fluoride utilization (NRC, 2005). Fish are very sensitive to aluminium in acidic water. Reduced feed consumption, weight loss and increased mortality have been observed (NRC, 2005).

12 Bioavailability

The gastrointestinal tract is an excellent barrier to the entry of aluminium in the body. Absorbability of orally ingested aluminium is generally extremely low, though it varies widely. An overview of the different types of dietary sources of aluminium, estimates of ingested quantity and absorbability is given in Table 5.

Table 5 Dietary aluminium sources and estimates of average intake and absorbability (Krewski *et al*., 2007)

Source	**Aluminium concentration**	**Daily intake (mg)**	**Average absorbability (%)**
Food	0.01 – 400 mg/kg	Females (> 14 y): 7.2 ± 0.3 Males (> 14 y): 8.6 ± 0.7	0.05 – 0.1
Drinking water	< 200 µg/L	0.16	0.3
Antacids	110 – 174 mg/tablet	120 - 7200	0.3
Buffered aspirin		200 - 1000	0.3

Aluminium absorbability is determined by the aluminium compound and by the presence of dietary ligands. Citrate is the primary absorption promoter (ATSDR, 2008; Berthon, 1996). Identified dietary constituents and factors that influence aluminium absorption are summarized in Table 6.

Table 6 Factors that affect aluminium absorption (adapted from ADTSR, 2008; Berthon, 1996; Krewski *et al*., 2007)

Chelating agents	Inhibitors	Phosphate, dissolved silica
	Promotors	Carboxylic acids, e.g. citric acid, lactatic acid and ascorbic acid
Metal ion interactions	Antagonisms	Calcium Iron (iron status)

ATSDR (2008) discussed possible biomarkers for the quantification of exposure to aluminium in humans. Exposure levels cannot be accurately related to serum or urine levels. High aluminium urine levels are an indication of high exposure levels. Though, quantification is difficult as much of the aluminium is rapidly excreted (ATSDR, 2008).

13 Metabolism

Ingested aluminium is absorbed in the upper intestine. Absorption mechanisms include passive and active transport across intestinal cells and paracellular diffusion between these cells. Citrate, which is generally recognized as the primary absorption promoter, may enhance aluminium absorption through the paracellular pathway by increasing permeability between cells (Sjögren *et al*., 2007). In the blood aluminium is approximately equally distributed between plasma and erythrocytes. Plasma aluminium is mainly associated with transferrin (> 90%) and citrate (~ 7 – 8 %) (Krewski *et al*., 2007; Sjögren *et al*., 2007). Tissue and organ aluminium uptake occurs via binding of the aluminium transferrin complex to the transferrin receptor, following the same internalization pathway as iron. Aluminium will enter the brain through the blood brain barrier. It has been put forward that the brain aluminium influx consists of two components namely, a transferrin receptor-mediated endocytosis of aluminium transferrin and a transferrin-independent mechanism influxing aluminium citrate (Sjögren *et al*., 2007; Verstraeten *et al*., 2008). The blood brain barrier has an active efflux of aluminium through a monocarboxylate transporter to counteract aluminium deposition in the brain (Verstraeten *et al*., 2008). Aluminium is primarily excreted by the kidneys (95 %). Hence, reduced renal function dramatically increases aluminium accumulation. Biliary secretions account for 2 % of aluminium elimination. A small fraction of aluminium could be retained in the body for years (Krewski *et al*., 2007; Sjögren *et al*., 2007).

14 Distribution in the animal body

Aluminium is not equally distributed between various tissues. In humans oral exposure studies investigating the distribution amongst various tissues revealed the following tissue accumulation order: bone (60%), lung (25%), muscle (10%), liver (3%) and brain (1%) (Krewski *et al*., 2007). Likely, the observed distribution of aluminium between different organs can be linked to differences in density of their transferrin receptors (ATSDR, 2008).

15 Deposition (typical concentration) in edible tissues and products

A compilation of aluminium concentrations in edible tissues and products is given in Annex 1. Aluminium concentrations in edible tissues and products linked with the dietary intake of various aluminium compounds and doses is reported in Annex 2.

Reported tissue levels (Annex 1) range between 0.07 – 8.92 mg/kg for milk, 0.26 – 0.3 mg/kg for muscle (poultry), 0.1 – 0.14 mg/kg for eggs, 0.51 – 13 mg/kg for fish.

16 Acute toxicity

The acute toxicity of aluminium compounds is relatively low (Krewski *et al*., 2007). Oral LD_{50} values are compiled in Table 7.

Table 7 Oral LD_{50} values (mg Al/kg bw) for various aluminium compounds (ATSDR, 2008)

Aluminium compound	**Species**	**LD_{50}**
Aluminium bromide	Sprague-Dawley rats	162
	Swiss Webster mice	164
Aluminium nitrate	Sprague-Dawley rats	261
	Swiss Webster mice	286
Aluminium chloride	Sprague-Dawley rats	370
	Swiss Webster mice	222
	Dobra Voda mice	770
Aluminium sulphate	Dobra Voda mice	980

17 Genotoxicity and Mutagenicity

Aluminium compounds have produced negative results in most short term mutagenic assays (ATSDR, 2008; Krewski *et al*., 2007; Sjögren *et al*., 2007). ATSDR (2008) summarized results from *in vitro* assays of genotoxicity of aluminium (Table 8). EFSA (2008) noted that the observed mechanisms of genotoxicity of aluminium compounds occurred at relatively high levels of exposure and that it is unlikely that they are relevant for humans exposed to aluminium via the diet.

Table 8 Results of *in vitro* genotoxicity assays of aluminium compounds (ATSDR, 2008)

Test system	**End point**	**Result**
Salmonella typhimurium	Gene mutation	-
Escherichia coli	DNA damage	-
Bacillus subtilis	Rec assay	-
L5178Y mouse lymphoma cells	Forward mutation	-
Syrian hamster embryo cells	Transformation assay	-
Rat ascites hepatoma cells	DNA cross-linking	+
Human peripheral blood lymphocytes	Micronuclei formation	+
Human peripheral blood lymphocytes	Chromosome abberations	+

18 Subchronic toxicity

EFSA (2008) summarized subchronic toxicity studies of various aluminium compounds (Table 9).

Table 9 Effects of subchronic oral exposure to various aluminium compounds (mg Al/(kg bw.day)) (EFSA, 2008)

Aluminium compound	Species	Duration	Concentration	Symptoms
Aluminium nitrate	Rats	28 d	104	Mild histopathological changes in spleen and liver
Aluminium nitrate	Rats	100 d	261	Decreased body weight, no histopathological changes
Aluminium hydroxide, sodium aluminium phosphate	Rats	28 d	140 – 300	No effects
Acidic sodium aluminium phosphate	Beagles	26 w	88 - 93	No effects
Basic sodium aluminium phosphate	Beagles	26 w	75	Male dogs: decreased food consumption, decreased body and testis weight; histopathological changes in liver and kidney. Female dogs: no effects

19 Chronic toxicity, including carcinogenicity

Toxicity studies have identified the nervous system as the most sensitive target of aluminium toxicity and most aluminium studies have focused on neurotoxicity and neurodevelopmental toxicity. There is substantial evidence that high aluminium concentrations cause oxidative stress for which the nervous system is particularly vulnerable (ATSDR, 2008, Verstraeten *et al*., 2008).

Aluminium toxicity occurs most frequently in patients with reduced renal function who accumulate aluminium as a result of long term intravenous hemodialysis therapy. Long term use of aluminium containing medications may provoke adverse effects in healthy people. Encephalopathy associated with long term dialysis and Alzheimer's Disease are pathologies for which there is a well documented link with the neurotoxicity of aluminium. The bone constitutes a primary site for deposition of aluminium. Elevated aluminium levels in humans have been associated with several bone disorders including osteomalacia and aplastic bone disease. (ATSDR, 2008; Krewski *et al*., 2007; Sjögren *et al*., 2007).

EFSA (2008) concluded that aluminium is unlikely to be a human carcinogen at exposures relevant to dietary intake. To reach this conclusion, EFSA (2008) took into account that there is no epidemiological evidence for carcinogenicity of aluminium compounds used therapeutically and that the IARC concluded that aluminium itself is unlikely to be a human carcinogen, despite the observation of an association between inhalation exposure to aluminium dust and aluminium compounds during production / processing and cancer in workers.

20 Reproduction toxicity

Reproductive consequences of aluminium only occur in cases of excessive high exposure (Krewski *et al*., 2007). The ATSDR (2008) reported not to have located any studies regarding reproductive effects nor developmental effects following acute-, or chronic-duration oral aluminium exposure in healthy humans.

In general, high doses of aluminium nitrate, chloride, or lactate given by gavage were observed to induce some signs of embryotoxicity in mice and rats, in particular, reduced fetal body weight or pup weight at birth and delayed ossification (EFSA, 2008).

An overview of some reproductive and developmental toxicity studies of aluminium compounds is given in Table 10 (EFSA, 2008).

Table 10 Summary of some reproductive and developmental toxicity studies of various aluminium compounds tested in animals (EFSA, 2008)

Aluminium compound / ***Exposure route***	**Species**	**Dose (mg Al/(kg bw.day))**	**Duration**	**Effect**
Aluminium nitrate and aluminium chloride *Intraperitoneal or subcutaneous*	Mice			Testicular toxicity; decreased sperm quality; reduced fertility
Aluminium chloride / *gavage*	Rabbits, male	6.4	16 w	Reduced testicular weight; impaired semen quality
Sodium aluminium phosphate / *diet*	Beagles, male	75	26 w	Decreased testicular weight; degeneration of germinal epithelium
Aluminium lactate / *oral administration*	Mice	57.58		Developmental toxicity: congenital malformation

21 Non observed adverse effect level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

For setting a tolerable intake for all dietary aluminium sources, EFSA (2008) selected neurodevelopmental toxicity observed in mice as a critical endpoint. EFSA stated that there was a lack of a clear dose-response relationship from the available studies and that consequently there are uncertainties in defining reliable NOAELs and LOAELs for the toxicity of aluminium. Two approaches were adopted to calculate a

Tolerable Daily Intake (TDI) (Table 11). Additionally, the EFSA took into account the cumulative nature of aluminium in the organism after dietary exposure. Hence, it was concluded that a Tolerable Weekly Intake (TWI) is more appropriate to be established rather than a TDI (Table 11). Finally, a TWI value of 1 mg Al/(kg bw.week) was established (EFSA, 2008). This strategy is in agreement with the procedure adopted by the Joint FAO/WHO expert committee, which established a provisional tolerable weekly intake (PTWI) value of 1 mg Al/(kg bw.week), which applies to all aluminium compounds in food, including additives (WHO, 2007). The Committee recommended that provisions for aluminium containing additives should be compatible with this PTWI value (WHO, 2007).

Table 11 Non Observed Adverse Effect Levels (NOAEL), Lowest Observed Adverse Effect Levels (LOAEL), Uncertainty Factors (UF) used by EFSA (2008) to establish Tolerable Daily Intake (TDI) for aluminium (EFSA, 2008)

Approach 1: Critical endpoint: neurodevelopmental toxicity in mice		
LOAEL = 50 mg Al/(kg bw.day)	UF = 100; inter and intra species variations; UF = 3 for using a LOAEL instead of a NOAEL; $UF_{combined}$ = 300	TDI = 0.17 mg Al/(kg bw.day)
Approach 2: Critical endpoint: neurodevelopmental toxicity in mice		
NOAEL = 10 mg Al/(kg bw.day)	UF = 100; inter and intra species variations;	TDI = 0.10 mg Al/(kg bw.day)

23 Toxicological risks for user/workers

Occupational exposure to aluminium powder has resulted in pulmonary fibrosis. It is the most commonly reported respiratory effect observed in workers exposed to fine aluminium dust, alumina (aluminium oxide), or bauxite. However, conflicting reports are available on the fibrogenic potential of aluminium.

In bauxite or potroom workers it is likely that the simultaneous exposure to silica was the causative agent rather than the aluminium exposure (ATSDR, 2008; Sjögren *et al*., 2007).

Astma has been associated with the inhalation of aluminium sulphate, aluminium fluoride and potassium aluminium tetrafluoride (Sjögren *et al*., 2007).

ATSDR (2008) located a number of studies where the neurotoxic potential of aluminium was investigated in workers chronically exposed to aluminium dust. None of these studies reported overt signs of neurotoxicity. Subjective neurological symptoms, e.g., incoordination, problems concentrating, headaches, depression, fatigue, were reported in aluminium potroom or foundry workers at aluminium smelters and aluminium welders.

24 Toxicological risks for the environment

Aluminium silicates are clay minerals which occur naturally in the environment. In its assessment of zeolite, the FEEDAP Panel considered it unlikely that the spreading of manure from treated animals will significantly alter the concentration of aluminium silicate in agricultural soil. Hence, it was concluded that the use of Zeolite does not pose a risk for the environment (EFSA, 2007). There was no other relevant information available on the environmental consequences of the use of aluminium as a feed additive in other principal literature sources.

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Annex 1: Aluminium concentrations in edible tissues and products

Table 1.1 Aluminium concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Dairy cattle	4				5.65 - 8.92	Ayar *et al* . (2009)
Dairy cattle	48				0.098	Anderson (1992)
Dairy cattle	16				0.19	Leblanc *et al* . (2005)[a]
Dairy cattle	3				0.07 - 0.1	Santos *et al* . (2004)[a]
Dairy cattle					0.07	Ysart *et al* . (2000)[a]

[a]: Total diet study

Table 1.2 Aluminium concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Poultry		0.26 [b]			0.1 [c]	Leblanc *et al* . (2005)[a]
Poultry		0.3			0.14	Ysart *et al* . (2000)[a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.3 Aluminium concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	5.36 DM	Alasalvar *et al* . (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	6.61 DM	
Fish	62	0.51	Leblanc *et al* . (2005) [a]
Shellfish	18	17.1	
Fish	3	3.7 - 13	Santos *et al* . (2004) [a]
Brushtooth lizardfish *Saurida undosquamis*	45	0.831 DM	Türkmen *et al* . (2005)
Red mullet *Mullus barbatus*	45	2.228 DM	
Gilthead seabream *Sparus aurata*	45	0.919 DM	

[a]: Total diet study

Table 1.4 Aluminium concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Holzing (AU)	23	0.57	Pechhacker *et al* . (2009)
Origin: Neustadt (AU)	25	0.56	
Origin: Hollabrunn (AU)	19	0.36	

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Annex 2: Aluminium concentrations in edible tissues and products linked with the dietary intake of various aluminium compounds and doses

Table 1 Aluminium concentrations in edible tissues and products (mg/kg)

Species / category	Source of Al supplemented	Al content of complete feed [1] (mg Al/kg)	Duration of study	Liver	Kidney	Reference
Lambs	10 % sand	910 DM	111 d	15.4 ^{c}	7.2 ^{cd}	Van Alstyne (2007)
	9.3 % sand + 0.7 % AlCl3	2320 DM		22.3 ^{cd}	9.4 ^{c}	
	7.5 % sand + 2.5 % WTR	2270 DM		16.7 ^{c}	7.1 ^{cd}	
	5 % sand + 5 % WTR	3970 DM		20.9 ^{cd}	7.5 ^{cd}	
	10 % WTR	7860 DM		25.3 ^{d}	5.4 ^{d}	

[1]: data from feed analyses; WTR: water treatment residual, i.e., by-products from a water purification procedure that contain high amounts of Al.
Statistics : Van Alstyne *et al* .(2007): means within columns lacking a common letter differ (P < 0.05);

Table 1 (continued) Aluminium concentrations in edible tissues and products (mg/kg)

Species / category	Source of Al supplemented	Dose of Al supplemented (mg Al/kg)	Al content of complete feed [1] (mg Al/kg)	Duration of study	Liver	Kidney	Muscle	Egg	Reference
Lambs			370 DM	100 d	543 DM	130 DM	120 DM		Felix *et al* . (2008)
	WTR[2]	2800	3000 DM		608 DM	106 DM	86 DM		
	WTR[2]	11000	12000 DM		596 DM	141 DM	105 DM		
	$AlCl_3$	2000	3100 DM		686 DM	121 DM	141 DM		
Lambs			168 DM	56 d	2.64	2.37	2.33		Valdivia *et al* . (1982)
	$AlCl_3.6H_2O$	2000			6.7	4.66	4.08		
Calves			117	39 d	3.5 DM	7.4 DM			Turner *et al* . (2008)
	sodium zeolite		130325		65 DM	55.4 DM			
Steers (beef type)			210.00 DM	84 d	7.6	4.5	3.8		Valdivia *et al* . (1978)
	$AlCl_3.6H_2O$	300			5.7	4.1	3.9		
	$AlCl_3.6H_2O$	600			10	6.0	5.4		
	$AlCl_3.6H_2O$	1200			11.2	5.4	4.7		

[1]: data from feed analyses; [2]: Water treatment residual (11.1 % Al); Sodium zeolite = aluminosilicate
Statistics: Turner *et al* . (2008): Al concentrations in liver and kidney : treatment group significantly different from control (P< 0.0001).
Valdivia *et al* . (1978): Al concentrations in all tissues tended to increase when dietary aluminium increased but trends were not significant statistically
Felix *et al* . (2008): Liver, kidney and muscle Al concentrations do not differ significantly
Valdivia *et al* . (1982): Al concentration in the liver differs significantly (P < 0.1).

Table 1 (continued) Aluminium concentrations in edible tissues and products (mg/kg)

Species / category	**Source of Al supplemented**	**Dose of Al supplemented (mg Al/kg)**	**Al content of complete feed [1] (mg Al/kg)**	**Duration of study**	**Liver**	**Kidney**	**Muscle**	**Eggs**	**Reference**
Laying hens		0	260	119 d				11.9	Wisser *et al* . (1990)
	$Al_2(SO_4)_3$	1500						11.6	
	$Al_2(SO_4)_3$	3000						11.8	

Statistics: Wisser *et al* . (1990): Al concentrations in eggs are not significantly different ($P > 0.05$).

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Arsenic

Executive summary of the monograph for arsenic

EU legislation governs the maximum content for arsenic in feedingstuffs. Arsenic is generally not accepted as an essential nutrient for higher animals. Studies with goats, chicks, hamsters and rats suggest that it may have an essential or a beneficial function in ultra trace amounts. Some organic arsenicals, e.g., roxarsone, have been used extensively as growth promoters for pigs and poultry because of their antibiotic and anticoccidial properties. Although arsenic is generally not accepted as an essential nutrient, apparent deficiency signs and beneficial effects have been found in animal studies. The most consistent signs of arsenic deprivation in rats and mice have been decreased S-adenosylmethionine (SAM), and increased S-adenosylhomocysteine (SAH) concentrations in the liver, and a decreased SAM/SAH ratio. Arsenic is relatively nontoxic to domestic animals. Rats and chicks are sensitive to inorganic arsenic compared to other species and pigs are relatively more sensitive to organic arsenic. Fish are less tolerant to dietary inorganic arsenic than mammals. Signs of chronic arsenic intoxication include depressed growth, feed efficiency and feed intake, convulsions, uncoordinated gait, and decreased hemoglobin. Apparently, arsenic carcinogenicity is not an issue for domestic animals. Both human and animal data indicate that more than 90 % of an ingested dose of dissolved inorganic trivalent or pentavalent arsenic is absorbed from the gastrointestinal tract. Organic arsenicals, namely, monomethylarsonic acid (MMA), dimethylarsinic acid (DMA) and organic arsenic compounds in seafood, are also readily absorbed (75 – 85 %). Seafood and fish have been identified as major source of arsenic in the human diet. In seafood and fish, arsenic is present predominantly in the organic forms of arsenobetaine and arsenocholine, which are virtually non-toxic. The carry-over of arsenic in its inorganic form into edible tissue of mammals and poultry is low. Food derived from terrestrial animals contributes only insignificantly to human exposure.

The toxicity of arsenic compounds depends on the chemical form and valence: inorganic forms are much more toxic than organic arsenicals, and trivalent arsenic is more toxic than pentavalent arsenic. Signs of acute arsenic toxicity include vomiting, oesophagal and abdominal pain and bloody diarrhea. In humans, arsenic is a chromosomal mutagen, i.e., an agent that induces mutations involving more than one gene, typically large deletions or rearrangements. In combination with many genotoxic agents, including ultraviolet light, arsenic is a synergistic co-mutagen. The genotoxicity of arsenic is due largely to the trivalent arsenicals. Inhalation exposure to arsenic may affect several organ systems. The implementation of the actual EU legislation, fixing maximum arsenic contents in feedingstuffs, limits the contribution of arsenic originating from animal excreta in the soil and the aquatic environment.

Arsenic Monograph

1 Forms/Sources of the element of importance in human and animal nutrition

Arsenic is a metalloid, displaying different valences (-3, 0, +3, +5) resulting in a broad variety of arsenic compounds with diverse chemical characteristics (Table 1) (EFSA, 2005).

Epidemiological data indicate that the most important source of arsenic exposure is contaminated ground water. Arsenic in ground water is primarily in inorganic form. Terrestric plants may accumulate arsenic as inorganic arsenic compounds, following uptake from the soil and groundwater via the roots and by absorption of airborne arsenic deposited on the leaves (EFSA, 2005). Organic arsenic compounds such as arsenobetaine, arsenocholine, tetramethylarsonium salts, arsenosugars and arsenic containing lipids are mainly found in marine organisms. Subsequently, seafood and fish have been identified as major sources of human food exposure (EFSA, 2005). Arsenobetaine accounts for >80 % of the total arsenic content in many types of seafood (Lorenzana *et al*., 2009).

Table 1 Concise summary of common naturally occurring arsenic compounds (EFSA, 2005)

Valence	Inorganic Arsenic species	Valence	Organic Arsenic species
III	As trioxide, arsenous oxide	V	Monomethylarsonic acid (MMA)
III	Arsenous acid (arsenites)	V	Dimethylarsinic acid (DMA)
V	As pentoxide	III	Arsenobetaine (AsB)
V	Arsenic acid (arsenate)	V	Trimethylarsine oxide (TMAO)
		III	Arsenocholine ion (AsC)
		III	Trimethylarsine (TMA)
		III	Tetramethylarsonium ion ($MeAs^{+}$)
		III	Trimethylarsoniumpropionate (TMAP)
		V	Phenylarsonic acid (PAA)
		V	Arsenosugars Dimethylarsinoylriboside, Trimethylarsonioriboside

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

Presently, in the EU the Directive 2002/32/EC[1] amended by the Directive 2009/141/EC[2] on undesirable substances in animal feed governs the maximum content for arsenic in feedingstuffs (see Table 2).

[1]OJ L 140, 30.5.2002, p. 10

[2] OJ L 308, 24.11.2009, p. 20

Table 2 Maximum allowed total arsenic (*) (**) content in feedingstuffs in the EU according to Directive 2002/32/EC[1] and Directive 2009/141/EC[2]

Products intended for animal feed	Maximum content in mg/kg (ppm) relative to a feedingstuff with a moisture content of 12 %
Feed materials, except:	2
Meal made from grass, from dried lucerne and from dried clover, dried sugar beet pulp and dried molasses sugar beet pulp	4
Palm kernel expeller	4 (***)
Phosphates and calcareous marine algae	10
Calcium carbonate	15
Magnesium oxide	20
Feedingstuffs obtained from the processing of fish or other marine animals, including fish	25 (***)
Seaweed meal and feed materials derived from seaweed	40 (***)
Iron particles used as tracer	50
Additives belonging to the functional group of compounds of trace elements, except:	30
Copper sulphate pentahydrate, copper carbonate	50
Zinc oxide, manganese oxide and copper oxide	100
Complete feedingstuffs, except:	2
Complete feedingstuffs for fish and complete feedingstuffs for fur animals	10 (***)
Complementary feedingstuffs, except:	4
Mineral feedingstuffs	12

*: The maximum levels refer to total arsenic

**: Maximum levels refer to an analytical determination of arsenic, whereby extraction is performed in nitric acid (5% w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency.

***: Upon request of the competent authorities, the responsible operator must perform an analysis to demonstrate that the content of inorganic arsenic is lower than 2 mg/kg. This analysis is of particular importance for the seaweed species *Hizikia fusiforme*.

3 Essential functions

Arsenic is generally not accepted as an essential nutrient for higher animals. However, responses to apparent arsenic deprivation have been reported for a variety of animal species. Hence, it may have an essential or beneficial function in ultra trace amounts. It has been suggested that arsenic affects the methylation of molecules whose functions are dependent on or influenced by methyl incorporation and has a function in methionine metabolism (NRC, 2005; Uthus, 2003).

4 Other functions

Some organic arsenicals have been used extensively as growth promoters for swine and poultry because of their antibiotic and anticoccidial properties. Roxarsone (3-nitro-4-hydroxyphenylarsonic acid) is still used in the feed of broiler poultry to control coccidial intestinal parasites, improve feed efficiency, and promote rapid growth (NRC, 2005). Additionally, phenylarsonic acid, arsanilic acid, 4-nitrophenylarsonic acid and 4-ureidophenylarsonic acid are reported to be used in various countries for the same reasons (EFSA, 2005).

5 Antimicrobial properties

The antimicrobial properties of some arsenic compounds are discussed in Chapter 4.

6 Typical deficiency symptoms

Although the NRC (2005) states that arsenic is generally not accepted as an essential nutrient, apparent deficiency signs and beneficial effects have been found in animal studies. The most consistent signs of arsenic deprivation in rats and mice have been decreased S-adenosylmethionine (SAM), and increased S-adenosylhomocysteine (SAH) concentrations in the liver, and a decreased SAM/SAH ratio.(Uthus & Seaborn, 1996). Nielsen (1996) summarized the observed deficiency signs in various species (Table 3).

Table 3 Reported deficiency signs of arsenic (Nielsen, 1996)

Species	**Deficiency signs**
Chick	Depressed growth
Goat	Depressed growth and serum triglycerides, abnormal reproduction characterized by impaired fertility and elevated perinatal mortality, death during lactation with myocardial damage
Hamster	Depressed plasma taurine and hepatic S-adenosylmethionine and elevated hepatic S-adenosylhomocysteine
Pig	Depressed growth and abnormal reproduction characterized by impaired fertility and elevated perinatal mortality
Rat	Depressed growth and abnormal reproduction, depressed hepatic putrescine, spermidine, spermine, and S-adenosylmethionine, and elevated hepatic S-adenosylhomocysteine

7 Animal requirements, allowances and use levels

Established scientific bodies did not publish any arsenic requirements for livestock species.

8 Concentration of the element in feed materials

Arsenic concentrations vary and plants growing on arsenic rich soils can accumulate much higher levels. In practice, most feed of terrestrial origin contains less than 0.3 mg/kg DM and rarely exceeds 1 mg/kg DM (SCAN, 2003). EFSA (2005) reported on total arsenic concentrations in feed materials (Table 4).

Table 4 Total arsenic concentration (mg/kg DM) in certain feed materials (EFSA, 2005)

Feed material	n	Mean
Fish meal	95	4.7
Fish oil	7	7.6
Oil seed meals	17	0.09
Maize grain, maize by-products	7	0.26
Other cereals and cereal by-products	47	0.06
Grass silage	28	0.12
Hay	2	0.05
Maize silage	2	0.05
Straw	4	0.05
Minerals and mineral supplements (unspecified)	42	6.8

9 Concentration of the element in complete feedingstuffs

EFSA (2005) reported on total arsenic concentrations in complete feedingstuffs and complementary feedingstuffs, obtained as part of routine surveillance in a number of member states (Table 5).

Table 5 Concentrations of total arsenic (mg/kg DM) in commercial complete feedingstuffs for farm livestock and fish (EFSA, 2005)

Species	n	Mean
Pigs < 17 weeks	19	0.72
Pigs (growers / finishers)	4	0.31
Pigs (sows)	15	0.85
Poultry layers	3	0.20
Poultry broilers	5	0.34
Ruminants beef	10	0.36
Ruminants dairy	12	0.24
Fish	421	4.25

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

According to NRC (2005) rats and chicks are relatively sensitive to inorganic arsenic compared to other species and pigs are relatively more sensitive to organic arsenic. Fish are less tolerant to dietary inorganic arsenic than mammals (NRC, 2005). The MTL established by NRC (2005) are compiled in Table 6.

Table 6 Maximum Tolerable Levels (MTL) for arsenic (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Rodents	30	
Poultry, swine, horse, cattle, sheep	30	Value derived from interspecies extrapolation
Fish	5	

Additionally to the arsenic MTL values NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

The signs of acute arsenic toxicosis include intense abdominal pain, vomiting, diarrhea, weakness, staggering gait, hypothermia and death (NRC, 2005). Chronic oral arsenic toxicosis in domestic animals is seldom reported. Signs of chronic arsenic intoxication include depressed growth, feed efficiency and feed intake, convulsions, uncoordinated gait, and decreased hemoglobin. Apparently, arsenic carcinogenicity is not an issue for domestic animals (NRC, 2005).

12 Bioavailability

12.1 General

Both human and animal data indicate that more than 90 % of an ingested dose of dissolved inorganic trivalent or pentavalent arsenic is absorbed from the gastrointestinal tract (EFSA, 2005; Fowler *et al.*, 2007). Gastrointestinal absorption of highly insoluble forms of arsenic is much lower, e.g., for arsenic trisulfide and lead arsenate absorbability values of 20 – 30 % have been reported in human studies (ATSDR, 2007; EFSA, 2005). Organic arsenicals, namely, monomethylarsonic acid (MMA), dimethylarsinic acid (DMA) and organic arsenic compounds in seafood, are readily absorbed (75 – 85 %) (Fowler *et al*., 2007). Absorbability is lower in ruminant species which is most likely caused by pre-systemic methylation of arsenic in the rumen (EFSA, 2005).

12.2 Arsenic status indicators

Arsenic is cleared from the blood within a few hours and blood arsenic concentrations reflect exposures only within the very recent past. Measurement of urinary arsenic levels is generally accepted as the most reliable indicator of recent arsenic exposure in human populations.

13 Metabolism

Generally, arsenic compounds are readily absorbed from the gastrointestinal tract (see 12. Bioavailability). Following absorption, arsenic is distributed between plasma and the erythrocytes, in which it is bound to the globin moiety of hemoglobin. The relative distribution between blood plasma and erythrocytes depends on the valence and dose of arsenic administered, as well as on the animal species (EFSA, 2005).

Absorbed arsenate is reduced to arsenite, either pre-systemically or in blood. Arsenite undergoes oxidative methylation in the liver by addition of a carbonium ion from S-adenosylmethionine, resulting in the formation of MMA (V). The pentavalent arsenic is then reduced to the trivalent form MMA (III). Formation of MMA (III) facilitates the addition of a second carbonium ion via oxidative methylation to yield DMA (V) that is generally considered as endpoint of arsenic biotransformation (EFSA, 2005; Fowler *et al*., 2007).

Ingested organoarsenicals are less extensively metabolized and are rapidly excreted (EFSA, 2005). Arsenobetaine is apparently not biotransformed *in vivo* but excreted as such mainly in urine. Arsenocholine is, to a great extent, oxidized to arsenobetaine (Fowler *et al*., 2007).

Arsenic and its metabolites are readily excreted in urine and bile. Arsenate is primarily eliminated via urine. In contrast, arsenite is excreted more into bile than urine (EFSA, 2005). Studies in humans indicate that ingested MMA and DMA are excreted mainly in urine (75 – 85 %) (ATSDR, 2007).

14 Distribution in the animal body

Arsenic is widely distributed in the body with the highest amounts in skin, hair, and nails. Probably this results from arsenite binding to SH groups of proteins such as keratin that are relatively plentiful in these tissues. Organs highest in arsenic are kidney and liver. These organs also accumulate the highest amount of arsenic when excessive amounts are ingested (NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

Seafood and fish have been identified as major source of arsenic in the human diet. In seafood and fish, arsenic is present predominantly in the organic forms of arsenobetaine and arsenocholine, which are virtually non-toxic (EFSA, 2005; NRC, 2005). The carry-over of arsenic in its inorganic form into edible tissue of mammals and poultry is low. Food derived from terrestrial animals contributes only insignificantly to human exposure (EFSA, 2005). Arsenic concentrations in edible tissues and products derived from monitoring studies and total diet studies are compiled in Annex 1 and concentrations linked with the dietary arsenic intake are reported in Annex 2.

16 Acute toxicity

The toxicity of arsenic compounds depends on the chemical form and valence: inorganic forms are much more toxic than organic arsenicals, and trivalent arsenic is more toxic than pentavalent arsenic. Hence, LD_{50} values differ dramatically between inorganic and organic arsenic compounds (Table 7) (EFSA, 2005; IARC, 2004).

Table 7 Oral LD_{50} values (mg As/kg bw) for various arsenic compounds (adapted from ATSDR, 2007; EFSA, 2005)

Arsenic compound	Species	LD_{50}
Inorganic arsenicals		
Arsenic trioxide	rodents	15 – 26
Inorganic (As^{3+}), single dose	rats	15 – 145
Calcium arsenate, single dose	rats	112
Organic arsenicals		
MMA	rodents	916
MMA, single dose	rats	2449 – 3184
DMA	rodents	648
DMA, single dose	mice	1200
Arsenobetaine	rodents	5500

Signs of acute toxicity include vomiting, oesophagal and abdominal pain and bloody diarrhea (EFSA, 2005).

17 Genotoxicity and Mutagenicity

The genotoxicity of arsenic is due largely to the trivalent arsenicals. In humans, arsenic is a chromosomal mutagen, i.e. an agent that induces mutations involving more than one gene, typically large deletions or rearrangements. Arsenic appears to have limited ability to induce point mutations (IARC, 2004). In combination with many genotoxic agents, including ultraviolet light, arsenic is a synergistic co-mutagen (IARC, 2004).

Inorganic arsenicals

Studies in human fibroblasts, lymphocytes, and leukocytes, mouse lymphoma cells, Chinese hamster ovary cells, and Syrian hamster embryo cells demonstrate that *in vitro* arsenic exposure can induce chromosomal aberrations and sister chromatid exchange. *In vitro* studies in human, mouse, and hamster cells have also been positive for DNA damage and repair and enhancement or inhibition of DNA synthesis (ATSDR, 2007).

Organic arsenicals

Several tests indicate that dimethylarsinic acid and roxarsone may be able to cause chromosome aberrations, mutations, and DNA strand breaks. *In vitro* studies with monomethylarsonic acid did not find significant increases in the occurrence of chromosome aberrations, forward or reverse mutations, unscheduled DNA synthesis (ATSDR, 2007)

18 Subchronic toxicity

The ATSDR Toxicological profile of arsenic includes information on the subchronic toxicity of several arsenic compounds on several organ systems and by several exposure routes (ATSDR, 2007).

19 Chronic toxicity, including carcinogenicity

19.1 Carcinogenicity

The IARC (2004) categorized arsenic in drinking water as carcinogenic to humans (Group 1). It was concluded that there is sufficient evidence in humans that arsenic in drinking water causes cancers of the urinary bladder, lung and skin. Several different mechanisms of arsenic-induced carcinogenicity have been proposed, and the trivalent species are implicated in most of these mechanisms. It should be noted, however, that trivalent species are formed *in vivo* after exposure to pentavalent arsenic. Methylated trivalent arsenic is more toxic, and genotoxic, than trivalent inorganic arsenic. In contrast, methylated pentavalent arsenic is less toxic, and genotoxic, than pentavalent inorganic arsenic (IARC, 2004). The proposed mechanisms of arsenic induced carcinogenesis include genotoxicity, altered DNA repair, induction of oxidative stress, altered DNA methylation, cell transformation, altered cell proliferation, altered cell signaling, altered steroid receptor binding and gene expression and enhanced gene amplification (IARC, 2004).

19.2 Other

The most distinct characteristic of arsenic toxicity is the classical cutaneous manifestations, including hyperpigmentation with depigmentation and palmoplantar hyperkeratosis. The symptoms have been consistently observed among those with occupational, environmental and medicinal exposures to arsenic through ingestion and inhalation (Fowler *et al*., 2007). Long-term low-dose exposure to ingested arsenic was reported to induce various gastrointestinal symptoms, including gastroenteritis, dyspepsia, nausea, diarrhea, anorexia, and abdominal discomfort (Fowler *et al*., 2007). Hepatic effects of chronic arsenic exposure include liver cirrhosis, portal hypertension without cirrhosis, and fatty degeneration (Fowler *et al*., 2007). Long-term exposure to arsenic has a general depressant effect on the hematopoietic system (Fowler *et al*., 2007).

Various cardiovascular symptoms have been linked to long-term arsenic exposure, including electromyographic abnormalities, peripheral, coronary, and cerebral artery diseases, carotid atherosclerosis, hypertension, and microcirculation abnormality (Fowler *et al*., 2007).

20 Reproduction toxicity

Inorganic arcenicals

In humans multiple studies associated exposure to arsenic in drinking water with increased spontaneous abortions, stillbirth, and preterm birth (ATSDR, 2007). In rats exposed to 0.24 mg As.(kg.day)$^{-1}$ for 28 days the following observations were made: decreased wet weights of ovary and uterus, inhibition of steroidogenic enzymes, decreased ovarian and uterine peroxidase activities, and decreased estradiol levels (ATSDR, 2007). Teratogenic effects have been shown to occur after administration of sodium arsenate to pregnant golden hamsters. Both reabsorption and malformation rates in the fetus increased with increasing doses of arsenate. The teratogenic effects were characterized by anencephaly, renal agenesis, and rib malformations. Similar teratogenic effects have been induced in mice and rats. In all cases the doses that provoked these teratogenic effects resulted in significant maternal toxicity or even lethality (Fowler *et al*., 2007).

Organic arsenicals

ATSDR (2007) did not locate any studies regarding reproductive effects nor regarding developmental effects in humans after oral exposure to organic arsenicals. In multiple studies that evaluated the reproduction toxicity of MMA, DMA and roxarsone in laboratory animals no histological alterations in male and female reproductive tissues were observed (ATSDR, 2007). In contrast, functional alterations have been reported in animals exposed to MMA and DMA, including a decrease in estrus in dogs and a decrease in pregnancy rate and male fertility index in rats (ATSDR, 2007). The developmental toxicity of organic arsenicals has been investigated in rats and rabbits for MMA and in rats, mice and rabbits for DMA. MMA was reported to have caused decreased fetal weights and increased incidence of fetuses with incomplete ossification of thoracic vertebrae in rats, an increased number of fetuses with supernumerary thoracic ribs and eight lumbar vertebrae in rabbits. DMA was reported to have provoked a decrease in fetal weight, a delay in ossification, a decrease in maternal body weight gain and an increase in the occurrence of diaphragmatic hernia in rats. Mice are less sensitive than rats to the developmental toxicity of DMA (ATSDR, 2007).

21 Non observed effect level (NOEL)

SCF, EVM, IOM and BfR did not establish an upper intake level for arsenic. Hence, no NOAEL level was identified to serve as the basis to establish an UL.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

SCF, EVM, IOM and BfR did not establish an upper intake level for arsenic. ATSDR (2007) established Minimal Risk Levels (MRL) which are defined as estimates of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. Oral exposure MRLs of several arsenic compounds established by ATSDR (2007) are compiled in Table 8.

Table 8. Oral exposure Minial Risk Levels for several arsenic compounds established by ATSDR (2007)

Arsenic compound	Duration of exposure	Oral MRL
Inorganic arsenic	≤ 14 d	0.005 mg As/(kg bw.day)
Inorganic arsenic	≥ 365 d	0.0003 mg As/(kg bw.day)
MMA	15 – 364 d	0.1 mg MMA/(kg bw.day)
MMA	≥ 365 d	0.01 mg MMA/(kg bw.day)
DMA	≥ 365 d	0.02 mg DMA/(kg bw.day)

23 Toxicological risks for user/workers

Most information on human inhalation exposure to arsenic derives from occupational settings such as smelters and chemical plants, where the predominant form of airborne arsenic is arsenic trioxide dust (ATSDR, 2007). An overview of pathologies and symptoms caused by inhalation exposure to arsenic are listed in Table 8.

Table 8 Effects of oral exposure to arsenic (ATSDR, 2007)

As compound	Species	Organ system	Symptoms and signs
Inorganic	Humans	Respiratory	Irritation of mucous membranes of nose and throat, laryngitis, bronchitis, rhinitis
	Rats	Respiratory	Irritation and hyperplasia in the lungs
Organic, DMA and MMA	Rats mice	Respiratory	Respiratory distress, Neither DMA nor MMA is considered a potent respiratory irritant
Inorganic	Humans	Cardiovascular	Increased incidence of Raynauds's phenomenon (peripheral vascular disease), increased vascospasticity in response to cold, increased systolic blood pressure.
Inorganic	Humans	Gastrointestinal	Nausia, vomiting, diarrhea, likely caused by mucociliary transport of arsenic dust from the lungs to the gut
Organic, DMA and MMA	Rats mice	Gastrointestinal	Diarrhea
Inorganic	Humans	Dermal	Hyperkeratosis, hyperpigmentation
Inorganic	Humans	Ocular	Chemical conjunctivitis, characterized by redness, swelling and pain
Inorganic	Humans	Neurological	Peripheral neuropathy
Inorganic	Humans	Developmental	Increased incidence of spontaneous abortion, increased incidence of congenital malformations, decreased average birth weight
Inorganic	Humans	Cancer	Increased incidence of lung cancer

24 Toxicological risks for the environment

Arsenic is present in all types of soils. Apart from the geological origin, arsenic in soil also comes from emissions from coal fired power plants, smelters, use in wood preservation and the now discontinued use of arsenical pesticides. Wide ranges of arsenic concentrations have been found in rivers and lakes and drinking water. The arsenic content of plants is determined by arsenic exposure *via* soil, water, air, fertilizers and other chemicals, the geological origin of the soil, and the species. Some organic arsenic compounds (*e.g.* arsanilic acid, 4-nitrophenylarsonic acid and 3-nitro-4-hydroxyphenylarsonic acid and their salts) have been used as feed additives for disease control and improvement of weight gain in swine and poultry in concentrations of 100 mg/(kg feed) since the mid 1940s. Their use has been abandoned in Europe but they are still in use in third countries such as USA (SCAN, 2003).

The toxicology of arsenic, including the environmental fate, has been fully documented by ATSDR (2007).

The implementation of the actual EU legislation (Directive 2003/100/EC[3]), fixing maximum arsenic contents in feed materials, limits the contribution of arsenic originating from animal excreta in the soil and the aquatic environment. Arsenic concentrations in manure are compiled in Table 9.

Table 9 Arsenic content of manure from several species

Species, category	**As content (mg/kg)**	**Reference**
Dairy cattle FYM	1.63 DM	Nicholson *et al*. (1999)
Dairy cattle slurry	1.44 DM	
Beef cattle FYM	0.79 DM	
Beef cattle slurry	2.60 DM	
Pig FYM	0.86 DM	
Pig slurry	1.68 DM	
Broiler / turkey	9.01 DM	
Layer	0.46 DM	
Broiler	4.9 DM	van Ryssen (2008)
Layer	2.5 DM	
Poultry	15.65	Jackson *et al*. (2003)

FYM: Farm yard manure

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Glossary

AsB: Arsenobetaine

AsC: Arsenocholine ion

DMA: Dimethylarsinic acid

$MeAs^+$: Tetramethylarsonium ion

MMA: Monomethylarsonic acid

PAA: Phenylarsonic acid

SAH: S-adenosylhomocysteine

SAM: S-adenosylmethionine

TMA: Trimethylarsine

TMAO: Trimethylarsine oxide

TMAP: Trimethylarsoniumpropionate

Annex 1 : Arsenic concentrations in edible tissues and products

Table 1.1 Arsenic concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pigs (6 m)	62	0.003	0.01	0.011	López-Alonso *et al*. (2007)
Pigs		0.0240	0.023	0.019	Uneyama *et al*. (2007) [a]

[a] : References herein

Table 1.2 Arsenic concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Veal	438	0.00427	0.0428			Alonso *et al*. (2002)
Beef cattle	56	0.00511				
Dairy cattle	16				0.003	Leblanc *et al*. (2005) [a]
Dairy cattle	40				0.0379	Licata *et al*. (2004)
Calves, male	229	0.00369	0.00958	0.00974		Alonso *et al*. (2000)
Calves, female	198	0.00383	0.0123	0.0134		
Cows	56	0.00425	0.0102	0.0152		
Calves	312	0.00446	0.0496	0.0663		Miranda *et al*. (2003)
Cattle, free range	100		0.016	0.025		Nriagu *et al*. (2009)
Cattle	97	0.023	0.017	0.043		Waegeneers *et al*. (2009)
Dairy cattle					0.0004	Ysart *et al.* (2000)

[a] : Total diet study

Table 1.3 Arsenic concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Poultry		0.022 [b]			0.008 [c]	Leblanc *et al*. (2005) [a]
Hens, private owners	22				0.01595	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.013	
Hens					< 0.008	Waegeneers *et al*. (2008)
Poultry		0.004			0.0009	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c]: Eggs and egg products (n = 30)

Table 1.4 Arsenic concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Carp		0.016 - 0.07	Casto-González & Méndez-Armenta (2008)[a]
Tench		0.028 - 0.101	
Sval		0.034 - 0.121	
Grey mullet		0.255 - 0.42	
Eel		0.084 - 0.124	
Sardine		3.53 - 3.94	
Tuna		0.99 - 1.25	
Anchovy		3.93 - 5.52	
Mackerel		1.73 - 7.47	
Swordfish		1.78 - 2.44	
Salmon		1.60 - 2.37	
Hake		3.22 - 4.55	
Red mullet		15.39 - 17.77	
Sole		4.55 - 8.40	
Cuttle fish		2.45 - 5.33	
Atlantic herring	3	1.4	Engman & Jorhem (1998)
Baltic herring	3	0.84	
Burbot	2	0.13	
Cod	4	2.6	
Eel	2	0.35	
Mackerel	4	1.8	
Perch	3	0.26	
Picked dogfish	1	5.4	
Pike	5	0.15	
Plaice	3	13	
Pollack	2	1.2	
Salmon	3	0.69	
Turbot	3	1.30	
Whitefish	3	0.19	
Fish	62	2.237	Leblanc *et al* . (2005)[b]
Shellfish	18	1.926	
Finfish		total: 0.728 - 31.7 inorganic: 0.003 - 0.49	Lorenzana *et al* . (2009)[a]
Shellfish		total: 0.81 - 67.9 inorganic: 0.001 - 2.43	

[a]: references herein; [b]: Total diet study

Table 1.5 Arsenic concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Bangladesh	2	0.0182	Al Rmalli *et al* . (2005)
Origin: Siena County (It)	51	0.00696	Pisani *et al* . (2008)

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Annex 2: Arsenic concentrations in edible tissues and products linked with the dietary intake of several arsenic compounds and doses

Table 1 Arsenic concentrations in edible tissues and products of poultry (mg/kg)

Species / category	Source of As supplemented	Dose of As supplemented (mg As/kg)	As content of complete feed [1] (mg As/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Laying hens	3-nitro-4hydroxyphenylarsonic acid (Roxarsone)	0		28 d	0.15 [e]			0.0264 [e]	Chiou *et al*. (1997)
		11			1.005 [d]			0.0463 [d]	
		22			1.609 [c]			0.0750 [c]	
		44			2.177 [b]			0.1451 [b]	
		88			3.429 [a]			0.2452 [a]	
Laying hens	Arsenic oxide (III)	0		12 d				white: 0.003 yolk: 0.001	Holcman & Stibilj (1997)
		7.5						white: 0.223 yolk: 0.073	
		15.0						white: 0.419 yolk: 0.143	
		30.0						white: 0.991 yolk: 0.301	
Japanese quail	4- arsanilic acid	0.0	0.37 DM	30 d	0.38 DM [x]	0.38 DM [x]	breast: 0.06 DM [x] leg: 0.12 DM [x]	0.13 DM [x]	Desheng & Niya (2006)
		17.3			0.81 DM [y]	1.51 DM [y]	breast: 0.39 DM [y] leg: 0.49 DM [y]	0.34 DM [y]	
		34.5			1.35 DM [z]	2.34 DM [z]	breast: 0.58 DM [z] leg: 0.64 DM [z]	0.50 DM [z]	

As content of complete feed [1]: data from feed analysis

Statistics : Chiou *et al* . (1997): Means with different superscripts are significantly different ($P<0.05$)

Desheng & Nia (2006): means with common superscripts do not differ significantly ($P < 0.05$), Anova

Table 1 (continued) Arsenic concentrations in edible tissues and products of cows (µg/kg)

Species / category	Source of As supplemented	Dose of As supplemented (mg As/day)	Duration of study	Liver	Kidney	Muscle	Reference
Cows		3.4	90 d	10	35	5	RIVM (1990)
	Arsenic trioxide	33		100	160	30	

Annex 2 References

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Boron

Executive summary of the monograph for boron

Boron compounds are presently authorized in the EU as food additives. Boron has not been established to be an essential nutrient for humans and no specific biochemical function for boron has been identified in higher animals or man. NRC classified boron as a possibly essential nutrient. Observed responses to boron deprivation suggest that boron has a role in maintaining structural integrity and, or function of cell membranes. Boron has a well documented effect on bone calcification and maintenance. Boron deprivation has been reported to cause developmental defects in fish and frogs. Boron intakes in the form of boric acid and borates that are approximately 100 to 1000 fold greater than normal are needed to induce reproductive and developmental toxicity in animals. Hence, it is unlikely that boron toxicity under normal environmental conditions is a concern for animals. Signs of boron toxicosis include decreased body, pancreas, spleen and kidney weight. Boron has been shown to cause specific adverse effects in the male reproductive tract in all species. Orally ingested boron, i.e., borate or boric acid, is readily and almost completely absorbed from the gastrointestinal tract (> 90%). Boron does not accumulate in the soft tissues. Contrarily, it accumulates in bone. The primary route of elimination is by glomerular filtration and >90 % of the administered dose is excreted via urine, regardless of the route of exposure or administration. NRC stated that boron is not deposited in any edible animal tissue or product to an extent that it would be a potential toxicological concern for humans. In humans lethal doses of boron are reported to be in the range of 400 – 900 mg/kg bw. The genotoxic potential of boric acid and borax was tested in multiple *in vitro* assays. The results indicate that boric acid and borax are not genotoxic. Chronic intake of boron doses between 2.5 mg/(kg bw.day) and 24.8 mg/(kg bw.day) are reported to have dermatitis, alopecia, anorexia, and ingestion. Oral exposure studies in laboratory animals have identified the developing fetus and the testes as the two most sensitive targets of boron toxicity in multiple species. Upper intake levels for boron of 10 mg/day and 20 mg/day for adults were established by EFSA and IOM, respectively. Occupational studies of workers exposed to dusts of sodium borates have identified irritation of the respiratory tract and eyes, without measurable changes in pulmonary function. There are no indications that the presence of boron in animal diets would have an environmental impact.

Boron Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Boron is a naturally occurring element that is found in the form of borates in the oceans, sedimentary rocks, coal, shale, and some soils. In nature boron is found only in compounds, for example with sodium and oxygen in borax ($Na_2B_4O_7.10\ H_2O$). In aqueous solution at near-neutral pH, monomeric boric acid [$B(OH)_3$] is the most common species present, regardless of whether the boron source is boric acid or borate. Boron occurs in food as borate or boric acid (EFSA, 2004).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

Boron compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[1]. The authorized boron compounds are: sodium borate, boric acid.

- As food supplements under Regulation EC 1170/2009[2]. The authorized boron compounds are: boric acid, sodium borate.

- As substances which may be added to foods under Regulation 1170/2009[2]. The authorized boron compounds are: boric acid, sodium borate.

3 Essential functions

Boron has not been established to be an essential nutrient for humans and no specific biochemical function for boron has been identified in higher animals or man (EFSA, 2004; IOM, 2001). The NRC (2005) classified boron as a possibly required nutrient based on the availability of circumstantial data that indicate the possibility that the element is essential but mechanistic information is lacking. A wide range of responses associated with a low intake of boron probably represent secondary effects of the primary action of the element. Observed responses to boron deprivation suggest that boron has a role in maintaining structural integrity and, or function of cell membranes (Nielsen, 2008).

4 Other functions

The best-documented effect of boron is on calcium metabolism or utilization, and thus, bone calcification and maintenance (EFSA, 2004). For humans, boron intakes of 1 - 3 mg/day compared to intakes between

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[1] OJ L 269, 14.10.2009, p. 9

[2] OJ L 314, 1.12.2009, p. 36

0.25 and 0.50 mg/day have beneficial effects on bone and brain health (Nielsen, 2008). Boron has been shown to increase certain steroid hormones, e.g., estrogen, testosterone. Hence, it may play a role in the prevention of chronic diseases such as coronary heart disease, arthritis and osteoporosis (Devirian & Volpe, 2003). Results from studies with rats and pigs indicate a role of boron in immune function. In humans an increased boron consumption has been associated with an decreased incidence of several types of cancer (Hunt, 2008).

5 Antimicrobial properties

Borates are used in disinfectants. Boromycin, a boroester, is an antibiotic produced by a strain of *Streptomyces antibioticus* (Hunt, 2008; RIVM, 2010).

6 Typical deficiency symptoms

Boron deprivation has been reported to cause developmental defects in fish and frogs. These effects have not been found consistently in rodent models (EFSA, 2004; IOM, 2001). Additionally, deprivation has been reported to cause an increased urinary calcium excretion in humans and animals. Boron deficiency exacerbates the signs of vitamin D_3 deficiency (Devirian & Volpe, 2003).

7 Animal requirements, allowances and use levels

Established scientific bodies did not publish any boron requirements for livestock species.

8 Concentration of the element in feed materials

The boron content of terrestrial plants varies between 2 and 95 mg/kg (NRC, 2005). Plant species within the subclass dicotyledoneae contain much more boron than do species from the subclass monocotlyledoneae e.g., barley: 2.3 mg B/kg DM; rice: 0.09 mg B/kg (Hunt, 2008; Moseman, 1994).

9 Concentration of the element in complete feedingstuffs

Data on boron concentrations in complete feedingstuffs are compiled in Table 1.

Table 1 Boron concentrations (mg/kg) in complete feedingstuffs of various species

Species	**Major feed components**	**B concentration**	**Reference**
Laying hens		3	Wilson & Ruszler (1998)
Mallard ducks	Duck developer mash	8 DM	Smith & Anders (1989)
Fisher rats	NIH-07 certified feed	< 20	Ku *et al*. (1991)

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Intakes of boron in the form of boric acid and borates that are approximately 100 – to 1000 – fold greater than normal are needed to induce reproductive and developmental toxicity in animals. Thus, other than waterfowl in specific habitats, it is unlikely that boron toxicity under normal environmental conditions is a concern for animals. Rainbow trout is considered to be the most sensitive fish species (NRC, 2005). The MTL established by NRC (2005) are compiled in Table 2.

Table 2 Maximum Tolerable Levels (MTL) for boron (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Rodents, cattle	150	
Poultry, swine, horse, sheep	150	MTL derived from interspecies extrapolation
Fish	-	Available data are insufficient to set a MTL

11 Typical symptoms of toxicosis

Signs of boron toxicosis include decreased body, pancreas, spleen and kidney weight (EVM, 2003; NRC, 2005). Boron has been shown to cause specific adverse effects in the male reproductive tract in all species, including shrunken scrota, inhibited spermiation, and degeneration of seminiferous tubules with loss or absence of germ cells (EVM, 2003). Inflammation and edema in the legs and around the dew claws, and reduced feed intake, growth, hematocrit, hemoglobin, and plasma phosphorus have been observed in cows consuming 150 – 300 mg B/(L water). Reduced hatchability, riboflavinuria and curled toe paralysis occurred in poultry. In young pigs an excessive boron intake was shown to affect serum thyroid hormone concentrations, the inflammatory response and growth (McDowell, 2003).

12 Bioavailability

Orally ingested boron was observed to be well absorbed (> 90 %) from the gastrointestinal tract in humans, rats, rabbits, sheep and cattle (EFSA, 2004; EPA, 2004; NRC, 2005). In rats, it was demonstrated that > 90 % of the ingested boron dose was absorbed within 3 hours (EPA, 2004).

13 Metabolism

Dietary boron, i.e., borate or boric acid, is readily, and almost completely absorbed. The mechanism remains unkown. It is likely, however, that most of the ingested borates are converted to boric acid prior to absorption (EFSA, 2004; NRC, 2005). Boron is distributed throughout the tissues and organs of animals and humans at concentrations between 0.05 and 0.6 mg/kg (EFSA, 2004). Boron does not accumulate in the soft tissues. Contrarily, it accumulates in bone, reaching steady-state levels approximately four fold higher than plasma levels after 1 – 4 weeks, depending on the dose (EPA, 2004).

The primary route of elimination is by glomerular filtration and > 90 % of the administered dose is excreted via urine, regardless of the route of exposure or administration (EFSA, 2004; IOM, 2001). In humans, excretion is relatively rapid, with a half-life of elimination of 24 hours or less. The elimination kinetics of boron from bone is different from soft tissue and body fluids (EFSA, 2004).

14 Distribution in the animal body

No data on the distribution of the total boron content of animals or humans was available in principal literature sources.

15 Deposition (typical concentration) in edible tissues and products

The NRC (2005) states that no animal tissue or fluid used as food will accumulate boron to the extent that it would be of potential toxicological concern for humans. Meat, fish and dairy products are poor sources of boron and vegetarians are identified as a potential high intake group (EFSA, 2004). Boron concentrations in edible tissues and products are reported in Annex 1 and boron concentrations in tissues linked with dietary boron intake are reported in Annex 2.

16 Acute toxicity

Symptoms of acute boron toxicity comprise a dose related decrease in body weight gain, incidence of minimal to mild extramedullary haematopoiesis of the spleen, hyperkeratosis and acanthosis of the stomach and testicular lesions (EFSA, 2004). EVM (2003) reported lethal doses to be in the range of 400 – 900 mg/(kg bw). Oral LD_{50} values reported by ATSDR (2007) and EFSA (2004) are listed in Table 3.

Table 3 Oral LD_{50} values for borates and boric acid (adapted from ATSDR, 2007; EFSA, 2004)

Compound	**Species**	**LD_{50}**
Boric acid and borates	Pigs, dogs, rabbits and cats	200 – 350 mg B/(kg bw)
Boric acid	Rats	898 – 550 mg B/(kg bw)
Borax	Rats	690 – 510 mg B/(kg bw)

17 Genotoxicity and Mutagenicity

Boric acid was demonstrated not to be mutagenic *in vitro* in *Salmonella enterica var*. Typhimurium, with and without metabolic activation and in the L5178Y mouse lymphoma *tk* assay with or without S-9. Boric acid was also negative in *in vitro* assays for chromosomal aberrations or sister chromatid exchanges in Chinese hamster ovary cells with or without metabolic activation system. Borax was negative in assays for mutagenicity in V79 Chinese hamster cells, C3H10T ½ mouse embryo fibroblasts and diploid human foreskin fibroblasts (EFSA, 2004). EFSA (2004) concluded that the available data indicated that boric acid and borax are not genotoxic.

18 Subchronic toxicity

The ATSDR Toxicological profile of boron includes information on the subchronic toxicity of several boron compounds on several organ systems and by several exposure routes ATSDR (2007).

19 Chronic toxicity, including carcinogenicity

Borates are used to treat epilepsy. Doses between 2.5 mg/(kg bw.day) and 24.8 mg/(kg bw.day) of boric acid administered chronically are reported to have provoked dermatitis, alopecia, anorexia, and indigestion (IOM, 2001).

No evidence of exposure-related cancer was observed in rats exposed to 81 mg B/(kg bw.day) as boric acid or borax for two years, in dogs exposed to 6,8 mg B/(kg bw.day) as boric acid or borax for two years nor in mice exposed to 201 mg B/(kg bw.day) as boric acid for two years (ATSDR, 2007).

20 Reproduction and developmental toxicity

Oral exposure studies in laboratory animals have identified the developing fetus and the testes as the two most sensitive targets of boron toxicity in multiple species (ATSDR, 2007; EPA, 2004; EVM, 2003). ATSDR (2007) reported on three monitoring studies that evaluated the effect of chronically increased exposure to boron in human populations, which did not provide any evidence of impaired fertility.

It was found that 58.5 mg B/(kg bw.day) produced testicular athrophy and complete suppression of fertility in rats. An effect of boric acid on the DNA synthesis activity of mitotic and meiotic germ cells and, to a lesser extent, on energy metabolism in Sertoli cells has been observed. It has been observed that boric acid interferes with the production and or maturation of early germ cells which offers an explanation for athrophy, but not for inhibited spermiation (EFSA, 2004).

ATSDR (2007) did not locate any studies that identified developmental toxicity in humans from exposure to boron. Several types of developmental effects, e.g., decreased fetal body weight, increased incidence of skeletal abnormalities, were observed in standard developmental toxicity studies involving oral exposure of pregnant mice, rats, and rabbits to boric acid or borate salts (ATSDR, 2007).

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

EFSA (2004) considered the human database on boron inadequate for establishing an UL. In consequence, the UL is based on the most sensitive end-point detected in animal studies, i.e., the NOAEL for decreased foetal body weight in rats following maternal exposure during pregnancy (Table 4). The IOM (2001) also selected reproductive and developmental effects in animals as the critical endpoint on which to base an UL for adults. The EFSA (2004) used an overall uncertainty factor (UF) of 60 whereas the IOM (2001) adopted an uncertainty factor of 10 for extrapolating from experimental animals to humans and an UF of 3 for intraspecies variability, leading to an overall UF of 30. EVM (2003) published an UL for adults of 9.6 mg/day using the same NOAEL and UF as EFSA (2004).

Table 4 Non Observed Adverse Effect Level (NOAEL) and Upper Intake Level (UL) for boron established by EFSA (2004) and IOM (2001)

	EFSA (2004)		IOM (2001)
NOAEL (mg/(kg bw.day)	9.6	**NOAEL (mg/(kg bw.day)**	9.6
		UF extrapolation rats to humans	10
		UF intraspecies	3
UF	60	**UF**	30
UL / live stage group (mg/day)		**UL / live stage group (mg/day)**	
1 - 3 years	3	1 - 3 years	3
4 - 6 years	4	4 - 8 years	6
7 - 10 years	5	9 - 13 years	11
11 - 14 years	7		
15 - 17 years	9	14 - 18 years	17
Adults	10	Adults	20
		Pregnancy: 14 - 18 years	17
		Pregnancy: 19 - 50 years	20
		Lactation: 14 -18 years	17
		Lactation: 19 - 50 years	20

23 Toxicological risks for user/workers

Boron is absorbed following inhalation exposure, although it is not clear how much is absorbed directly through the mucous membranes of the respiratory tract and how much is cleared by mucociliary activity and swallowed (EPA, 2004). Boron absorbed following inhalation exposure, is distributed evenly throughout the soft tissues of the body as boric acid and is not metabolized. Hence, there is no reason to expect route specific differences in systemic targets (EPA, 2004).

ATSDR (2007) did not locate any studies in humans after inhalation exposure to boron regarding death, cardiovascular, gastrointestinal, hematological, muscoskletal, or renal effects. Occupational studies of workers exposed to dusts of sodium borates have identified irritation of the respiratory tract and eyes, without measurable changes in pulmonary function. A minimal risk level of 0.01 mg/m^3 has been derived for acute duration inhalation exposure to boron (14 days or less) (ATSDR, 2007).

24 Toxicological risks for the environment

ATSDR (2007) compiled information on sources of boron release to the environment. The sources related to agriculture include boron containing fertilizers and herbicides, the application of fly ash or sewage sludge as a soil amendment, the use of waste water for irrigation or the land disposal of boron containing industrial wastes. Environmental risk limits for boron were assessed by RIVM (2010). There are no indications in principal literature sources that the presence of boron in animal diets would have an environmental impact.

25 References

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Annex 1: Boron concentrations in edible tissues and products

Table 1.1 Boron concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pork		loin: 0.0169			Choi & Jun (2008)

[a] : References herein

Table 1.2 Boron concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Dairy Cattle	48				0.333	Anderson (1992)
	4				0.13	Anderson et al. (1994)[a]
Cattle		< 0.015 - < 0.05			0.20	Diana *et al*. (2008)
Cattle		0.0275 - 0.5643			0.3570	Choi & Jun (2008)
Lamb		0.2				Naghii *et al*. (1996) [a]
		0.55 [b]			0.23	Rainey *et al*. (2002) [a]

[a] : Total diet study; [b]: Beef stews, pot pies, mixtures

Table 1.3 Boron concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Poultry		1.100	0.25		0.160	Choi & Jun (2008)
Poultry		< 0.015 - 0.09			< 0.015 - 0.12	Diana *et al*. (2008)
Poultry		0.4			white: 0.2 yolk: 0.6	Naghii *et al*. (1996) [a]
		0.48 [b]				Rainey *et al*. (2002) [a]

[a]: Total diet study; [d]: Chicken mixtures

Table 1.4 Boron concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Fish		0.012 - 0.652	Choi & Jun (2008)
Shellfish		0.2171 - 3.274	
Fish, not fried		0.74	Rainey *et al*. (2002)[a]

[a]: Total diet study

Table 1.5 Boron concentrations in honey (mg/kg)

Description	Honey	Reference
	0.3562	Choi & Jun (2008)
	6.07 -7.2	Diana et al., (2008)
	2.314 - 8.456	Fernandez-Torres *et al*. (2005)
	5.0	Naghii *et al*. (1996) [a]

[a]: Total diet study

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Annex 2 Boron concentrations in edible tissues and products linked with the dietary intake of boric acid

Table 1 Boron concentrations in edible tissues and products (mg/kg)

Species / category	Source of B supplemented	Dose of B supplemented (mg B /kg)	B content of complete feed [1] (mg B/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Plasma	Reference
Male Fischer rats			< 20		0.66	1.55	3.69		1.94	Ku *et al*. (1991)
	Boric acid		1575	7 d	13.13	19.8	14.23		16.0	
Mallard ducks		0	8 DM		NQ [a]			NQ [a]		Smith *et al*. (1991)
	Boric acid	30	35 DM		NQ [a]			3 DM [b]		
		300	288 DM		15 DM [b]			13 DM [c]		
		1000	1000 DM		33 DM [c]			49 DM [d]		
White leghorn chicks			3	72 wk	0.49		breast: 0.69 thigh: 0.46			Wilson & Ruszler (1998)
	Boric acid	50			2.41 a		breast: 4.07 [a] thigh: 2.93 [a]			
		100			3.74 a		breast: 6.35 [b] thigh: 4.15 [a]			
		200			5.70 b		breast: 12.42 [c] thigh: 6.68 [b]			
		400			14.08 c		breast: 20.18 [d] thigh: 13.78 [c]			

[1]: Data from feed analysis; NQ: concentration below the limit of quantification

Statistics: Smith et al. (1991): means sharing the same letter within each column are not significantly different ($P < 0.05$). Anova;
Wilson & Ruszler (1998): means with different superscripts per category differ significantly ($P < 0.05$)

Table 1 (continued) Boron concentrations in edible tissues and products (mg/kg)

	Source of B supplemented	Dose of B supplemented (mg B/(rat.day))	Duration of study	Liver	Kidney	Muscle	Plasma	Reference
Male rats		0	6 wk	0.30	0.38			Naghii & Samman (1996)[1]
	Boric acid	2		1.13	3.04		1.05	
		12.5		11.40	20.20		11.19	
		25		19.36	32.32		19.80	

[1]: Rats receiving boron in their drinking water

Statistics: All reported values within each column are significantly different ($P< 0.05$), Anova

Annex 2: References

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Bromine

Executive summary of the monograph for bromine

Bromine is widely distributed in nature and is present almost exclusively as bromide salts. Bromine is not considered to be an essential nutrient and there are no known essential biochemical functions of bromine. Bromine is not supplemented to animal diets and dietary levels result primarily from the decomposition of methyl bromide following fumigation of hay, feed ingredients or occasionally complete feeds. NRC established maximum tolerable levels ranging between 2500 mg/kg DM for poultry and 200 mg/kg DM for horses and sheep. The most sensitive indicators of bromine toxicosis in rodents are changes in behaviour and weight gain. Bromine has a comparable metabolic profile and tissue distribution to chlorine. It is rapidly and completely absorbed after oral ingestion. With the exception of erythrocytes, bromine is almost exclusively distributed in the extracellular fluids, including gastric secretions and saliva. Urine is the primary excretory pathway for bromine. In humans, the half-life of bromine at normal dietary chlorine levels is 10 to 12 days. Bromine salts irritate the gastric mucosa and cause nausea and vomiting. Acute intoxication in humans is rare. Bromine has been a main constituent of sedative potions. Chronic bromine intoxications have occurred in patients using these medications for longer periods of time. Symptoms include apathy, disturbed coordination, loss of memory, drowsiness, loss of emotional control, tremors and depressed tendon reflexes. In rats it has been demonstrated that high levels of bromine can influence iodine metabolism. Upper intake levels for bromine have not been established by scientific bodies. There were no indications reported that the presence of bromine in animal diets would have consequences for the environment.

Bromine Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Bromine is widely distributed in nature and is found almost exclusively as bromine salts (NRC, 2005; van Leeuwen *et al*., 1987). Bromine is the main degradation product of brominated hydrocarbons, e.g., methyl bromide, excessively used in agriculture for preplanting fumigation of soils, post-harvest fumigation of grains, spices, nuts, fruits and tobacco (Pavelka, 2004).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

No information was available on the authorization of use of the element in human and animal nutrition.

3 Essential functions

Bromine is not considered to be an essential nutrient and there are no known essential biochemical functions of bromine (NRC, 2005).

4 Other functions

There was no information available on other functions of bromine in principal literature sources.

5 Antimicrobial properties

There was no information available on antimicrobial properties of bromine in principal literature sources.

6 Typical deficiency symptoms

Bromine is not an essential trace element and no bromine deficiency symptoms have been described.

7 Animal requirements, allowances and use levels

Bromine is not an essential trace element and no bromine requirements have been established by scientific bodies.

8 Concentration of the element in feed materials

Inorganic bromine salts that result from the decomposition of methyl bromide following fumigation of hay, feed ingredients, or occasionally complete feeds are the primary sources of bromine in animal diets (NRC, 2005). Bromine concentrations in feed materials are listed in Table 1.

Table 1 Bromine concentrations in feed materials (mg/kg)

Feed material: products based on:	**Bromine concentration**	**Reference**
Rice	0.5	Greve (1983)
Wheat	2.1	
Soya been	1.3	
Maize	1.2	
Sorghum	1.2	
Citrus	0.7	
Alfalfa	1.6	
Fish meal	12.6	
Grass	26 DM	Vreman *et al*. (1985)
Hay	8 – 9	Lynn *et al*. (1963)
Hay, native clover	25	
Hay, alfalfa	4 - 12	

9 Concentration of the element in complete feedingstuffs

Bromine concentrations in complete feedingstuffs for dairy cattle have been monitored. Lynn *et al*. (1963) reported values ranging between 5 and 9 mg/kg and Vreman *et al*. (1985) reported a bromine level of 24 mg/kg DM.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

MTL values established by NRC (2005) are compiled in Table 2.

Table 2 Maximum Tolerable Levels (MTL) for bromine (mg/kg DM) (NRC, 2005)

Species	**MTL**	**Additional remarks**
Poultry	2500	
Rodents	300	
Swine, cattle	200	
Horse, sheep	200	Value derived from interspecies extrapolation
Fish	-	Available data were considered insufficient to set a MTL

11 Typical symptoms of toxicosis

Data on which to base the toxicity of bromine in animal feeds come mostly from studies in humans and laboratory animals. The most sensitive indicators of bromine toxicosis in rodents are changes in behavior and weight gain. In rats, disturbances in thyroid and renal function and a decreased fertility have been observed (NRC, 2005).

12 Bioavailability

Bromine metabolism in living organisms, with the exception of marine sponges and gorgonians, is that of the bromide ion. After oral ingestion, bromine is rapidly and completely absorbed in the gastrointestinal tract using the transport systems for the chloride ion (NRC 2005; Pavelka, 2004). Vaiseman *et al*. (1986) measured oral absorbabilities of bromine in humans to range between 75 and 118 % with a mean of 96%.

13 Metabolism

Ingested and absorbed bromine is distributed almost exclusively in the extracellular fluids, including gastric secretions and saliva, with the exception of erythrocytes. In mammals bromine is not incorporated into organic molecules. Urine is the primary excretory pathway for bromine. The glomerulus filters bromine which competes with chlorine for reabsorption in the tubulus. Most of the bromine in saliva and gastric juice is reabsorbed in the small intestine, and little bromine is found in the feces (NRC, 2005; Pavelka, 2004; van Leeuwen *et al*., 1987). The half life of bromine at normal dietary chloride levels is 10 – 12 days in humans. The half life is strongly dependent upon the dietary chloride level and sodium chloride can be used to treat bromine toxicosis (NRC, 2005).

14 Distribution in the animal body

Bromine is distributed almost exclusively in the extracellular fluid with the exception of the erythrocytes. It was found to be partitioned in the body similarly to chlorine and under conditions of enhanced intake, bromine replaces chlorine throughout the tissues and fluids of the body. There is no significant accumulation of bromine in any mammalian organ which might be related to the lack of a specific function of this ion (Pavelka, 2004; van Leeuwen *et al*., 1987).

15 Deposition (typical concentration) in edible tissues and products

Bromine concentrations in edible tissues and products are reported in Annex 1 and bromine concentrations in tissues linked with dietary bromine intake are reported in Annex 2.

16 Acute toxicity

Bromine salts irritate the gastric mucosa and cause nausea and vomiting. The resulting food or feed refusal coupled with the pharmacokinetics of bromine make it unlikely that systemic toxicosis would occur resulting from short term oral exposure. This is consistent with the fact that acute intoxication with bromine salts in individuals without previous chronic exposure is rare (NRC, 2005; van Leeuwen *et al*.,1987). In rodents oral LD_{50} - values are reported to be in the range of 3.5 to 7 g/kg bw (NRC, 2005).

17 Genotoxicity and Mutagenicity

Potassium bromate is a carcinogen but is not a known contaminant of animal feeds. Polybrominated biphenyls are liver carcinogens (NRC, 2005).

18 Subchronic toxicity

No information was available on subchronic toxicity of bromine in principal literature sources.

19 Chronic toxicity, including carcinogenicity

Bromine has been the main constituent of sedative potions. A considerable number of individuals has been exposed to relatively high bromine doses via their medication. Chronic bromine intoxications have occurred in patients abusing these medications for longer periods of time. The classical clinical picture of chronic bromine intoxication is called bromism. Symptoms consist of an altered functioning of the central nervous system and dermatological abnormalities. Apathy, disturbed coordination, loss of memory, drowsiness, loss of emotional control, tremors and depressed tendon reflexes have been observed (van Leeuwen *et al*., 1987).

It has been demonstrated in rats that high levels of bromine can influence the iodine metabolism. Excess bromine may decrease the accumulation of iodide in the thyroid and skin and rise iodide excretion by the kidneys. In lactating dams it was shown that a high bromine intake decreased iodine and increased bromine transfer through the milk to the suckling (Pavelka, 2004).

20 Reproduction and developmental toxicity

In rats, a marked reduction of prostate weight was observed at dietary concentrations of 4800 and 19200 mg NaBr/kg bw. The highest dose caused atrophy of the seminiferous tubules and reduced spermatogenesis. The testosterone concentrations were decreased which consequently led to a lowering in secretory activity of the prostate gland. In female rats bromine has been reported to affect the reproductive organs and cause a decrease in number of corpora lutea. In aquatic organisms, e.g., guppy, bromine was observed to markedly impair reproductive performance (van Leeuwen *et al*., 1987).

21 Non Observed Adverse Effect Level (NOAEL)

A NOAEL value identified to establish an upper intake level is reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

In man, alterations of neurophysiological variables appeared to be the most sensitive effect of bromine toxicity. From studies with human volunteers a NOAEL value of 4 mg/kg bw could be identified. Based upon this value a provisional acceptable daily intake for bromine of 0.4 mg/kg bw could be derived (van Leeuwen *et al*., 1987).

23 Toxicological risks for user/workers

Toxicological risks have been described for workers occupationally exposed to the fumigant methyl bromide. Under these circumstances the health risk of being exposed to an additional dose of bromine is orders of magnitude less than the health risk of exposure to an alkylating compound like methyl bromide (van Leeuwen *et al*., 1987).

24 Toxicological risks for the environment

No toxicological risks for the environment have been described linked to the presence of bromine in animal feed in principal literature sources.

25 References

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Annex 1: Bromine concentrations in edible tissues and products

Table 1 Bromine concentrations in edible tissues and products (mg/kg)

Product description	Br concentration	Reference
Milk	3	Greve (1983)
Dairy products	4	
Milk	2.8	Rose *et al*. (2001)[a]
Dairy produce	3.9	
Cattle meat	4	Greve (1983)
Pork meat	4	
Meat and egg products	3	
Carcass meat	2.6	Rose *et al*. (2001)[a]
Poultry	2.2	
Eggs	2.6	
Fish (fresh water and marine)	7	Greve (1983)
Eel (fresh water and marine)	4	
Fish	6.7	Rose *et al*. (2001)[a]

[a]: Total diet study

Annex 1: References

Greve, P. A. 1983. Bromide-Ion Residues in Food and Feedstuffs. Food and Chemical Toxicology 21:357-359.

Rose, M., P. Miller, M. Baxter, G. Appleton, H. Crews, and M. Croasdale. 2001. Bromine and iodine in 1997 UK total diet study samples. Journal of Environmental Monitoring 3:361-365.

Annex 2 : Bromine concentrations in edible tissues and products linked with the dietary intake of bromine

Table 1 Bromine concentrations in edible tissues and products (mg/kg)

Species / category	Source of Br supplemented	Dose of Br supplemented (mg Br/kg)	Br content of complete feed [1] (mg Br/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Dairy cattle								< 1	Lynn *et al*. (1963)
	NaBr	50		22 d				3	
	NaBr	100		19 d				5	
	NaBr	200		28 d				12	
	CH_3Br fumigated grain		53	39 d				8	
	CH_3Br fumigated grain		100	39 d				8	
	CH_3Br fumigated grain		220	39 d				15	
Dairy cattle			22 DM	35 d	3.8	14.2	3.0	6.1	Vreman *et al*. (1985)
	NaBr	46.5 DM	69 DM		11.5	31.4	9.4	17.4	
	NaBr	93.1 DM	115 DM		27.1	87.5	20.8	30.5	
Rats			36	56 d	6.2	10.9	triceps: 8.2		Williford *et al*. (1974)
	CH_3Br fumigated grain		290		91.4	139.3	triceps: 59.6		
			601		175.9	292.1	triceps: 108.5		
			1177		304.5	527.9	triceps: 178.8		

[1]: data from feed analysis;

Statistics: Williford *et al*. (1974): all treatment means differed significantly ($P< 0.01$)

Annex 2: References

Lynn, G. E., C. A. Lassiter, S. A. Shrader, and O. H. Hammer. 1963. Occurrence of Bromides in Milk of Cows Fed Sodium Bromide and Grain Fumigated with Methyl Bromide. Journal of Agricultural and Food Chemistry 11:87- 91

Vreman, K., A. H. Roos, and L. G. M. T. Tuinstra. 1985. The Excretion of Inorganic Bromide Into Milk of Dairy-Cows After Oral-Administration. Netherlands Milk and Dairy Journal 39:173-181.

Williford, J. H., R. F. Kelly, and P. P. Graham. 1974. Residual Bromide in Tissues of Rats Fed Methyl-Bromide Fumigated Diets. Journal of Animal Science 38:572-576.

Cadmium

Executive summary of the monograph for cadmium

EU legislation governs the maximum content for cadmium in products intended for animal feed and in foodstuffs. Cadmium is not considered an essential element for animals and humans. The cadmium concentration in forages and crops remains usually below 1 mg/kg DM. Cadmium impurities are often present in mineral feed material. Phosphate sources are likely sources of cadmium contamination which can contribute significantly to the total diet cadmium concentration. NRC established a maximum tolerable level for cadmium of 10 mg/kg DM for livestock species, rodents and fish. All major organ systems are affected by chronic ingestion of high cadmium levels with the kidney and liver as the primary target organs in most species. Cadmium causes damage to the proximal tubule cells and the interstitial fibrosis in the kidney cortex which may result in proteinuria, glycosuria, amino aciduria, and polyuria. Cadmium absorption in men and women in Western populations have been estimated to be about 5 % - 10 %, respectively. Absorbed cadmium is transported to the liver where it is bound to metallothionein. The formation of cadmium metallothionein complexes occurs also in other organs e.g., the intestines, lungs and kidneys. The continuous formation of these complexes traps cadmium and limits its elimination. Cadmium accumulates primarily in the kidneys. Urinary cadmium levels are widely accepted as a measure of the body burden and the cumulative amount of cadmium in the kidneys. The blood cadmium concentration is considered the most valid marker of recent cadmium exposure. Muscle and bone do not accumulate cadmium. The mammary gland effectively limits cadmium transport into milk and little cadmium is transported into eggs. The symptoms of the oral ingestion of large amounts of cadmium include fluid loss, edema, organ destruction and gastrointestinal symptoms. In rat and mice, oral LD_{50} values for cadmium range from 100 – 300 mg/kg bw. The kidney is the critical target organ for dietary exposure to cadmium. The earliest manifestations of cadmium induced renal damage are the increased excretion of low molecular weight proteins, in particular β_2-microglobulin and α_2-microglobulin. Severe cadmium induced renal damage results in depressed glomerular function. Prolonged cadmium exposure causes osteomalacia and osteoporosis. Recently it was confirmed that even low-level cadmium exposure has negative effects on bone mineral density. IARC classified cadmium as a human carcinogen (Group 1). ATSDR considered the available evidence insufficient to conclude whether or not cadmium is a carcinogen by the oral route. WHO and EFSA established tolerable weekly intakes for cadmium of 7µg/ kg bw and 2.5 µg/kg bw, respectively. A chronic duration oral exposure minimal risk level of 0.1 µg/(kg bw.day) for cadmium was derived by ATSDR. Inhaled cadmium particles are partially deposited in the respiratory tree and absorbed. Cadmium absorbed after inhalation exposure is widely distributed in the body. Long term inhalation exposure to cadmium may lead to chronic obstructive lung disease, lung cancer and renal tubular dysfunction. The implementation of the actual EU legislation, fixing maximum cadmium contents in feedingstuffs, limits the contribution of cadmium originating from animal excreta in the soil and the aquatic environment.

Cadmium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Cadmium found in mammals, birds, and fish is believed to be bound to proteins. In the aquatic environment at low salinity, cadmium is present as free Cd^{2+}, $Cd(OH)_2$, and organic complexes at levels dependent on pH and amounts of soluble organic material. In seawater cadmium exists almost solely as $CdCl_2$ and $CdCl^+$ (EFSA, 2009).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Presently, in the EU the Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2] on undesirable substances in animal feed governs the maximum tolerable levels of cadmium in feedingstuffs (Table 1).

Table 1 Maximum allowed cadmium content in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2]

Products intended for animal feed	**Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12%**
Feed materials of vegetable origin	1
Feed materials of animal origin	2
Feed materials of mineral origin except:	2
▪ Phosphates	10
Additives belonging to the functional group of compounds of trace elements except:	10
▪ Copper oxide, manganeous oxide, zinc oxide and manganous sulphate monohydrate	30
Additives belonging to the functional group of binders and anti-caking agents	2
Premixtures	15

[1] OJ L 140, 30.5.2002, p. 10

[2] OJ L 318, 6.12.2005, p. 19

Table 1 (continued) Maximum allowed cadmium content in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2]

Products intended for animal feed	**Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12%**
Mineral feedingstuffs containing < 7% phosphorus	5
Mineral feedingstuffs containing ≥ 7% phosphorus	0.75 per 1% phosphorus, with a maximum of 7.5
Complementary feedingstuffs for pet animals	2
Other complementary feedingstuffs	0.5
Complete feedingstuffs for cattle, sheep, and goats and feedingstuffs for fish except:	1
▪ Complete feedingstuffs for pets	2
▪ Complete feedingstuffs for calves, lambs, and kids and other complete feedingstuffs	0.5

2.2 *Human nutrition*

In the EU, Regulation EC 1881/2006[3] ammended by Regulation EC 629/2008[4] sets maximum levels (ML) for cadmium in certain foodstuffs, as summarized in Table 2.

Table 2 Maximum Levels (ML) for cadmium (mg/kg) in foodstuffs in the EU set by Regulations EC 1881/2006[3] and EC 629/2008[4]

Foodstuffs	**ML**
1. Meat (excluding offal) of bovine animals, sheep, pig, and poultry	0.050
2. Horsemeat, excluding offal	0.20
3. Liver of bovine animals, sheep, pig, poultry, and horse	0.50
4. Kidney of bovine animals, sheep, pig, poultry, and horse	1.0
5. Muscle meat of fish, excluding species listed in 6 and 7	0.050

[3] OJ L 364, 20.12.2006, p. 19

[4] OJ L 173, 3.7.2008, p. 6

Table 2 (continued) Maximum Levels (ML) for cadmium (mg/kg) in foodstuffs in the EU set by Regulations EC 1881/2006[3] and EC 629/2008[4]

Foodstuffs	**ML**
6. Bonito (*Sarda sarda*), common two-banded seabream (*Diplodus vulgaris*), eel (*Anguilla anguilla*), grey mullet (*Mugil labrosus labrosus*), horse mackerel or scad (*Trachurus spp*), louver or luvar (*Luvarus imperialis*), mackerel (*Scomber spp*.), sardine (*Sardina pilchardus*), sardinops (*Sardinaops spp*), tuna (*Thunnus spp, Euthynnus spp, Katsuwonus pelamis*), and wedge sole (*Dicologoglossa cuneata*)	0.10
7. Muscle meat of bullet tuna (*Auxis spp*)	0.20
8. Muscle meat of anchovy (*Engraulis spp*) and swordfish (*Xiphias gladius*)	0.30
9. Crustaceans, excluding brown meat of crab and excluding head and thorax meat of lobster and similar large crustaceans (*Nephropidae* and *Palinuridae*)	0.50
10. Bivalve molluscs	1.0
11. Cephalopods (without visera)	1.0
12. Cereals, excluding bran, germ, wheat, and rice	0.10
13. Bran, germ, wheat and rice	0.20
14. Soybeans	0.20
13. Vegetables and fruit, excluding leaf vegetables, fresh herbs, fungi, stem vegetables, root vegetables, and potatoes	0.050
16. Stem vegetables, root vegetables and potatoes, excluding celeriac. For potatoes the maximum level applies to peeled potatoes	0.10
17. Leaf vegetables, fresh herbs, celeriac and the following fungi: *Agaricus bisporus* (common mushroom), *Pleurotus ostreatus* (Oyster mushroom), *Lentinula edodes* (Shiitake mushroom)	0.20
18. Fungi, excluding those listed in point 17	1.0
19. Food supplements excl. food supplements listed in point 20	1.0
20. Food supplements consisting exclusively or mainly of dried seaweed or of products derived from seaweed	3.0

3 Essential functions

Cadmium is not considered an essential nutrient for animals (EFSA, 2009; NRC, 2005).

4 Other functions

A number of studies with rodents, chickens and livestock have reported increased weight gain when low levels of cadmium were added to diets. The bases for these effects are unknown and may result of antibiotic or pharmacologic actions (NRC, 2005).

5 Antimicrobial properties

There was no information found on antimicrobial properties of cadmium relevant for animal husbandry in principal literature sources.

6 Typical deficiency symptoms

Cadmium is not an essential trace element and no deficiency symptoms haven been described (NRC, 2005).

7 Animal requirements, allowances and use levels

Cadmium is not an essential trace element and no requirements have been established by scientific bodies.

8 Concentration of the element in feed materials

The uptake of cadmium by plants is variable. In contrast to other elements, cadmium is rather mobile and can be absorbed by plants via roots and its concentration decreases in the following order: root > leaves > stem > subterranean storage organs > fruits/grains. The cadmium concentration in forages and crops grown on non-contaminated soils remains usually below 1.0 mg/kg DM (EFSA, 2004; SCAN, 2003). EFSA (2004) reported on total cadmium concentrations in feed materials, mineral supplements and premixtures (Table 3). Additionally, it was remarked that the reported values of cadmium in forage crops are relatively high which may be attributed to crops that have been grown on soil to which high levels of calcium have been added (EFSA, 2004). Cadmium impurities are often present in mineral feed material. Phosphate sources are likely sources of cadmium contamination which can contribute significantly to the total diet cadmium concentration (SCAN, 2003; NRC, 2005).

Table 3 Mean cadmium concentrations (mg/kg DM) in feed materials and forages

Feed material	**n**	**Cd concentration (EFSA, 2004)**	**Feed material**	**n**	**Cd concentration Spiegel *et al*. (2009)**
Barley	6	0.11	Spring barley	30	0.019
Citrus pulp	10	0.19	Spring durum	30	0.056
Fish meal	44	0.40	Winter durum	15	0.038
Maize grain and maize byproducts	29	0.06	Winter rye	49	0.018
Rapeseed, extracted	20	0.15	Winter wheat	136	0.036
Soya bean meal	17	0.07			
Sugar beet pulp	12	0.14			
Sunflower meal	32	0.41			
Wheat and wheat by-products	27	0.19			
Grass/herbage (fresh)	1217	0.62			
Hay	950	0.73			
Silage – grass	244	0.09			
Silage – maize	345	0.28			
All forage	2761	0.32			
Mineral supplement / pre-mixture		0.58			

[1]: included phosphorus containing mineral nutrients, trace mineral mixes, buffers, and limestone

9 Concentration of the element in complete feedingstuffs

Cadmium concentrations in complete feedingstuffs are compiled in Table 4.

Table 4 Mean cadmium concentrations (mg/kg DM) in commercial complete feedingstuffs

Complete feedingstuff	**n**	**Cd conc. (EFSA, 2004)**	**Complete feedingstuff**	**n**	**Cd conc. (Nicholson *et al*., 1999)**
Poultry - unspecified	33	0.16			
Poultry - layers	12	0.16	Layer	4	0.39
Poultry - broilers	8	0.19	Broiler starter	4	0.19
			Broiler grower	4	0.16
			Broiler finisher	3	0.12
			Turkey various	6	0.15
			Turkey grower	4	0.14
			Turkey finisher	3	0.19

Table 4 (continued) Mean cadmium concentrations (mg/kg DM) in commercial complete feedingstuffs

Complete feedingstuff	**n**	**Cd conc. (EFSA, 2004)**	**Complete feedingstuff**	**n**	**Cd conc. (Nicholson *et al.*, 1999)**
Fish	207	0.17			
Pigs < 17 weeks	14	0.16	Rearer-creep	4	0.18
Pigs > 16 weeks	10	0.07	Rearer - weaner	4	0.13
Pigs unspecified	150	0.09	Rearer- grower	5	< 0.10
			Rearer finisher	7	< 0.10
Pigs (sows)	4	0.09	Sow - dry	3	0.16
			Sow - lactating	3	< 0.10
Ruminants[1]	358	0.11			

[1]: Complete feedingstuffs and complementary feeds

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

NRC (2005) established a MTL value of 10 mg/kg DM for rodents, poultry, swine, horses, cattle, sheep and fish. Additionally to the cadmium MTL values, NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Virtually all major organ systems are affected by chronic ingestion of high cadmium levels with the kidneys and liver as the primary target organs in most species. Usually, the nephrotoxicity of cadmium leads to the first signs of toxicosis. Cadmium causes damage to the proximal tubule cells and interstitial fibrosis in the kidney cortex, resulting in proteinuria, glycosuria, amino aciduria, and polyuria (NRC, 2005). In cattle, which have been chronically exposed to cadmium, various clinical abnormalities such as loss of appetite, renal failure, hypertension, anaemia, growth retardation, impaired reproductive function, abortions, teratogenic lesions, and tumor development have been reported (EFSA, 2004). In pigs, the most prominent clinical signs of cadmium exposure are growth retardation and mycrocytic, hypochromic anaemia. In laying hens reduced egg production has been observed. In fish, toxic effects of cadmium include structural damage of the gills and kidneys, osmoregulatory disturbances and enzyme inhibition in the liver and kidneys (EFSA, 2004).

12 Bioavailability

12.1 General

In humans the absorbability of cadmium in known to vary according to a number of factors including the nutritional status of the individual, the gender, the smoking status and age, and dietary factors such as the cadmium content, the presence of divalent and trivalent cations e.g., zinc, iron and calcium which compete with cadmium for absorption (EFSA, 2009; Nordberg *et al*., 2007).

According to European biomonitoring data, cadmium absorption in men and women in Western populations can be estimated to be about 5 % and 10 %, respectively (EFSA, 2009). Nordberg *et al*. (2007) reported on two human studies that measured average cadmium absorbabilities to be 4.6 % and 6 %. In persons with low body iron stores (serum ferritin levels < 20 µg/L) cadmium absorption was on average four times higher than that in subjects with normal stores (Nordberg *et al*., 2007). Studies with different animal species have shown that 0.5 – 7 % of the ingested cadmium is absorbed. The apparently lower absorption by laboratory animals (1 – 2%) and ruminants (1%), as compared to humans, may be more related to differences in the standard diets than to differences in physiological parameters. Retention and absorption in the gastrointestinal tract is higher in younger than in older animals (EFSA, 2004).

12.2 *Cadmium status indicators / biomarkers of cadmium exposure*

Blood cadmium is considered the most valid marker of recent exposure and is usually assessed in whole blood. In blood, cadmium is found in the erythrocytes, where it is bound to high- or low-molecular weight fractions. Plasma cadmium concentrations are low. Consequently, differences in hematocrit levels may cause some variability of the cadmium concentration in whole blood (EFSA, 2009). The urinary cadmium concentration is mainly determined by the body burden of cadmium and is proportional to the concentration in the kidneys. Ideally, urinary cadmium is assessed as the amount excreted over 24 h (EFSA, 2009). Comparisons of group-average urinary cadmium excretion in humans with group average tissue amounts indicated good agreement between the levels of urinary and kidney cadmium, fair agreement between the levels of urinary and liver or whole body cadmium, and no agreement between the level of urinary cadmium and the daily cadmium intake (EFSA, 2009; Nordberg *et al*., 2007).

13 Metabolism

The absorption of dietary cadmium can be compared to a saturable process with fractional absorption which decreases at high concentrations. Generally, cadmium absorption from food is not dependent on chemical complexation except for metallothionein-bound cadmium for which data suggest that it is partly taken up intact from the gastrointestinal tract (EFSA, 2009; Nordberg *et al*., 2007). Following absorption, cadmium is transported to the liver where it is bound to metallothionein (MT) forming a Cd-MT complex, the main form found in animal tissues. The formation of Cd-MT complexes can occur in the intestines, the liver and the lungs. Circulating Cd-MT complexes reach the kidneys, where they are filtered by the glomerulus, and reabsorbed by the proximal tubule cells. Minor changes in the intracellular pH and lysosomal enzyme activity cleave the Cd-MT complex and the resulting free cadmium ions accumulate in the kidney (EFSA, 2004; EFSA, 2009). The continuous synthesis of Cd-MT in the liver, kidneys and other organs traps cadmium in these organs, and limits its elimination. It has been estimated that only < 0.01% of the body burden is excreted daily, to a large extent with urine, but also with bile, the gastrointestinal tract, saliva, the skin and sweat. When renal damage has occurred, cadmium excretion with urine increases dramatically. The biological half-life of cadmium is reported to be 10 - 30 years in the kidneys and 4.7 - 9.7 years in the liver. Following low level exposure, the long half-life and the probable transfer of cadmium from other tissues to the kidney, results in an accumulation of cadmium in the kidneys during the entire life-span (EFSA, 2004; Nordberg *et al*., 2007).

14 Distribution in the animal body

Upon chronic exposure to low environmental cadmium levels, the largest fraction (50-75%) of cadmium is found in the liver and kidneys, with the renal cortex having the highest concentrations. With increasing exposure, a greater proportion of the body burden will be found in the liver. In spite of low concentrations of cadmium in muscles, bone and skin, these tissues may represent a significant contribution (20 %) to the body burden (EFSA, 2004). Animals and humans appear to have a similar pattern of distribution that is relatively independent of route of exposure (oral, inhalation, dermal) but somewhat dependent on duration of exposure (ATSDR, 2008).

15 Deposition (typical concentration) in edible tissues and products

Cadmium accumulation is greatest in the kidneys, followed by the liver, testes, pancreas and spleen. Muscle and bone do not accumulate cadmium at high levels. There are no major differences in the amount of cadmium that accumulates across different types of muscles. Tissue levels increase with time of exposure; when dietary levels are high, tissue levels eventually reach a plateau (NRC, 2005).
The mammary gland effectively limits cadmium transport into the milk. Very little cadmium is transported into avian eggs (EFSA, 2004). Cadmium concentrations in edible tissues and products are reported in Annex 1 and cadmium concentrations in edible tissues and products linked with the dietary intake of several cadmium compounds and doses are reported in Annex 2.

16 Acute toxicity

Intentional ingestion of cadmium has been used as means of suicide, causing death due to massive fluid loss, edema, and widespread organ destruction. Ingestion of food or beverages contaminated with high amounts of cadmium gives rise to acute gastrointestinal symptoms. The non observed adverse effect level of a single oral dose is estimated to be 3 mg elemental Cd/person, and lethal doses range from 350 to 8900 mg (ATSDR, 2008; EFSA, 2009). In rats and mice, acute oral LD_{50} values for cadmium range from 100 to 300 mg/kg bw (ATSDR, 2008).

17 Genotoxicity and Mutagenicity

In vitro studies have shown that cadmium induces genetic mutations in hamster and mouse cells, transformation in rodent cells, unscheduled DNA synthesis in rat cells, DNA breaks in human cells, DNA lesions in hamster cells, and that it inhibits DNA repair in human and hamster cells. Chromosomal aberrations following cadmium exposure have been observed in Chinese hamster ovary cells. Studies on human cells have produced mixed results (ATSDR, 2008). Contradictory results were obtained in humans where no chromosome anomalies were detected in Itai-Itai patients or in cadmium workers in some studies whereas others have described significant increases in these anomalies (Nordberg *et al*., 2007).

18 Subchronic toxicity

The ATSDR Toxicological Profile for Cadmium includes information on the subchronic toxicity of several cadmium compounds on several organ systems and by several exposure routes (ATSDR, 2008).

19 Chronic toxicity, including carcinogenicity

The kidney is the critical target organ for dietary exposure to cadmium and renal damage is characterized by cadmium accumulation in convoluted proximal tubules, thereby causing cell dysfunction and damage. The earliest manifestations of cadmium induced renal damage are increased urinary excretion of low-molecular weight proteins, in particular β_2-microglobulin and α_2-microglobulin. The amount of β_2-microglobulin excreted into the urine is proportional is to the severity of the damage. Severe cadmium induced renal damage results also in depressed glomerular function, with rises in the levels of serum creatinine and serum β_2-microglobulin, and culminates in uremia in some cases (EFSA, 2009; Nordberg *et al*., 2007).

The frontier interest in health effects caused by prolonged cadmium exposure related to bone effects. An increasing incidence of osteoporosis is occurring in industrialized countries worldwide. The influence of cadmium on bone matter can be divided into osteomalacia and osteoporosis. The most severe form of chronic cadmium poisoning caused by prolonged oral cadmium ingestion is Itai-Itai disease which was first reported from the Jinzu river basin in Japan. The clinical picture shows renal injury manifested by tubular and glomerular dysfunction and bone injury consisting of a combination osteomalacia and osteoporosis. Recently, the negative effects of low-level cadmium exposure on bone mineral density have been confirmed. Even in the absence of cadmium induced renal tubular dysfunction, low-level environmental exposure to cadmium seems to mobilize bone minerals from the skeletal tissue (EFSA, 2009; Nordberg *et al*., 2007).

IARC (1993) concluded that there was sufficient evidence to classify cadmium as a human carcinogen, i.e., IARC classification 'Group 1'. ATSDR (2008) concluded that neither human nor animal studies provide sufficient evidence to determine whether or not cadmium is a carcinogen by the oral route. In humans, little evidence was found of an association between oral exposure to cadmium and increased cancer rates. Additionally, it was remarked that the considered studies had poor statistical power (ATSDR, 2008).

20 Reproduction toxicity

Several studies have examined the possible association between increased cadmium exposure and male reproductive toxicity. The majority of the studies focused on sex steroid hormone levels and the results of these studies are inconsistent (ATSDR, 2008). EFSA (2009) concluded that the possible developmental neurotoxicity of cadmium at low exposure levels is unclear and needs to be ascertained.

21 Non observed adverse effect level (NOAEL)

To derive a chronic duration oral exposure minimal risk level for cadmium, ATSDR considered three possible approaches: (1) NOAEL/LOAEL approach using a single environmental exposure study finding an increased prevalence of abnormal renal effect biomarker levels, (2) selection of a point of departure from a published benchmark dose analysis, or (3) selection of a point of departure based on analysis of the dose-response functions from a number of environmental exposure studies (meta-analysis of environmental exposure studies). The last methodology was selected for the derivation of the minimal risk level because it uses the whole dose-response curves from several studies rather than data from a single study (ATSDR, 2008). To establish a tolerable weekly intake for cadmium, the CONTAM Panel used a model based estimation of the relationships between urinary cadmium and dietary cadmium intake (EFSA, 2009).

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

The WHO considered renal tubular dysfunction the critical health outcome with regard to the toxicity of cadmium. A provisional tolerable weekly intake for cadmium of 7µg/(kg bw) was set (WHO, 2004). ATSDR (2008) established an intermediate-duration (15 – 364 days) oral exposure minimal risk level for cadmium of 0.5 µg/(kg bw.day) and a chronic duration (≥ 1 year) oral exposure minimal risk level of 0.1

µg/(kg bw.day). The CONTAM Panel established a tolerable weekly intake for cadmium of 2.5 µg/(kg bw) (EFSA, 2009).

23 Toxicological risks for user/workers

Cadmium metal and cadmium salts have low volatility and exist in air primarily as fine suspended particulate matter. When inhaled, large particles (diameter > 10 µm) tend to be deposited in the upper airway, while small particles (approximately 0.1 µm) tend to penetrate into the alveoli. Particle size is a key determinant of cadmium absorption in the lung (ATSDR, 2008). Based on model predictions it is suggested that about 5 % of particles > 10 µm will be deposited in the respiratory tree whereas up to 50 % of particles < 0.1µm will be deposited. Between 50 and 100% of cadmium deposited in the alveoli will ultimately be absorbed. Absorbed cadmium is widely distributed in the body. In workers dying from inhalation of cadmium, lung-cadmium concentration are somewhat lower than liver or kidney cadmium concentrations (ATSDR, 2008). Cadmium excretion in urine of occupational workers increases proportionally with the body burden of cadmium, but the amount excreted represents only a small fraction of the total body burden unless renal damage is present (ATSDR, 2008).

In humans, inhalation exposure to high levels of cadmium oxide fumes or dust is intensely irritating to respiratory tissue, but symptoms can be delayed. Acute inhalation of cadmium may lead to severe chemical pneumonitis. Long term inhalation exposure may lead to chronic obstructive lung disease, lung cancer and to renal tubular dysfunction (ATSDR, 2008; Nordberg *et al*., 2007). ATSDR (2008) derived minimal risk levels for acute-duration inhalation exposure (< 14 days) and chronic-duration inhalation exposure (≥ 1 year) to cadmium of 0.03 $\mu g/m^3$ and 0.01 $\mu g/m^3$, respectively.

24 Toxicological risks for the environment

The main exogenous sources of cadmium in soils are superphosphate fertilizers and sewage sludges. EC legislation aims to restrict the accumulation of cadmium in soils where sewage sludge has been applied (EFSA, 2004). The following limit values are set according to Directive 86/278/EEC[5]: limit value for cadmium concentration in soil: 1 to 3 mg/kg DM of soil with a pH of 6 to 7, limit value for cadmium in sludge for use in agriculture: 20 to 40 mg/kg DM, limit value for the amount of cadmium which may be added annually to agricultural land based on a 10-year average: 0.15 kg/(ha.year). Furthermore, the implementation of the actual EU legislation, fixing maximum cadmium contents in feedingstuffs, limits the contribution of cadmium originating from animal excreta in the soil and the aquatic environment.

Cadmium concentrations in manure from multiple monitoring studies are compiled in Table 5.

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[5] OJ L 181, 4.7.1986, p.6

Table 5 Cadmium content of manure from various species

Species, category	Cd content (mg/kg DM)	Reference
Dairy cattle FYM	0.38	Nicholson *et al*. (1999)
Dairy cattle slurry	0.33	
Beef cattle FYM	0.13	
Beef cattle slurry	0.26	
Pig FYM	0.37	
Pig slurry	0.30	
Broiler / turkey	0.42	
Layer	1.06	
Cattle, FYM, Se	0.16	Öborn *et al*. (2008)
Cattle, FYM, RF	0.25	
Broiler	0.32	van Ryssen (2008)
Layer	0.50	
	(g/m^3)	
Pig, gestating	0.09	Moral *et al*. (2008)
Pig, farrowing	0.08	
Pig, weaner	0.09	
Pig, finisher	0.13	

FYM: Farm yard manure; Se: Sweden; RF: Research facility

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Glossary

Cd-MT: Metallothionein bound cadmium

Annex 1: Cadmium concentrations in edible tissues and products

Table 1.1 Cadmium concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pork	5	loin: 0.013			Bordajandi *et al*. (2004)
Hogs	326	0.21	0.14	0.30	Coleman *et al*. (1992)
Boars / sows	280	0.13	0.21	0.65	
Pork	31	0.006			Gerber *et al*. (2009)
Pigs	20	0.011	0.012	0.066	Gyori *et al*. (2005)
Pigs	426	0.001	0.019	0.11 [a]	Jorhem & Sundström (1993)
Pork		< 0.001	0.042	0.261	Larsen *et al*. (2002) [b]
Pigs (6 m)	62	0.009	0.073	0.308	López-Alonso *et al*. (2007)

[a]: n = 893

Table 1.2 Cadmium concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Veal	438	0.0013	0.032			Alonso *et al*. (2002)
Beef	56	0.0014				
	4				0.002 - 0.03	Ayar *et al*. (2009)
Calves (6 - 12 m)	195		0.014	0.072		Blanco-Penedo *et al.* (2006) [b]
Cattle	118	0.0017 - 0.0089				Blanco-Penedo *et al.* (2010)
Calves	327		0.19	0.36		Coleman *et al*. (1992)
Heifers / Steers	287	0.13	0.30	0.38		
Bulls / Cows	95	0.12	0.24	1.52		
Lambs	165	0.20	0.14	0.18		
Mature sheep	34		0.24	0.83		
Lamb		chop: 0.012 loin: 0.007				Gerber *et al*. (2009)
Beef		sirloin: 0.005 - 0.006 rib-eye: 0.006 braising steak: 0.005				
Cattle	34	0.001	0.070	0.35 [c]		Jorhem & Sundström (1993)
Beef		< 0.001	0.105	0.785		Larsen *et al*. (2002)[a]
Calf	26	0.0014	0.042	0.198		
Lamb		0.0018				
Dairy cattle	16				0.0004	Leblanc *et al*. (2005)[a]
Male calves	230	0.00084	0.0080	0.0513		Alonso *et al*. (2000)
Female calves	200	0.00084	0.0076	0.0579		
Cows	56	0.00094	0.0833	0.388		
Calves, industrialized area	78	0.0013	0.030	0.161		Miranda *et al*. (2005)
Calves, rural area	92	0.001	0.023	0.096		
Dairy cattle		0.0005	0.033 - 0.044	0.330-0.410		Olsson *et al*. (2001)
Dairy cattle	3				0.00003 - 0.005	Santos *et al*. (2004)[a]
Cattle	97	0.002	0.191	1.142		Waegeneers *et al*. (2009)
Dairy cattle					0.0002	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: calves grazing on pastures fertilized with pig slurry; [c]: n= 187

Table 1.3 Cadmium concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken and eggs	5	0.003 - 0.022	0.023		0.0006 - 0.0008	Bordajandi *et al*. (2004)
Chickens (young)	311		0.13	4.92		Coleman *et al*. (1992)
Chickens (mature)	308	0.12	0.71	1.03		
Turkeys (young)	60	0.28	0.27	0.56		
Ducks	111		0.15	0.25		
Hens	108	femoral: 0.04 pectoral: 0.03	0.7	2.63		Doganoc (1996)
Chicken		breast: 0.005 leg: 0.006				Gerber *et al*. (2009)
Chicken	25	< 0.001	0.024		< 0.0006	Larsen *et al*. (2002)[a]
Turkey		< 0.001	0.035			
Poultry		0.0019 [b]			0.0004 [c]	Leblanc *et al*. (2005)[a]
Muscovy ducks	5	0.004 DM	0.557 DM	1.514 DM		Lucia *et al*. (2008)
Pekin ducks	5	0.005 DM	1.884 DM	5.295 DM		
Mule ducks	5	0.005 DM	1.840 DM	4.207 DM		
Hens, private owners	22				0.00053	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.00027	
Hens	98				< 0.0005 - 0.0005	Waegeneers *et al*. (2008)
Poultry and eggs		0.0025			0.0004	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Cadmium concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	0.27 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	0.17 DM	
Atlantic herring	3	0.01	Engman & Jorhem (1998)
Baltic herring	3	0.024	
Burbot	2	< 0.0004	
Cod	4	0.0003	
Eel	3	0.0082	
Mackerel	3	0.0073	
Perch	3	< 0.0005	
Picked dogfish	2	0.0015	
Pike	5	< 0.0004	
Plaice	4	< 0.0008	
Pollack	2	0.0006	
Salmon	3	< 0.0005	
Turbot	3	0.0005	
Whitefish	3	< 0.0004	
Chub mackerel	60	0.04 - 0.06	Ersoy & Celik (2009)
Mediterranean horse mackerel	60	0.04 - 0.27	
Golden grey mullet	60	0.04 - 0.07	
Round herring	60	0.05 - 0.09	
Fish	62	0.0016	Leblanc *et al*. (2005) [a]
Shellfish	18	0.0827	
Fish	3	0.0015 - 0.0043	Santos *et al*. (2004) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	1.310 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	0.831 DM	
Gilthead seabream *Sparus aurata*	45	1.341 DM	
Clarias gariepinus	38	< 0.001	Türkmen *et al*. (2007)
Carasobarbus luteus	23	0.002	

[a]: Total diet study

Table 1.5 Cadmium concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Holzing (AU)	23	0.00040	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.00023	
Origin: Hollabrunn (AU)	19	0.00036	
Origin: Siena County (It)	51	0.0039	Pisani *et al*. (2008)

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Annex 2: Cadmium concentrations in edible tissues and products linked with the dietary intake of several cadmium compounds and doses

Table 1 Cadmium concentrations in edible tissues and products of pigs and poultry (mg/kg)

Species / category	Source of Cd supplemented	Dose of Cd supplemented (mg Cd/kg)	Cd content of complete feed [1] (mg Cd/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Pigs			0.08 DM	([3])	0.13 DM [x]	0.64 DM [x]	0.02 DM [x]		Lisk *et al*. (1982)
	Cd - fortified corn[2]		0.24 DM		0.21 DM [y]	1.50 DM [y]	0.02 DM [x]		
Laying hens			0.08 - 0.13	80 w	1.43 DM	9.5 DM	breast: < 0.062 DM leg: < 0.062 DM	white and yolk: < 0.062 DM	Hinesley *et al*. (1985)
	Cd fortified corn and soybean		0.46 - 0.76		4.86 DM	45.8 DM	breast: < 0.062 DM leg: 0.113 DM	white and yolk: < 0.062 DM	
	Cd fortified corn and soybean		0.77 - 1.08		6.66 DM	69.5 DM	breast: < 0.062 DM leg: 0.131 DM	white and yolk: < 0.062 DM	
Chicks		0	0.21	42 d	0.23 DM [a]	0.39 DM [a]	0.07 DM [a]		Leach *et al*. (1979)
	$CdSO_4.8H_2O$	3			4.75 DM [a]	9.27 DM [b]	0.15 DM [a,b]		
	$CdSO_4.8H_2O$	12			15.13 DM [b]	49.69 DM [c]	0.26 DM [b]		
	$CdSO_4.8H_2O$	48			87.19 DM [c]	239.07 DM [d]	0.75 DM [c]		
Laying hens		0	0.22	48 w	2.99 DM [a]	17.1 DM [a]	0.12 DM [a]	0.16 DM [a,b]	Leach *et al*. (1979)
	$CdSO_4.8H_2O$	3.0			33.47 DM [a]	273.9 DM [b]	0.57 DM [a]	0.13 DM [a]	
	$CdSO_4.8H_2O$	12.0			41.82 DM [a]	708.3 DM [c]	1.66 DM [a]	0.14 DM [a]	
	$CdSO_4.8H_2O$	48.0			203.54 DM [b]	540.7 DM [c]	6.46 DM [b]	0.22 DM [b]	

Cd content of complete feed [1]: data from feed analysis; [2]: corn grown on municipal sewage sludge-amended soil; [3] : duration of trial: from 17.6 kg bw till 90 kg bw

Statistics:

Lisk *et al*. (1982): Means with different superscripts in each column differ significantly (P < 0.01)

Leach *et al*. (1979): means not sharing a common superscript in each column differ significantly (P < 0.05)

Table 1 (continued) Cadmium concentrations in edible tissues and products of pheasants (*Phasianus colchicus*) (mg/kg)

Species / category	Source of Cd supplemented	Dose of Cd supplemented (mg Cd/L drinking water)	Cd content of complete feed [1] (mg Cd/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Pheasants			< 0.01	12 w	0.04	0.10	0.02		Toman *et al*. (2005)
	$CdCl_2$	1.5 [2]			3.53 [*]	9.64 [***]	0.03		

[2]: average daily water consumption was 0.16 L/bird

Statistics: [*] means differ significantly (P <0.05); [***]: means differ significantly (P< 0.001)

Table 1 (continued) Cadmium concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Cd supplemented	Dose of Cd supplemented (mg Cd/day)	Cd intake from feed [1] (mg Cd/day)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Dairy Cows			3.2	3 m	0.64	1.35	0.054		Sharma *et al*. (1982)
	$CdCl_2$	40			0.73	3.58	0.064		
	$CdCl_2$	200			3.21 *	8.83 *	0.018		

Statistics:

Sharma *et al*. (1982): *: Means differ significantly from control (P< 0.05), T-test

Table 1 (continued) Cadmium concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Cd supplemented / Diet	Cd content of complete feed (mg Cd/kg)	Duration of study	Liver	Kidney	Muscle	Milk (mg/L)	Reference
Dairy Cows		0.25 DM	554 d [1]	0.48 DM [x]	2.95 DM [x]	0.18 DM	0.032	Smith *et al*. (1991)
	$CdCl_2$	1 DM		2.03 DM [x]	18.75 DM [x]	0.39 DM	0.034	
	$CdCl_2$	5 DM		14.41 DM [y]	132.17 DM [y]	0.24 DM	0.038	
Ewes	Basal diet	0.3 DM	2 years	0.5 DM	2.4 DM	< 0.7 DM		Sanson *et al*. (1984)
	Basal diet + 3.5% cottonseed meal	0.2 DM		0.6 DM	3.1 DM	< 0.7 DM		
	Basal diet + 7% sewage sollids	0.5 DM		0.8 DM	3.7 DM	< 0.7 DM		

[1]: Milk collection period: 121 - 150 d after start lactation

Statistics:

Smith *et al*. (1991): Means with different superscripts (x,y) differ significantly (P < 0.05)

Annex 2: References

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Cerium

Executive summary of the monograph for cerium

Cerium is a rare earth element and more specifically a lanthanoid. NRC did not classify cerium as an essential nutrient and no essential function has yet been demonstrated. Rare earth elements have been widely used in China as growth promoters. Increases in body weight gain and improvements of feed conversion were observed in studies evaluating rare earth element supplementation in pigs and broilers. It was suggested that rare earth elements promote animal growth by inhibiting undesirable bacterial strains in the gastrointestinal tract. Rare earth elements are generally considered to be nontoxic to animals. NRC did not establish maximum tolerable levels but stated that dietary concentrations of 100 mg/kg DM should be considered safe. Lanthanides are generally excepted to be poorly absorbable. In contrast, high cerium absorbabilities have been measured in neonates of several species. Lanthanides are primarily deposited in the liver and the skeleton. In edible tissues and products the cerium concentrations are in the µg/kg range. The acute toxicity of rare earth elements is low. Genotoxic effects, carcinogenic and teratogenic effects have not been reported for rare earths and are considered unlikely. Inhalation exposure to rare earths was shown to contribute to the development of progressive pulmonary fibrosis and they possess a mild toxic potential compared to other fibrogenic dusts. There were no indications that the presence of cerium in animal diets would have environmental consequences.

Cerium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

The transfer of rare earth elements from the soil into plants is low. Only little accumulation of rare earth elements is reported in animal tissues and edible products (Redling, 2006).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorization of use of cerium and cerium compounds in human and animal nutrition.

3 Essential functions

NRC (2005) did not classify cerium as an essential nutrient.

4 Other functions

In China, rare earth elements have been used as feed additives for their growth promoting effects. In studies on pigs, increases in body weight gain and improvements of feed conversion rate have been observed. Organically bound rare earth elements, e.g. rare earth ascorbates and citrates, were shown to further enhance performance in pigs and poultry (Redling, 2006).

5 Antimicrobial properties

It has been suggested that rare earth elements promote animal growth by selectively influencing bacterial species within the gastrointestinal tract and inhibiting the development of undesirable strains (Redling, 2006).

6 Typical deficiency symptoms

No cerium deficiency signs have been reported in principal literature sources.

7 Animal requirements, allowances and use levels

No scientific bodies have established cerium requirements.

8 Concentration of the element in feed materials

The concentrations of rare earth elements in plants are generally reported to be low. Though they vary considerably depending on the plant species and growing conditions. The following values have been reported: rice: 0.5 – 1 mg/kg; wheat: 1 – 2 mg/kg (Redling, 2006).

9 Concentration of the element in complete feedingstuffs

In pig feed cerium concentrations were reported in the range of 296 – 400 µg/kg (Redling, 2006).

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

The rare earth elements are relatively nontoxic to animals. NRC did not establish MTL values for cerium. It was stated that, taken the limited available information into account, rare earth dietary concentrations of 100 mg/kg DM should be considered safe (NRC, 2005).

11 Typical symptoms of toxicosis

No typical symptoms of toxicosis for cerium were reported in principal literature sources.

12 Bioavailability

In general, ingested lanthanides are only poorly absorbed. Contrarily, in newborn pigs, it was observed that 91 % of an orally administered ^{144}Ce intake was absorbed. Cerium was reported to be considerably absorbed by neonate mice, rats and pigs (NRC, 2005; Redling, 2006).

13 Metabolism

It is generally agreed that rare earths are predominantly excreted with feces through both bile as well as through the wall of the gastrointestinal tract (Redling, 2006).

14 Distribution in the animal body

The liver and the skeleton were shown to be the organs with the highest deposition of lanthanides. High concentrations have also been reported in oocytes, ovaries, testes, the intestine and cecum (Redling, 2006). In humans, values of the cerium concentration in total blood and lung were reported of respectively, < 0.002 mg/L and 0.05 µg/kg (Redling, 2006).

15 Deposition (typical concentration) in edible tissues and products

Cerium concentrations in edible tissues and products are given in Table 1.

Table 1 Cerium concentrations in edible tissues (µg/kg) derived from various feed trials as compiled by Redling (2006)

	Ce concentration		
Species	Muscle	Liver	Kidney
Broiler	Breast: 7	19	
Broiler	Breast: 21 Thigh: 17	25	10.7
Pigs	< 33 DM	< 52 DM	< 34 DM
Piglets	13.9	15.8	

16 Acute toxicity

Rare earths are generally considered to be of low toxicity. Oral LD_{50} values are reported in Table 2 (Redling, 2006).

Table 2 Oral LD_{50} values for cerium (Redling, 2006)

Compound	**Species**	**LD_{50} (mg/kg bw)**
$CeCl_3$	Mice, male	1959
$CeCl_3$	Rats	2110
$CeCl_3$	Mice	5277
$Ce(NO_3)_3$	Rats, female	4200
CeO_2	Rats	> 5000

17 Genotoxicity and Mutagenicity

No information on genotoxic effects of cerium was reported in principal literature sources. Redling (2006) stated that genotoxic effects of ingested rare earth elements are not to be expected.

18 Subchronic toxicity

No information on the subchronic toxicity of cerium was reported in principal literature sources.

19 Chronic toxicity, including carcinogenicity

Rare earths are mainly deposited in the liver and hepatotoxic effects have been observed. The induction of the fatty liver phenomenon, i.e. the massive hepatic accumulation of neutral fat esters, has been shown following intravenous injection of rare earths but not following oral exposure (Redling, 2006).

Lanthanides were shown to associate to both the organic and inorganic matrix of bone. Although the skeleton is the second major deposition site or rare earth elements, no toxic effects on bone structure have been found (Redling, 2006).

20 Reproduction and developmental toxicity

No information on reproductive and developmental effects of cerium was reported in principal literature sources. Redling (2006) stated that teratogenic effects of ingested rare earth elements are not to be expected.

21 Non Observed Adverse Effect Level (NOAEL)

Upper intake levels have not been established by scientific bodies for cerium, hence, no NOAEL level was identified to serve as the basis to establish an upper intake level.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

No scientific body has yet established an UL for cerium. An acceptable daily intake was suggested by some authors for rare earth nitrates and rare earth oxides of respectively, 12 – 120 mg/day and 6 – 60 mg/day (Redling, 2006).

23 Toxicological risks for user/workers

Inhalation exposure of stable rare earths was shown to contribute to the development of progressive pulmonary fibrosis. The accumulation of fine granular dust particles containing rare earth elements, mainly cerium, may cause interstitial disorders and emphysema. Compared to other fibrogenic dusts, e.g., quarts and silica, the toxic potential of rare earth dusts is mild (Redling, 2006).

24 Toxicological risks for the environment

There were no indications in principal literature sources that the presence of rare earth elements in animal diets would have environmental consequences.

25 References

NRC (National Research Council of the National Academies). 2005. Mineral Tolerance of Animals, 2 nd Revised Edition. The National Academies Press, Washington D.C., USA.

Redling, K. 2006. Rare Earth Elements in Agriculture with Emphasis on Animal Husbandry. Inaugural-Dissertation zur Erlangung der tiermedizinischen Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München. 326 pp. Deutsche Veterinärmedizinische Gesellschaft Service Gmbh, Gieβen, Germany.

Chromium

Executive summary of the monograph for chromium

Several chromium compounds are presently authorized as food additives in the EU. Chromium is a metallic element which can exist in several oxidation states of which the biologically important are trivalent and hexavalent chromium. NRC classified chromium as an essential element. Contrarily, EFSA considered the available data inconclusive and adopted a classification of chromium as a nutritionally or pharmacologically beneficial element. Chromium(III) is a well known factor potentiating insulin dependent glucose entry into cells. Hexavalent chromium is much more toxic than trivalent chromium. Maximum tolerable levels have not been established for hexavalent chromium as it is generally not ingested orally. Trivalent chromium is relatively nontoxic due to its poor intestinal absorption and limited entry of absorbed chromium(III) into cells. NRC established maximum tolerable levels ranging between 100 – 500 mg/kg DM and 3000 – 30000 mg/kg DM for soluble chromium(III) compounds and chromium oxide, respectively. Hexavalent chromium has a much greater bioavailability than even water soluble forms of inorganic trivalent chromium. Chromium oxide, an insoluble form of trivalent chromium is essentially unavailable. Trivalent chromium is absorbed in the upper small intestine by a non-saturable passive diffusion process. More than 99 % of trivalent chromium in blood appears in plasma, primarily bound to transferrin. Chromium(III) mainly accumulates in the liver and moderately accumulates in kidneys, spleen and muscle. Chromium(III) is mostly excreted via urine, with only small amounts being eliminated through bile and perspiration.

In general, *in vitro* mutagenicity tests have yielded positive results for hexavalent chromium and negative results for trivalent. The genotoxicity of chromium(III) cannot be fully excluded. Few adverse effects have been associated with the excess intake of chromium from food. Chronic interstitial nephritis in humans has been attributed to the ingestion of chromium picolinate. Animal studies assessing reproductive and developmental effects of chromium(III) and chromium(VI) compounds, yielded conflicting results. IOM, SCF, EVM and BfR considered the available data insufficient to derive an upper intake level for chromium(III). EVM established a guidance level of 0.15 mg/(kg bw.day) for the total intake of chromium(III) per day. The FEEDAP Panel concluded in its assessment that any additional exposure of consumers resulting from the use of supplementary chromium in animal nutrition should be avoided. Chromium can be absorbed from the lungs. The FEEDAP Panel advised that any occupational exposure to chromium(III) in feeds should be kept to a minimum. Chromium(III) is ubiquitously present in the environment. The FEEDAP Panel concluded that the contribution of chromium present in excretions of terrestrial animals to the natural levels of chromium in soil and the aquatic environment would not pose an environmental risk.

Chromium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Chromium is a metallic element which can exist in several oxidation states of which the biologically important are trivalent and hexavalent chromium. Trivalent chromium is ubiquitous in nature, occurring in air, water, soil and biological materials, while hexavalent chromium compounds are generally believed to be man-made and do not occur naturally in the environment. Feed and food contain chromium in both inorganic forms and organic complexes. However, the precise speciation of dietary chromium compounds is not known (EFSA, 2009).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal nutrition

Chromium compounds are currently not authorized in the EU as feed additives. In the US, chromium tripicolinate (57.155) is allowed as a source of supplemental chromium in swine diets, with the supplementation level restricted to 200 ppb of chromium. Chromium L-methionine complex is currently withdrawn and considered an unapproved food additive (AAFCO, 2010).

2.2 Human nutrition

Chromium compounds are presently authorized in the EU:

– As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[1]. The authorized chromium compounds are: chromium(III) chloride and its hexahydrate; chromium(III) sulphate and its hexahydrate.

– As food supplements under Regulation EC 1170/2009[2]. The authorized chromium compounds are: chromium(III) chloride, chromium(III) lactate trihydrate, chromium nitrate, chromium picolinate, chromium(III) sulphate.

– As substances which may be added to foods under Regulation EC 1925/2006[3] as amended by Regulation EC 1170/2009. The authorized chromium compounds are: chromium(III) chloride and its hexahydrate, chromium(III) sulphate and its hexahydrate.

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[1] OJ L 269, 14.10.2009, p. 9

[2] OJ L 314, 1.12.2009, p. 36

[3] OJ L 404, 30.12.2006, p. 26

– Directive 2008/100/EC[4] lays down a Recommended Daily Allowance (RDA) for chromium of 40 µg.

3 Essential functions

NRC (2005) classified chromium as an essential element. EFSA (2009) thoroughly assessed the essentiality of chromium and concluded that there is no conclusive evidence supporting essentiality or non-essentiality of trivalent chromium as a trace element. A classification of chromium as a nutritionally or pharmacologically beneficial element was adopted (EFSA, 2009).

4 Other functions

Chromium(III) is a well known factor potentiating insulin-dependent glucose entry into the cells. Currently, the predominant hypothesis on the trivalent chromium action is the chromodulin-mediated role on the insulin activated glucose uptake by cells. In this model, the chromium(III) action on insulin receptors is carried out by a chromium-oligopeptide complex, often referred to as chromodulin. Chromium(III) via insulin action is thought to participate also in protein metabolism by stimulating the amino acids uptake by cells. Chromium(III) supplementation in farm animals was shown to tend to decrease serum cortisol levels in several species. In male rats, oral chromium(III) supplementation was shown to elicit a significant, dose related trend towards reduced serum leptin. Results of studies that evaluated the effect of chromium(III) supplementation on carcass composition were variable (EFSA, 2009).

5 Antimicrobial properties

There was no information available on antimicrobial properties of chromium in principal literature sources.

6 Typical deficiency symptoms

No experimental evidence of chromium deficiency has been demonstrated. Symptoms of chromium deficiency in farm animals have not yet been recognized in field conditions (EFSA, 2009).

7 Animal requirements, allowances and use levels

Chromium(III) requirements for livestock species have not been established by scientific bodies.

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[4] OJ L 285, 29.10.2008, p. 9

8 Concentration of the element in feed materials

Chromium(III) and chromium(VI) are taken up by plants: chromium(VI) is taken up actively by sulphate carriers and immediately converted to chromium(III) in roots; in contrast, chromium(III) is taken up passively, being retained by the ion-exchange sites of cell walls. Chromium concentrations in plants are generally in the following order: roots> leaves> fruits. The chromium content in whole cereals is mostly concentrated in pericarps. Feed phosphate sources appear to be a major source of chromium in certain animal diets. Feed grade monocalcium phosphate and defluorinated phosphate sources are reported to vary in chromium content between 83 and 110 mg/kg, respectively (NRC, 2005). EFSA (2009) reported chromium concentrations in feed materials (Table 1).

Table 1 Total chromium concentrations in feed materials (mg/kg) (EFSA, 2009)

Feed material	n	Mean	Range
Wheat grain, durum	3	0.027	0.020 - 0.032
Wheat grain	12	0.020 - 0.058	0.013 - 0.071
Wheat bran	5	0.124 - 0.141	0.078 - 0.177
Corn grain	7	0.006 - 0.144	0.004 - 0.186
Barley grain	4	0.018	0.013 - 0.021
Barley bran	4	0.058	0.029 - 0.095
Soybeans	5	0.497	0.383 - 0.639
Feed grade phosphates	4	49	21 - 72
Mineral mixtures	21	45.9	1.5 - 220

9 Concentration of the element in complete feedingstuffs

Chromium concentrations in complete feedingstuffs are reported in Table 2.

Table 2 Mean total chromium concentrations in complete feedingstuffs (mg/kg)

Complete feedingstuff	n	Cr conc. (EFSA, 2009)	Complete feedingstuff	n	Cr conc. (Nicholson *et al.*, 1999)
Poultry feed	2	0.82 – 0.85	Broiler starter	4	1.77 DM
Poultry feed	1	1.27	Broiler grower	4	1.44 DM
			Broiler finisher	3	0.22 DM
			Layer	4	0.76 DM

Table 2 (continued) Mean total chromium concentrations in complete feedingstuffs (mg/kg)

Complete feedingstuff	**n**	**Cr conc. (EFSA, 2009)**	**Complete feedingstuff**	**n**	**Cr conc. (Nicholson *et al*., 1999)**
Swine feed		0.75 – 1.50	Rearer-creep pig feed	4	0.35 DM
			Rearer-weaner pig feed	4	0.75 DM
			Rearer-grower	5	0.54 DM
			Rearer-finisher	7	0.80 DM
			Sow-dry	3	1.31 DM
			Sow-lactating	3	0.81 DM
Ruminant compound feed		0.3 – 1.6			
Rabbit feed	1	0.5			
Various feeds	70	1.93			

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Episodes of acute toxicity of chromium compounds in food-producing species are seldom encountered, mainly because of the low solubility and bioavailability of chromium compounds, including oxides which are among the most common sources of chromium in the environment. Chromium oxide has been used for decades as a digestibility marker in cattle, sheep and pigs at dietary chromium levels up to 3000 mg/kg without signs of acute toxicity (EFSA, 2009; NRC, 2005). Hexavalent chromium is much more toxic than trivalent chromium. NRC did not define MTL-values for domestic animals because hexavalent chromium is generally not ingested orally. MTL values established by NRC (2005) are compiled in Table 3. Chickens have shown to be more tolerant to soluble compounds of trivalent chromium compared to mammalian species.

Table 3 Maximum Tolerable Levels (MTL) for chromium (mg/kg DM) (NRC, 2005)

Species	**MTL**	**Additional remarks**
Soluble Cr^{3+}		
Poultry	500	
Rodents	100	
Swine, horses, cattle, sheep	100	Value derived from interspecies extrapolation
CrO		
Rodents	30000	
Poultry, fish	3000	
Swine, horses, cattle, sheep	3000	Value derived from interspecies extrapolation

Additionally to the chromium MTL values NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues. The FEEDAP Panel evaluated the toxicity data available from trivalent chromium supplementation studies and concluded that for many studies the results support the conclusions reached by NRC (2005) on MTL values of chromium(III). Additionally, it was remarked that few studies investigated the potential toxicity biomarkers in target species. Those studies show signs of intolerance or toxicity at considerable lower levels than the NRC MTL-values (EFSA, 2009).

11 Typical symptoms of toxicosis

Reduced weight gain due to excessive chromium(III) ingestion has been observed in cattle, pigs, horses and rodents. Impaired reproduction is also shown in several species. Reduced milk production was shown in dairy cattle. In laying hens chromium(III) toxicity effects included the impairment of a number of cytochrome P450-dependent monooxygenases (EFSA, 2009; NRC, 2005).

12 Bioavailability

12.1 General

When ingested hexavalent chromium has a much greater bioavailability than even water soluble forms of inorganic trivalent chromium. However, hexavalent chromium is not likely to be consumed orally. Chromium oxide, an insoluble form of trivalent chromium is essentially unavailable (NRC, 2005). The average absorption rate of chromium naturally contained in food, estimated on the basis of metabolic balance studies or on urinary excretion, is considered to be in the range of 0.4 - 2.5 % (EFSA, 2009). EFSA (2009) reported estimated absorbabilities of several chromium compounds in several species (Table 4).

Table 4 Chromium absorbabilities for several chromium compounds as reported by EFSA (2009)

Species	Chromium compound	Absorbability (%)
Rats	Cr - chloride	0.9%
Rats	Cr - nicotinate	1.3
Rats	Cr - picolinate	1.1
Rats	Cr - dinicotinic acid-diglycine-cysteine-glutamic acid	0.6
Human	Cr - chloride	0.1 - 0.4 %
Human	Cr - picolinate	2.8 %
Human	Cr - brewer yeast	5 - 10 %

Dietary factors that enhance chromium absorption include starch, simple sugars, ascorbic acid, oxalate, nicotinic acid, organic acids, histamine and some amino acids. Phytate, calcium, manganese, titanium, zinc, vanadium and iron were reported to inhibit chromium absorption (EFSA, 2009).

12.2 *Chromium status indicators / biomarkers to identify and quantify chromium exposure*

Exposure to chromium may result in increased chromium concentrations in blood, urine, expired air, hair, and nails; of these, elevations of chromium in blood and urine are considered the most reliable indicators of exposure. More detailed information is given on elimination kinetics and reliability of the indicators in the ATSDR Toxicological Profile (ATSDR, 2008).

13 Metabolism

Trivalent chromium is absorbed in the upper small intestine by a non-saturable passive diffusion process (EFSA, 2009). More than 99 % of trivalent chromium in blood appears in plasma, primarily bound to transferrin. When the saturation of transferrin with iron increases over 50 % in blood, iron may compete with chromium(III) binding and thus affects transport. Generally, iron-binding proteins are involved in chromium binding, transport and storage. Absorbed chromium(III) is mostly excreted via urine, with only small amounts being eliminated through bile and perspiration (EFSA, 2009).

14 Distribution in the animal body

Chromium(III) mainly accumulates in the liver and moderately accumulates in kidneys, spleen and muscle. It is also found in many other organs, such as heart, pancreas, lung, bone and brain (EFSA, 2009).

15 Deposition (typical concentration) in edible tissues and products

A compilation of chromium concentrations in edible tissues and products is given in Annex 1. Chromium concentrations in edible tissues and products linked with the dietary intake of various chromium compounds and doses are reported in Annex 2, which is adopted from the FEEDAP Opinion (EFSA, 2009).

16 Acute toxicity

Lethal ingested doses of chromium(VI) have been reported in humans: 29 mg Cr(VI)/kg bw as potassium dichromate, 357 mg Cr(VI)/kg bw as chromic acid and 4.1 mg Cr(VI)/kg bw as chromic acid. The observed effects included gastrointestinal hemorrhage and necrosis, renal failure and necrosis, fatty degeneration of the liver. Chromium(III) compounds are less toxic than chromium(VI) compounds and higher chromium(III) doses are required to produce signs of acute toxicosis (ATSDR, 2008; NRC, 2005). ATSDR (2008) reported oral LD_{50} values of chromium(VI) and chromium(III) compounds (Table 5).

Table 5 Oral LD_{50} values for chromium(VI) and chromium(III) compounds (ATSDR, 2008)

Species	**Cr compound**	$\mathbf{LD_{50}}$
Female rats	Cr(VI) compounds: sodium chromate, sodium dichromate, potassium chromate, ammonium dichromate	13 - 19 mg Cr/kg bw
Male rats	Cr(VI) compounds: sodium chromate, sodium dichromate, potassium chromate, ammonium dichromate	21 - 28 mg Cr/kg bw
Female rats	Cr(VI) compound: Calcium chromate	108 mg Cr/kg bw
Male rats	Cr(VI) compound: Calcium chromate	249 mg Cr/kg bw
Rats	Cr(III) compound: Chromium acetate	2365 mg Cr/kg bw
Female rats	Cr(III) compound: Chromium nitrate	183 mg Cr/kg bw
Male rats	Cr(III) compound: Chromium nitrate	200 mg Cr/kg bw

17 Genotoxicity and Mutagenicity

In general, *in vitro* mutagenicity tests have yielded positive results for hexavalent chromium and negative results for trivalent (EVM, 2003). ATSDR (2008) made an extensive compilation of the available *in vivo* and *in vitro* genotoxicity studies with chromium(VI) and chromium(III) compounds. The following conclusions were drawn:

- Chromium(VI) compounds were positive in the majority of the reported tests, and their genotoxicity was related to the solubility and, therefore, to the bioavailability to the targets;
- Results of occupational exposure studies in humans provided evidence of chromium(VI)-induced DNA strand breaks, chromosome aberrations, increased sister chromatid exchange, unscheduled DNA synthesis, and DNA protein cross links;
- These findings from occupational exposure studies are supported by results of in vivo studies in animals, in vitro studies in mammalian cells, yeast and bacteria, and studies in cell free systems;
- Compared to chromium(VI), chromium(III) was more genotoxic in subcellular targets but lost this ability in cellular systems;
- The reduction of chromium(VI) in cells to chromium(III) and its subsequent genotoxicity may be greatly responsible for the final genotoxic effects;

– Reduction of chromium(VI) can also result in the formation chromium(VI), which is highly reactive and capable of interaction with DNA.

The FEEDAP Panel adopted in its assessment the consideration that chromium(III) is the likely ultimate intracellular toxic form of chromium(VI) and the most recent literature and carcinogenicity studies in rats and mice indicate that chromium(III) may be a genotoxic compound under *in vivo* conditions. Hence, it was concluded that the genotoxicity of ingested chromium(III) could not be fully excluded (EFSA, 2009).

18 Subchronic toxicity

ATSDR (2008) reported on oral subchronic exposure studies to chromium(IV) and chromium(III) compounds with rats and mice.

19 Chronic toxicity, including carcinogenicity

Few serious adverse effects have been associated with the excess intake of chromium from food, i.e., trivalent chromium. Chronic interstitial nephritis in humans has been attributed to the ingestion of chromium picolinate. Additionally, there are reports of hepatic adverse effects and rhabdomyolysis in humans (IOM, 2001).

IARC (1997) classified chromium(VI) as carcinogenic to humans (Group 1) and metallic chromium and chromium(III) compounds as not classifiable as to their carcinogenicity to humans (Group 3).

20 Reproduction and developmental toxicity

IOM (2001) and ATSDR (2008) located no studies regarding reproductive and developmental effects in humans after oral exposure to chromium(VI) or chromium(III) compounds.

ATSDR (2008) extensively reported on animal studies assessing the reproductive and developmental effects of chromium(VI) and chromium(III) compounds (Table 6). It was concluded that studies on the reproductive effects of chromium(III) yielded conflicting results (ATSDR, 2008).

Table 6 Summary of studies assessing reproductive and developmental effects of oral chromium(III) exposure (ATSDR, 2008)

Species	Dose	Duration	Effect
Rats	1806 mg Cr(III)/(kg bw.day) as chromium oxide	60 d; 5d/week	Normal fertility, gestational length, litter size, no developmental effects
Rats	40 mg Cr(III)/(kg bw.day) as chromium chloride	12 w	Significant alterations in sexual behavior, significantly lower weight of testes, seminal vesicles, and perpetual glands
Male mice	13 mg Cr(III)/(kg bw.day) as chromium chloride		Decreased number of pregnant (untreated) females following mating with exposed males
Female mice	74 mg Cr(III)/(kg bw.day) as chromium chloride	8 d	Significantly decreased weights of reproductive tissues in the offspring

21 Non Observed Adverse Effect Level (NOAEL) and LOAEL (Lowest Observed Adverse Effect Level)

NOAEL and LOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

IOM (2001) was not able to identify a NOAEL or LOAEL value from the available studies on damaging effects of chromium(III) to establish an UL. EVM (2003) considered the available data insufficient to derive an UL value. Based on a study with rats a NOAEL value of 15 mg/(kg bw.day) was identified. A combined uncertainty factor of 100 was applied to calculate a guidance level of 0.15 mg/(kg bw.day) for the total intake of chromium(III). Chromium(III) ingestion via chromium picolinate is also excluded from the guidance level (EVM, 2003). SCF (2003) also concluded that the available data from studies on subchronic, chronic and reproductive toxicity of soluble chromium(III) salts were insufficient to derive a UL value. BfR (2006) proposed an upper level for trivalent chromium (not including chromium picolinate) in food supplements of 60 µg/day. ATSDR (2008) established oral minimal risk levels for exposure to hexavalent chromium compounds of 0.005 mg Cr(VI)/(kg bw.day) and 0.001 mg Cr(VI)/(kg bw.day) for intermediate and chronic exposure, respectively.
The FEEDAP Panel concluded, taking into account concerns on consumer safety for chromium(III), that any additional exposure of consumers resulting from the use of supplementary chromium in animal nutrition should be avoided (EFSA, 2009).

23 Toxicological risks for user/workers

The identification of chromium in urine, serum, and tissues of humans occupationally exposed to soluble chromium(III) or chromium(VI) compounds in air indicates that chromium can be absorbed from the lungs (ATSDR, 2008). ATSDR (2008) established Minimal Risk Levels (MRL) for intermediate duration (15 – 365 days) inhalation exposure to insoluble chromium(III) particulate compounds of 0.005 mg Cr(III)/m^3 and to soluble chromium(III) particulate compounds of 0.0001 mg Cr(III)/m^3. The available data for acute and chronic duration inhalation exposure to chromium(III) compounds were considered insufficient to establish MRLs. The FEEDAP Panel concluded that due to concerns for allergenicity and potential genotoxicity, any occupational exposure to chromium(III) in feeds should be kept to a minimum (EFSA, 2009).

24 Toxicological risks for the environment

Chromium, as a natural element, is ubiquitous in the environment, occurring in a number of oxidation states. Chromium(III) is the predominant naturally occurring form. The Predicted No Effect Concentrations (PNEC) for chromium(III) are established to be 2.8 mg/kg wet weight for soil, 4.7 µg/L for the surface water compartment and 31 mg/kg wet weight for sediment. Given that the vast majority of chromium(VI) will be reduced to chromium(III) in soil and sediment, the FEEDAP Panel considered the PNEC values established for chromium(III) most relevant compared to those established for chromium(VI) (EFSA, 2009). Chromium(III) is ubiquitously present in the environment. The FEEDAP Panel concluded that the contribution of chromium present in excretions of terrestrial animals to the natural levels of chromium in soil and the aquatic environment would not pose an environmental risk (EFSA, 2009).

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Annex 1: Chromium concentrations in edible tissues and products

Table 1.1 Chromium concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pigs	71	0.014	< 0.010	< 0.010	Jorhem & Sundström (1993)
Pigs (6 m)	62	0.131	0.120	0.077	López-Alonso *et al*. (2007)

Table 1.2 Chromium concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Cattle	7	< 0.010	0.012	< 0.010		Jorhem & Sundström (1993)
Dairy cattle	16				0.02	Leblanc *et al*. (2005)[a]
Dairy cattle	3				0.0004 - 0.0017	Santos *et al*. (2004)[a]
Dairy cattle					0.01	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: calves grazing on pastures fertilized with pig slurry

Table 1.3 Chromium concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Poultry		0.03 [b]			0.05 [c]	Leblanc *et al*. (2005)[a]
Poultry and eggs		0.09			0.04	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.5 Chromium concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Holzing (AU)	23	0.0030	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.0059	
Origin: Hollabrunn (AU)	19	0.0040	
Turkey	25	0.0025 - 0.0379	Tuzen *et al*. (2007)

Table 1.4 Chromium concentrations in edible tissues (mg/kg) of fish

Species - category	**n**	**Muscle**	**Reference**
Sea bass – cultured (*Dicentrarchus labrax*)	3	0.17 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	0.15 DM	
Atlantic herring	3	0.006	Engman & Jorhem (1998)
Baltic herring	3	0.009	
Burbot	2	0.004	
Cod	4	0.006	
Eel	3	0.006	
Mackerel	4	0.007	
Perch	3	0.011	
Picked dogfish	2	0.013	
Pike	5	0.006	
Plaice	4	0.064	
Pollack	2	0.004	
Salmon	3	0.004	
Turbot	3	0.006	
Whitefish	3	0.013	
Chub mackerel	60	0.04 - 0.06	Ersoy & Celik (2009)
Mediterranean horse mackerel	60	0.04 - 0.06	
Golden grey mullet	60	0.04	
Round herring	60	0.04 - 0.07	
Fish	62	0.08	Leblanc *et al*. (2005) [a]
Shellfish	18	0.09	
Fish	3	0.018 - 0.032	Santos *et al*. (2004) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	1.654 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	2.719 DM	
Gilthead seabream *Sparus aurata*	45	1.309 DM	
Clarias gariepinus	38	0.013	Türkmen *et al*. (2007)
Carasobarbus luteus	23	0.023	

[a]: Total diet study

Annex 1: References

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Annex 2: Chromium concentrations in edible tissues and products linked with the dietary intake of various chromium compounds and doses (adopted from EFSA, 2009).

Table 1. Chromium concentrations in tissues (µg/kg) of cattle for fattening and in milk (µg/L) from dairy cows fed diets supplemented with various sources of trivalent chromium

Animal species	Cr content of complete control diet (mg/kg)	Cr(III) dose supplemented to control complete feed (mg/kg)	Source of Cr(III) supplemented	Duration of study	Muscle	Liver	Kidney	Heart	Rib fat	Milk	Method of Cr analysis	Reference
Cattle[1]	ND	Control		146 d		25	13				GF-AAS	Spears et al., 2004
		0.4	$CrCl_3$			21	12					
		0.8	Cr nicotinate			20	11					
Cattle[1]	ND	Control		125 d	116	41	108				GF-AAS	Spears et al., 2004
		0.8	Cr-methionine		81	38	127					
Dairy cows[3]	ND	Control		28 d before calving and 28 d during lactation						55	ICP-AES	Hayirli et al., 2001
		0.03	Cr methionine							55		
		0.06	Cr methionine							57		
		0.12	Cr methionine							57		
Steers[1,4]	1.65[6]	Control	Cr yeast	138 d	510	140	200		430		GF-AAS	Chang et al., 1992
		0.2			560	200	270		200			
Steers[1,5]	1.65[6]	Control		138 d	730	230	380		330		GF-AAS	Chang et al., 1992
		0.2	Cr yeast		600	290	220		170			

[1] chromium tissue concentrations on dry matter basis
[2] chromium tissue concentrations on wet weight basis
[3] supplemented dose in mg kg^{-1} $BW^{0.75}$ which corresponded in three Cr(III) supplemented groups to Cr contents 0.22, 0.39 and 0.83 mg kg^{-1} complete feed, respectively
[4] 70-d growing period on urea-corn feed
[5] 70-d growing period on soybean meal
[6] Cr contents of complete diet to finishing steers
ND – not determined
GF-AAS – graphite furnace atomic absorption spectrophotometry
ICP-AES – inductively coupled plasma atomic emission spectroscopy

Table 2. Chromium concentrations in tissues (µg/kg) of pigs for fattening and sows fed diets supplemented with various sources of trivalent chromium

Animal species	Cr content of complete control diet (mg/kg)	Cr(III) dose supplemented to control complete feed (mg/kg)	Source of Cr(III) supplemented	Duration of study	Muscle	Liver	Kidney	Heart	Pancreas	Bone	Ovary	Adrenals	Method of Cr analysis	Reference
Pigs[1]	ND	Control		From 18 to 100 kg b.w.	2	9^{d}	10^{d}	8^{e}	3de				GF-AAS	Ward, 1995
		0.2	$CrCl_3$		6	17^{cd}	15^{cd}	19^{bcd}	30^{b}					
		0.2	Cr acetate		5	35^{b}	78^{b}	15^{bcde}	2^{e}					
		0.2	Cr oxalate		4	35^{b}	50^{bc}	22^{b}	4^{cde}					
		0.2	Cr nicotinate		3	13^{cd}	35^{cd}	9de	12^{cd}					
		0.2	Cr picolinate		5	20^{c}	38^{cd}	16^{bcde}	8^{cde}					
		0.2	CrNGCG[3]		7	9^{cd}	10^{d}	20^{bc}	4^{cde}					
Pigs[1]	2.7	Control		50 d	<1.5	21^{a}	27^{a}	4					GF-AAS	Anderson et al., 1997a
		0.3	Cr picolinate		<1.5	29^{b}	57^{b}	11						
Pigs[1]	2.1	Control		75 d	96	12^{a}	42^{a}			27^{a}	4^{a}		ICP-MS	Lindemann et al., 2008
		5.0	Cr picolinate		151	91^{c}	185^{d}			95^{d}	51^{c}			
		5.0	Cr propionate		219	21^{a}	61^{ab}			45^{ab}	4^{a}			
		5.0	Cr methionine		82	41^{b}	106^{c}			81^{cd}	24^{b}			
		5.0	Cr yeast		205	14^{a}	77^{bc}			59^{bc}	12^{ab}			
Pigs[2]	ND		Control	35 d	33^{a}	24^{a}	48^{a}	49^{a}					GF-AAS	Wang and Xu, 2004
		0.2	Cr nanopartic.		93^{b}	59^{b}	90^{b}	75^{b}						
Sows[1]	ND	Control		3 parities		23	36				11	16	ICP-MS	Lindemann et al., 2004
		0.2	Cr picolinate			37^{L}	56^{L}				31	20^{L}		
		0.6	Cr picolinate			88^{L}	133^{L}				49	34^{L}		
		1.0	Cr picolinate			92^{L}	176^{L}				32	48^{L}		

[1] chromium tissue concentrations on dry matter basis
[2] chromium tissue concentrations on wet weight basis
[3] Cr nicotinate-glycine-cysteine- glutamate complex
ND – not determined
GF-AAS – graphite furnace atomic absorption spectrophotometry
ICP-MS – inductively coupled plasma mass spectrometry
[a,b,c] Means in a column with different letters in superscripts are statistically different ($P<0.05$)
[L] Means in column show significant linear response ($P<0.005$)

Table 3. Chromium concentrations in tissues and animal products (µg/kg) from poultry fed diets supplemented with various sources of trivalent chromium

Animal species	Cr content of complete control diet (mg/kg)	Cr(III) dose supplemented to control complete feed (mg/kg)	Source of Cr(III) supplemented	Duration of study	Muscle		Liver	Kidney	Heart	Lungs	Spleen	Gizzard	Egg white	Egg yolk	Method of Cr analysis	Reference
Broilers[2]	4,6			21 d	Breast	Thigh									AAS	Amatya et al., 2004
		Control			60^{a}	230^{a}	360^{b}		1760^{a}	880^{a}	140^{a}					
		0.2	$CrCl_3$		400^{b}	1030^{b}	250^{a}		1850^{a}	6000^{c}	1970^{b}					
		0.2	Cr yeast		390^{b}	1420^{b}	210^{a}		2870^{b}	4900^{bc}	3760^{b}					
Broilers[2]	4,6 in starter 4.9 in grower			35 d	Breast	Thigh									AAS	Amatya et al., 2004
		Control			200^{a}	1860^{a}	420^{b}		350	460	1440^{a}					
		0.2	$CrCl_3$		460^{b}	4170^{b}	300^{a}		440	550	2200^{b}					
		0.2	Cr yeast		660^{b}	4540^{b}	310^{a}		440	790	2840^{b}					
Broilers[1]	1.1			35 d	Carcase										AAS	Samanta et al., 2008
		Control			270^{a}											
		0.5	$CrCl_3$		510^{b}											
Broilers[1]	1.7			35 d	Breast	Thigh									AAS	Ahmed et al., 2005
		Control			400	450	590									
		0.2	$CrCl_3$		600	750	370									
Broilers	ND			56 d	Breast										AAS	Debski et al., 2004
		Control			40											
		0.2	Cr yeast		52											
Laying[1] hens	0.22	Control		28 d										160^{a}	GF-AAS	Dębski et al., 2001
		0.5	Cr yeast											380^{b}		
Laying hens[1]	3.0	Control		35 d										390	ICP-AES	Piva et al., 2003
		21.2^{3}	$CrCl_3$											400		
		31.9^{3}	Cr yeast											380		
		41.8^{3}	Cr AN[4]											430		
Turkeys[2]	0.5			35 d	Breast	Thigh									AAS	Anderson et al., 1989
		Control			0.8	0.8	1.9	3.3	0.9	12	3.7	1.0	15	1.8		
		25	$CrCl_3$		1.1^{L}	1.0	36^{L}	88^{L}	1.8^{L}	12^{L}	13^{L}	1.9^{L}	14	1.2		
		100	$CrCl_3$		2.8^{L}	2.0	168^{L}	224^{L}	8.0^{L}	41^{L}	50^{L}	8.0^{L}	29	2.0		
		200	$CrCl_3$		3.5^{L}	3.7	326^{L}	541^{L}	12.0^{L}	59^{L}	67^{L}	12.0^{L}				

[1] chromium tissue concentrations on dry matter basis; [2] chromium tissue concentrations on wet weight basis; [3] analysed Cr contents in supplemented complete feed; [4] chromium aminoniacinate

ND – not determined; AAS - atomic absorption spectrophotometry; ICP-AES - inductively coupled plasma atomic emission spectroscopy; GF-AAS – graphite furnace atomic absorption spectrophotometry; [a,b,c] Means in a column with different letters in superscripts are statistically different ($P<0.05$); [L] Means in column show significant linear response ($P<0.05$)

Table 3 (continued). Chromium concentrations in tissues and animal products (µg/kg) from poultry fed diets supplemented with various sources of trivalent chromium

Animal species	Cr content of complete control diet (mg/kg)	Cr(III) dose supplemented to control complete feed (mg/kg)	Source of Cr(III) supplemented	Duration of study	Muscle	Liver	Kidney	Heart	Lungs	Spleen	Gizzard	Egg white	Egg yolk	Method of Cr analysis	Reference
Japanese quails[1]	4.0	Control		38 d	1.3^{b}	2.6^{b}	2.4^{c}							GF-AAS	Uyanik et al., 2005
		20	$CrCl_3$		1.4^{b}	2.6^{b}	2.4^{c}								
		40	$CrCl_3$		2.0^{ab}	3.7^{ab}	3.1^{bc}								
		80	$CrCl_3$		2.6^{a}	4.5^{a}	4.2^{b}								
		100	$CrCl_3$		2.3^{a}	4.1^{ab}	5.9^{a}								
Japanese quails[2], laying hens	1.1	Control		93 d	260	130	230							GF-AAS	Sahin et al., 2002
		0.2	Cr picolinate		300^{L}	200^{L}	290^{L}								
		0.4	Cr picolinate		310^{L}	270^{L}	310^{L}								
		0.8	Cr picolinate		340^{L}	350^{L}	390^{L}								
		1.2	Cr picolinate		370^{L}	380^{L}	440^{L}								

[1] chromium tissue concentrations on dry matter basis; [2] chromium tissue concentrations on wet weight basis; [3] analysed Cr contents in supplemented complete feed; [4] chromium aminoniacinate
ND – not determined; AAS - atomic absorption spectrophotometry; ICP-AES - inductively coupled plasma atomic emission spectroscopy; GF-AAS – graphite furnace atomic absorption spectrophotometry; [a,b,c] Means in a column with different letters in superscripts are statistically different ($P<0.05$); [L] Means in column show significant linear response ($P<0.05$)

Table 4. Chromium concentrations in tissues (µg/kg) of rabbits and rainbow trouts fed diets supplemented with various sources of trivalent chromium

Animal species	Cr content of complete control diet (mg/kg)	Cr(III) dose supplemented to control complete feed (mg/kg)	Source of Cr(III) supplemented	Duration of study	Muscle	Liver	Kidney	Heart	Lungs	Spleen	Method of Cr analysis	Reference
Rabbits, pregnant[1]	0.54	Control		One gravidity plus lactation period	200	180	400	90	180	100	GF-AAS	Sahin et al., 2001
		0.2	$CrCl_3$		220	260	420	120	220	140		
		0.4	$CrCl_3$		240	310	480	180	300	150		
Newborns from rabbits above[1]	-	Control			320	240	440	110	140	110	GF-AAS	Sahin et al., 2001
		0.2	$CrCl_3$		340	280	430	140	180	130		
		0.4	$CrCl_3$		370	350	470	170	210	140		
Rabbits, weaned growing[1]	0.54	Control		4 months	330	260	450	120	180	120	GF-AAS	Sahin et al., 2001
		0.2	$CrCl_3$		350	380	480	150	190	160		
		0.4	$CrCl_3$		390	400	470	170	240	170		
Rainbow trouts[2]	ND	Control		58 d		300					GF-AAS	Kucukbay et al., 2006
		0.4	Cr picolinate			350^{L}						
		0.8	Cr picolinate			380^{L}						
		1.6	Cr picolinate			420^{L}						

[1] chromium tissue concentrations on dry matter basis
[2] chromium tissue concentrations on wet weight basis
ND – not determined
GF-AAS – graphite furnace atomic absorption spectrophotometry
[L] Means in column show significant linear response ($P<0.001$)

Table 5. Chromium concentrations in tissues (µg/kg) of rats and mice fed diets supplemented with various sources of trivalent chromium

Animal species	Cr content of complete control diet (mg/kg)	Cr(III) dose supplemented to control complete feed (mg/kg)	Source of Cr(III) supplemented	Duration of study	Muscle	Liver	Kidney	Heart	Spleen	Testicle	Bone	Method of Cr analysis	Reference
Rats[1]	ND	Control		20 wk		6^{a}	8^{a}					GF-AAS	Anderson et al., 1997b
		100	$CrCl_3$			91^{b}	700^{b}						
		100	Cr picolinate			550^{c}	2200^{c}						
Rats[2]	ND	Control		42 d	11.3^{a}	6.1^{a}	9.1^{a}	1.1	1.2			GF-AAS	Zha et al., 2007a
		0.3	$CrCl_3$		13.0^{a}	9.4^{a}	25.1^{b}	1.8	1.3				
		0.3	Cr picolinate		11.4^{a}	27.6^{b}	59.9^{c}	1.8	1.8				
		0.3	Cr nanopartic.		20.6^{b}	31.6^{b}	75.5^{d}	1.9	1.8				
Rats[2]	0.2	Control		42 d	11.3^{c}	16.1^{b}	49.1^{b}	1.1	1.2	0.8		GF-AAS	Zha et al., 2007b
		0.075	Cr nanopartic.		11.6^{c}	24.0^{ab}	59.0^{ab}	1.7	1.5	1.3			
		0.150	Cr nanopartic.		15.1^{c}	29.9^{a}	69.6^{a}	1.9	1.0	0.8			
		0.300	Cr nanopartic.		20.6^{ab}	31.6^{a}	75.5^{a}	1.9	1.8	0.9			
		0.450	Cr nanopartic.		23.6^{a}	32.1^{a}	76.8^{a}	2.3	1.2	1.0			
		0.600	Cr nanopartic.		22.6^{a}	29.8^{a}	76.7^{a}	2.1	1.3	0.9			
		1.200	Cr nanopartic.		15.6^{bc}	32.9^{a}	85.9^{a}	2.5	1.7	0.2			
Rats[1,5]	0.03	Control		42 d	16^{abc}	10^{f}	23^{d}	12^{bc}				GF-AAS	Anderson et al., 1996
		5.0	$CrCl_3$		14^{bc}	10^{def}	74^{cd}	5^{d}					
		5.0	Cr acetate		27^{a}	40^{abc}	397^{b}	17^{b}					
		5.0	$CrK(SO_4)_2$		13^{abc}	5^{bcd}	407^{b}	8^{bc}					
		5.0	Cr histidinate		17^{abc}	7^{ef}	49^{d}	9^{cd}					
		5.0	Cr glycinate		21^{abc}	40^{cde}	343^{b}	20^{b}					
		5.0	Cr nicotinate		12^{c}	15^{def}	133^{c}	12^{bc}					
		5.0	Cr NAHIS[3]		16^{abc}	19^{def}	394^{b}	13^{bc}					
		5.0	Cr picolinate		24^{ab}	48^{a}	368^{b}	28^{a}					
		5.0	Cr NGCG[4]		27^{a}	49^{ab}	850^{a}	27^{a}					
Mice[1]	0.07	Control		26 d		44	63^{a}		98	62	25^{a}	GF-AAS	Seaborn and Stoecker, 1989
		1.0	$CrCl_3$			37	89^{b}		116	66	42^{b}		
Mice[2]	0.12	Control		7 wk		156^{a}		1200^{a}				AAS	Schrauzer et al., 1986
		5.0	Cr yeast			270^{b}		1800^{b}				X-ray fluorescence	

[1] chromium tissue concentrations on dry matter basis; [2] chromium tissue concentrations on wet weight basis; [3]Cr dinicotinic acid dihistidine
[4]Cr nicotinate-glycine-cysteine- glutamate complex; [5] Cr levels in muscle, liver and heart are given in values approximated from figures only
ND – not determined; GF-AAS – graphite furnace atomic absorption spectrophotometry; AAS – atomic absorption spectrophotometry;
[a,b,c] Means in a column with different letters in superscripts are statistically different ($P<0.05$);

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Cobalt

Executive summary of the monograph for cobalt

Several cobalt compounds are presently authorized as feed additives in the EU. Cobalt functions as an essential component of vitamin B12. Mammals lack the ability to synthesize vitamin B12. Non-ruminant livestock and humans require a dietary source of vitamin B12. Ruminal microorganisms synthesize vitamin B12 which serves to meet the animal's vitamin B12 requirement. Hence, ruminants have a dietary requirement for cobalt. Clinical manifestations of cobalt deficiency in ruminants comprise anorexia, anemia, fatty liver, increased perinatal mortality, infertility and disease susceptibility. Cobalt toxicosis in animals is very rare because concentrations of cobalt normally present in animal diets are much lower than those able to cause toxicosis. Characteristic signs of chronic cobalt toxicosis for most species are reduced feed intake and body weight, emaciation, anemia, hyperchromemia, debility, increased liver cobalt and increased disease susceptibility. The efficiency of vitamin B12 synthesis in the rumen is rather low. Ruminal production of vitamin B12 is increased by an increased cobalt intake, roughage content of the diet and total feed intake. Inorganic sources of cobalt must be partially soluble in the rumen to be of nutritional value to ruminants when used as feed supplements. Cobaltous and cobaltic oxides have a lower nutritive value than soluble inorganic salts e.g., CoCO3 and CoSO4. Gastrointestinal absorption of cobalt depends on transport mechanisms similar to that of iron. Absorbed cobalt is cleared rapidly from the body, mainly through renal clearance. Faecal elimination is the major route of excretion following oral exposure.

In mammalian cells the mutagenic potential of cobalt ions has been clearly demonstrated. Two molecular mechanisms apply, namely, a direct effect of cobalt(II) ions to damage DNA through a Fenton-like mechanism and an indirect effect through inhibition of the DNA repair mechanisms. IARC evaluated the carcinogenic risks to humans of cobalt in hard metals and of cobalt sulphate. IARC categorized cobalt sulphate and other soluble cobalt(II) salts as possibly carcinogenic to humans (Group 2B). EVM established a guidance level for cobalt of 0.023 mg/(kg bw.day). The respiratory system is the critical organ when humans are exposed to cobalt through inhalation. Observed pathologies after chronic inhalation exposure include respiratory irritation, inflammation of the nasopharynx, diminished pulmonary function, wheezing, asthma, pneumonia and fibrosis. There were no indications that the presence of cobalt in animal diets would have an environmental impact.

Cobalt Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

The cobalt content of living plants depends on the species, the cobalt content of the soil, and numerous environmental factors. The mean cobalt concentration reported for terrestrial plants was 0.48 mg/kg (Bowen, 1966). Supplemental sources of cobalt in animal nutrition include both inorganic and organic forms : oxides, acetates, sulphates, carbonates, nitrates, chlorides and glucoheptonates.

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

Cobalt compounds presently authorized in the EU as additives in feedingstuffs (EC 1334/2003)[1] are listed in Table 1.

Table 1 Conditions of use of cobalt compounds according to the Commission Regulation EC 1334/2003[1]

Element	Additive	Chemical formula	Maximum content of the element in the complete feedingstuff (all animal species/categories) (mg/kg)
Co	Cobaltous acetate, tetrahydrate	$Co(CH_3COO)_2.4H_2O$	2
	Basic cobaltous carbonate, monohydrate	$2CoCO_3.3Co(OH)_2.H_2O$	
	Cobaltous chloride, hexahydrate	$CoCl_2.6H_2O$	
	Cobaltous sulphate, heptahydrate	$CoSO_4.7H_2O$	
	Cobaltous sulphate, monohydrate	$CoSO_4.H_2O$	
	Cobaltous nitrate, hexahydrate	$Co(NO_3)_2.6\ H_2O$	

In a recent assessment the FEEDAP Panel recommended modifying the authorization of cobalt compounds in feedstuffs by (i) restricting the use of cobalt compounds as additives to feed for ruminants (except milk replacer), horses and rabbits, (ii) limiting cobalt supplementation in feed for ruminants (except milk replacer), horses and rabbits to a maximum of 0.3 mg Co/kg complete feed, and (iii) reducing the authorized maximum cobalt content from all sources from 2 to 1 mg/kg complete feed for all species except fish. Any negative consequences of these measures on animal health and the efficiency of animal production are not expected (EFSA, 2009b).

[1] OJL 187, 26.7.2003, p11

In the US, the following cobalt compounds are allowed in animal feeds: cobalt acetate, cobalt carbonate, cobalt chloride, cobalt choline citrate complex, cobalt glucoheptonate, cobalt gluconate, cobalt oxide, cobalt sulphate, cobalt amino acid complex, cobalt amino acid chelate, cobalt proteinate (AAFCO Official Publication §57: Mineral Products) (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

Table 2 Range of cobalt guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	**Range (mg/kg)**
Chickens	NRS - 5
Turkeys	NRS - 5
Swine	NRS - 5
Dairy cattle	0.1 - 10
Beef cattle	0.1 - 10
Sheep	0.1 - 10
Horses	0.1 - 10
Goats	0.1 - 10
Ducks and geese	NRS - 5
Salmonid fish	NRS
Mink	NRS
Rabbits	0.1 - 5

NRS: No requirement specified

At present no cobalt sources/forms are authorised in the EU in the manufacture of food supplements[2].
In a recent EFSA opinion (EFSA, 2009) the ANS Panel concluded that, given the toxicological profile of cobalt(II) chloride hexahydrate, including genotoxicity and carcinogenicity, the proposed uses of cobalt(II) chloride hexahydrate added for nutritional purposes in food supplements as a source of cobalt are of safety concern.

3 Essential functions

The only known function of cobalt is as an essential component of vitamin B_{12} (cobalamine). Discovery that increased dietary cobalt can prevent the disease called unthriftiness in sheep and cattle was made in the

[2] OJL 183, 2.7.2002, p51

thirties of the former century. The cobalt incorporation into the structural centre of vitamin B_{12} and therapeutic efficiency of vitamin B_{12} injection to ruminants with Co deficiency were demonstrated some twenty years later (McDowell, 2003). Vitamin B_{12} is a cofactor for the enzymes methylmalonyl CoA mutase and methionine synthase. Methylmalonyl CoA mutase is responsible for conversions of methylmalonyl CoA to succinyl CoA and is important in propionate metabolism. Methionine synthase is involved in the regeneration of methionine following loss of its methyl group and in the maintenance of biologically active folate concentrations in tissues (NRC, 2005).

Mammals lack the ability to synthesize vitamin B_{12}. Non-ruminant livestock and humans require a dietary source of vitamin B_{12}. Ruminal bacteria synthesize enough vitamin B_{12} to meet the requirements of ruminants provided that adequate dietary cobalt is supplied (NRC, 2005).

4 Other functions

It has been suggested that ruminant diets with cobalt content above requirements may have some beneficial effects in terms of enhanced ruminal digestion of fibre from lower quality forages, increased total number of anaerobic bacteria in rumen and increased production of lactic acid in rumen (Lopez-Guisa and Satter, 1992; Paragon, 1993). However present literature data are not unequivocal The minimum dietary cobalt content required to maximise feed intake and growth performance of growing cattle finished on a corn silage-based diet has been found to range between 0.16 and 0.18 mg/kg DM (Schwarz *et al*. 2000). Ruminal fluid contains normally about 40 µg Co/L (Miller *et al*., 1988).

5 Antimicrobial properties

There was no information available on antimicrobial properties of cobalt in principal literature sources.

6 Typical deficiency symptoms of ruminants

Ruminants appear to be more sensitive to vitamin B_{12} deficiency than non-ruminants since they are dependent on gluconeogenesis to meet their tissue requirements for glucose (NRC, 2001). Cobalt deficiency in ruminants is a vitamin B_{12} deficiency, brought about by the inability of the rumen microorganisms, when dietary cobalt is inadequate, to synthesize sufficient vitamin B_{12}. In general, the common signs of cobalt-vitamin B_{12} deficiency in animals are reduction in body weight gain, feed intake and feed conversion (McDowell, 2003).

Biochemical manifestations of cobalt deprivation include failure of the propionate metabolism, methylation and disturbance of the lipid metabolism (McDowell, 2003; Underwood & Suttle, 1999). Clinical manifestations comprise anorexia, anemia, fatty liver, increased perinatal mortality, infertility and disease susceptibility. Mild cobalt deficiency is impossible to diagnose clinically. The only way to determining a lack of dietary cobalt is by measuring the response in temperament, appetite and weight that follows cobalt feeding or vitamin B_{12} injection (McDowell, 2003; Underwood & Suttle, 1999). Under grazing conditions, lambs are the most sensitive to cobalt deficiency, followed by mature sheep, calves, and mature cattle (McDowell, 2003).

7 Animal requirements, allowances and use levels

There is no evidence that cobalt is needed when adequate vitamin B_{12} is present in the diet for monogastric species. Therefore, established scientific bodies do not establish cobalt requirements for monogastric species. However, coprophagous animals, rabbits (caecotrophy) and horses receive some supplies of vitamin B_{12} from microbial fermentation in the hindgut. The nutritional importance in the overall supply however is not well understood. In ruminants the ruminal microorganisms incorporate Co into vitamin B_{12}, which is utilized by both microorganisms and the ruminant (McDowell, 2003; NRC, 2005; Underwood & Suttle, 1999). The cobalt requirements published by established bodies are summarized in Annex 3.1, use levels are compiled in Annex 3.2.

8 Concentration of the element in feed materials

Plants generally contain 0.1 to 0.5 mg Co/kg DM. Due to local occurrence of soils deficient in Co the forages may not meet the animal requirements for cobalt (Ammerman, 1970). Alkaline soils or liming can prevent adequate uptake of cobalt by plants (Mills, 1981). Cobalt concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Cobalt concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and maximum tolerable levels (MTL)

MTL values for cobalt can principally be affected by iron status of the animal and by the dietary concentration of sulphur amino acids. Age and antioxidant status of the animal may also affect the level of cobalt that can be tolerated without adverse effects on animal performance or health (NRC, 2005). MTL values established by NRC (2005) are compiled in Table 3. Additionally to the cobalt MTL values, NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

Table 3 Maximum Tolerable Levels (MTL) for cobalt (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Swine	100	
Rodents, Poultry, Cattle, Sheep	25	
Horse	25	Value derived from interspecies extrapolation
Fish		Data insufficient to set a MTL

11 Typical symptoms of toxicosis

Cobalt toxicosis in animals is very rare because concentrations of cobalt normally present in animal diets are much lower than those needed to cause toxicosis. Characteristic signs of chronic cobalt toxicosis for most species are reduced feed intake and body weight, emaciation, anemia, hyperchromemia, debility, increased liver cobalt and increased disease susceptibility (McDowell, 2003; NRC, 2005).

12 Bioavailability

12.1 General

Data on cobalt absorption from the gut are rather scarce. Different factors may affect the absorption (e.g., amount and solubility of the cobalt compound, presence of amino acids and sulphydryl groups in the diet and the iron status of the animal). (ATSDR, 2004; Lison, 2007). In humans absorption of orally ingested cobalt is reported to vary between 5 – 45 % (Lison, 2007) and 18 – 97 % (ATSDR, 2004). Absorbability data are reported in Table 4. In laboratory animals such as rats and mice the reported apparent absorption of cobalt from cobalt chloride was in a range of 13 to 34% whereas Co from insoluble cobalt oxide showed 1 to 3% absorption only (Kirchgessner *et al*., 1994; Ayala-Fierro *et al*., 1999).

Table 4 Absorbability of various cobalt compounds in humans and animals

Species	Cobalt source	Dose	Absorbability (%)	Reference
Hamster	Cobalt oxide		< 0.5	Lison (2007)
Rats	Cobalt chloride		30	
Rats	Cobalt chloride	0.01 µg/rat	11	
Rats	Cobalt chloride	1000 µg/rat	34	
Rats	Cobalt oxide		1 - 3	ATSDR (2004)
	Cobalt chloride		13 – 34	
Humans	Cobalt chloride		5 - 44	Lison (2007)
Humans			18 - 97	ATSDR (2004)

In ruminants, the apparent absorption rate was estimated to be very low, in the range of 1 to 2% (Looney *et al*., 1976; Van Bruwaene *et al*., 1984).
The efficiency of vitamin B_{12} synthesis is rather low. Girard *et al*.(2009) measured, in an experiment with dairy cows, that only 4% of dietary cobalt was used for cobalamin synthesis and only 20 % of cobalamin synthesized in the rumen reaches the small intestine of which some 25% is absorbed. The availability of cobalt for vitamin B_{12} synthesis in the rumen is determined by the cobalt compound and dietary factors. Ruminal production of vitamin B_{12} is increased by an increased cobalt intake, roughage content of the diet and total feed intake (Ammerman *et al*., 1995; Underwood & Suttle, 1999). Inorganic sources of cobalt must be partially soluble in the rumen to be of nutritional value to ruminants when used as feed supplements. Cobaltous and cobaltic oxides have a lower nutritive value than soluble inorganic salts (e.g., $CoCO_3$ and $CoSO_4$) when assessed by increase in liver cobalt (Underwood & Suttle, 1999).
In three experiments lasting 20 d, performed on sheep: 0, 20, 40 and 60 mg/kg cobalt in the form of sulphate, oxide, carbonate or glucoheptonate were added to basic diet. It was shown that based on liver and kidney cobalt concentrations, cobalt in form of sulphate, carbonate and glucoheptonate was better bioavailable than oxides (Kawashima *et al*. 1997).
Kawashima *et al*. (1997 b) estimated based on *in vitro* experiments the relative bioavailability of various cobalt sources for ruminants: 100%, 91 %, 84 % and 0% for cobalt sulphate, cobalt carbonate, cobalt glucoheptonate and oxide, respectively.

12.2 Indicators of cobalt status in ruminants

Vitamin B_{12} synthesis combined with a suboptimal cobalt supply, is the most adequate response criterion for assessing the relative biological value of cobalt sources for ruminants (Jongbloed *et al*., 2002).

13 Metabolism

Gastrointestinal absorption of cobalt depends on transport mechanisms similar to that of iron. Hence, cobalt absorption is influenced by the iron status that regulates the expression of the involved transport proteins (Lison, 2007). After absorption cobalt is distributed systemically. Absorbed cobalt is cleared rapidly from the body, mainly through renal clearance. Faecal elimination is the major route of cobalt excretion following oral exposure (Barceloux, 1999; Lison, 2007).

14 Distribution in the animal body

About 43% of body Co is stored in muscles and approximately 14 % is stored in bone. Kidneys and liver contain the highest cobalt concentrations (McDowell, 2003). Exposure of animals to high dietary cobalt concentrations greatly increase concentrations of cobalt in a number of tissues. Cobalt concentrations in liver and kidney increase to the greatest extent. Increases in muscle cobalt in animals given high concentrations of cobalt are relatively small (NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

A compilation of cobalt concentrations in edible tissues and products is given in Annex 1. Cobalt concentrations in edible tissues and products linked with the dietary intake of various cobalt compounds and doses is given in Annex 2.

16 Acute toxicity

Oral ingestion of a lethal dose of cobalt chloride was reported to have provoked coaglutative necrosis of the stomach mucosa, small bullae formation on the esophageal mucosa and brain edema (Barceloux, 1999).

17 Genotoxicity and Mutagenicity

The ATSDR (2004) did not locate any studies regarding genotoxic effects in humans following oral or dermal exposure to cobalt. However, in mammalian cells the mutagenic potential of cobalt ions has been clearly demonstrated. Two molecular mechanisms apply, namely, a direct effect of cobalt(II) ions to damage DNA through a Fenton-like mechanism and an indirect effect through inhibition of the DNA repair mechanisms (ATSDR, 2004; Lison, 2007). The capacity of Co(II) ions to compete with other species in zinc finger proteins involved in cell cycle control and / or DNA repair may provoke the observed DNA repair inhibition (ATSDR, 2004; Lison, 2007). ATSDR (2004) and WHO (2006) summarized the following reported effects of exposure to cobalt compounds (metal, salts, or hard metal): clastogenic effects in mammalian cells, including human lymphocytes; transformation in hamster cells; sister chromatid exchanges in human lymphocytes; micronucleus formation in mouse bone marrow cells and human lymphocytes.

18 Subchronic toxicity

WHO (2006) summarized medium-term exposure studies with several cobalt compounds (Table 5).

Table 5 Medium-term exposure studies assessing the effects of the dietary intake of several cobalt compounds (WHO, 2006)

Species	Cobalt compound	Dose (mg Co/(kg bw.day)	Duration	Effect
Rats	Cobalt sulphate; cobalt chloride	26 – 30.2	2 – 3 m	Increased heart weight; degenerative heart lesions
Rats	Cobalt sulphate	8.4	24 w	Reductions in cardiac enzyme activity levels; reduced mitochondrial ATP production
Rats	Cobalt chloride	10 – 18	4 – 5 m	Renal injury e.g., histological alteration of proximal tubulus

19 Chronic toxicity, including carcinogenicity

Chronic toxicity data are available from the monitoring of patients who were administered cobalt containing medication. A daily oral intake of 18.5 – 37 mg cobalt was tolerated for long periods of time without significant toxicity. The oral administration of 3 – 4 mg cobalt chloride/(kg bw) to children with sickle cell resulted in goitrogenic effects (Barceloux, 1999).

The IARC (2006) evaluated the carcinogenic risks to humans of cobalt in hard metals and of cobalt sulphate. This risk assessment resulted in the IARC (2006) categorizing cobalt sulphate and other soluble cobalt (II) salts as ‘possibly carcinogenic to humans’ (Group 2B).

20 Reproduction toxicity

ATSDR (2004) located no studies regarding reproductive effects in humans after oral exposure to cobalt. ATSDR (2004), Lison (2007) and WHO (2006) listed numerous studies on reproductive effects in mice and rats after oral exposure to cobalt. The observed effects for these species included testicular degeneration and athrophy, reduced fertility, reduced number of viable fetuses. In rats developmental toxicity occurs at exposure levels that also cause maternal toxicity. Stunted growth, and decreased survival have been observed (Lison, 2007; WHO, 2006).

21 Non observed adverse effect level (NOAEL)

There were no NOAEL values identified to establish upper intake levels by the considered scientific bodies.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

EVM (2003) established a guidance level of 0.023 mg/(kg bw.day) for cobalt. The available data were considered insufficient to set a UL.

23 Toxicological risks for user/workers

Inhaled cobalt containing particles can be rapidly absorbed in the lung. The extent of respiratory absorption is determined by the solubility of the cobalt particles. In case of inhalation of insoluble particles, cobalt accumulates in the lungs (Lison, 2007). The respiratory system is the critical organ when humans are exposed to cobalt through inhalation and toxic manifestations have been reported at different levels, including the upper respiratory tract, the trachea and bronchi, and the alveolar parenchyma (Lison, 2007). The observed pathologies in humans include respiratory irritation, inflammation of the nasopharynx, diminished pulmonary function, wheezing, asthma, pneumonia and fibrosis which occurred at exposure levels ranging from 0.007 to 0.893 mg Co/m^3 and an exposure duration from 2 to 17 years (ATSDR, 2004; Lison, 2007).

24 Toxicological risks for the environment

ATSDR (2004) ranked anthropogenic activities that may elevate cobalt levels in soil as follows: mining, processing of cobalt-bearing ores, the application of cobalt-containing sludge or phosphate fertilizers, the disposal of cobalt containing wastes and atmospheric deposition from activities such as the burning of fossil fuels, smelting, and metal refining.

Elevated cobalt concentrations have been found in the roots of sugar beets and potato tubers in soils with high cobalt concentrations. The acidity of the soil influences cobalt uptake by plants. Higher cobalt concentrations were found in rye grass foliage, oats and barley grown on acidic soils (ATSDR, 2004).

Cobalt is emitted to the aquatic environment mainly in connection with mining activities. Anthropogenic emissions to the atmosphere are smaller than natural fluxes (Bjerregaard & Andersen, 2007). There were no indications in principal literature sources that the presence of cobalt in animal diets would have an environmental impact.

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Annex 1 Cobalt concentrations in edible tissues and products

Table 1.1 Cobalt concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Hogs	324	0.21	0.22	0.23	Coleman *et al* . (1992)
Boars / sows	280	0.20	0.22	0.22	
Pigs		< 0.0045			Dabeka & McKenzie (1995)[a]
Pigs	36	0.001	0.010	0.004	Jorhem & Sundström (1993)
Pigs (6 m)	62	0.003	0.023	0.027	López-Alonso *et al* . (2007)

[a] Total diet study

Table 1.2 Cobalt concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Calves (6 - 12 m)	195		0.0696	0.0253		Blanco-Penedo *et al.* (2006)
Calves	327	0.23	0.27	0.28		Coleman *et al* . (1992)
Heifers / Steers	287	1.92	0.25	0.25		
Bulls / Cows	95	0.21	1.15	0.22		
Lambs	165	0.21	0.22	0.22		
Mature sheep	34	0.21	0.24	0.23		
Dairy cattle					whole: < 0.001; skim: < 0.0008	Dabeka & McKenzie (1995)[a]
Beef cattle		steak: < 0.0055				
Veal		0.0098				
Lamb		< 0.0039				
Cattle	3	steak: 0.0063	0.194		0.001	Hokin *et al* . (2004)[a]
Lamb	3	0.001	0.0726	0.053		
Cattle	3	0.001	0.043	0.008		Jorhem & Sundström (1993)
Dairy cattle	16				0.001	Leblanc *et al* . (2005)[a]

[a] Total diet study

Table 1.3 Cobalt concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chickens (young)	311	0.21	0.22	0.22		Coleman *et al* . (1992)
Chickens (mature)	308	0.20	0.22	0.22		
Turkeys (young)	61	0.20	0.22	0.22		
Ducks	99	0.21	0.22	0.24		
Poultry		< 0.0045			< 0.0042	Dabeka & McKenzie (1995) [a]
Hens	144				yolk: 0.0046 - 0.0049 albumen: 0.00114 - 0.00136	Giannenas *et al* . (2009)
Poultry		0.002 [b]			0.005 [c]	Leblanc *et al* . (2005) [a]
Hens, private owners	22				0.00515	Van Overmeire *et al* . (2006)
Hens, commercial farms	19				0.00235	

[a] :Total diet study; [b]: Poultry and game (n = 24); [c]: Eggs and egg products (n = 30)

Table 1.4 Cobalt concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	0.90 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	0.92 DM	
Marine fish		< 0.0189	Dabeka & McKenzie (1995) [a]
Freshwater fish		0.0143	
Atlantic herring	3	0.005	Engman & Jorhem (1998)
Baltic herring	3	0.004	
Burbot	2	0.003	
Cod	4	0.002	
Eel	3	0.02	
Mackerel	4	0.004	
Perch	3	0.006	
Picked dogfish	2	0.002	
Pike	5	0.002	
Plaice	4	0.005	
Pollack	2	0.005	
Salmon	3	0.004	
Turbot	3	0.008	
Whitefish	3	0.003	
Fish	62	0.007	Leblanc *et al*. (2005) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	2.156 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	0.953 DM	
Gilthead seabream *Sparus aurata*	45	1.295 DM	

[a]: Total diet study

Table 1.5 Cobalt concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Holzing (AU)	23	< 0.01	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	< 0.01	
Origin: Hollabrunn (AU)	19	0.02	
Origin: Siena County (It)	51	0.011	Pisani *et al*. (2008)

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Annex 2: Cobalt concentrations in edible tissues and products linked with diets supplemented with various sources of cobalt

Table 1 Cobalt concentrations in edible tissues and products (mg/kg)

Species / category	Source of Co supplemented	Dose of Co supplemented (mg Co/(kg bw.day))	Co content of complete feed (mg Co/kg)	Duration of study	Liver	Kidney	Muscle	Serum	Reference
Rats				56 d			0.018	0.0011	Clyne *et al* . (1988)
	$CoSO_4.7H_2O$	4.25					0.483	0.124	

Statistics : Clyne *et al* . (1988): muscle Co conc.: P < 0.001; serum Co conc. : P < 0.001.

Table 1 (continued) Cobalt concentrations in edible tissues and products (mg/kg)

Species / category	Source of Co supplemented	Dose of Co supplemented (mg Co/kg)	Co content of complete feed [1] (mg Co/kg)	Duration of study	Liver	Kidney	Muscle	Serum	Reference
Sheep (wethers)		0	0.17 DM	60 d	0.20 DM	0.77 DM	0.10 DM		Henry *et al* . (1997)
	$CoSO_4.7H_2O$	20			3.74 DM	3.27 DM	0.14 DM		
	$CoSO_4.7H_2O$	40			7.33 DM	4.83 DM	0.26 DM		
Lambs (wethers)		0	0.15 DM	20 d	0.23 DM	0.24 DM	0.052 DM		Kawashima *et al* . (1997)
	Co sulphate RG	20			2.21 DM	2.32 DM	0.129 DM		
	Co sulphate RG	40			2.57 DM	4.01 DM	0.177 DM		
	Co sulphate RG	60			6.66 DM	6.51 DM	0.521 DM		
	Co oxide BP	40			2.46 DM	2.51 DM	0.110 DM		
	Co oxide FG	40			1.01 DM	1.20 DM	0.065 DM		
	Co oxide RG	40			0.34 DM	0.22 DM	0.049 DM		
	Co carbonate FG	40			4.95 DM	3.75 DM	0.196 DM		
	Co carbonate RG	40			3.82 DM	3.69 DM	0.112 DM		

[1]: data from feed analysis
RG: Reagent grade; FG: Feed grade; BP: by-product
Statistics : Henry *et al* . (1997): dietary Co level on liver, kidney and muscle Co concentration: P < 0.01, Anova.
Kawashima *et al* . (1997): dietary Co level on liver, kidney and muscle Co concentration: P < 0.0001, Anova.

Table 1 (continued) Cobalt concentrations in edible tissues and products (mg/kg)

Species / category	Source of Co supplemented	Dose of Co supplemented (mg Co/kg)	Co content of complete feed [1] (mg Co/kg)	Duration of study	Liver	Kidney	Muscle	Milk (mg/L)	Reference
Dairy Cattle		0	0.37 DM	120 d	2.19			0.089	Kincaid *et al*. (2003)
	Co glucoheptonate	0.62	0.68 DM		2.5			0.093	
	Co glucoheptonate	1.23	1.26 DM		1.28			0.09	
Dairy Cattle		0	0.19 DM	120 d	1.9			0.089	Kincaid & Socha (2007)
	Co glucoheptonate	0.49	0.57 DM		1.94			0.12	
	Co glucoheptonate	0.98	0.93 DM		2.00			0.13	
Pigs	$CoCl_2.6H_2O$	0		84 d	1.16 DM	0.39 DM			Huck & Clawson (1976)
		200			8.40 DM	16.72 DM			
		400			10.85 DM	39.73 DM			
		600			12.72 DM	35.89 DM			

[1:] data fron feed analysis

Statistics : Kincaid *et al*. (1997): Co milk concentration not significantly different;

Kincaid & Socha (2007): Co liver concentrations: not significantly different, Co milk concentrations: P= 0.038;

Huck & Clawson (1976): liver Co conc. and kidney Co conc. increased significantly with dietary Co level, P<0.1.

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Annex 3.1 : Cobalt Requirements

Bovines:

Category - Definition	Co. Req. (Meschy, 2007) (mg /kg DM)
Bovines	0.07

Bovines: Beef Cattle

Category - Definition	Co Req. (NRC, 2000) (mg /kg DM)	Category - Definition	Co Req. (GfE, 1995) (mg /kg DM)
Growing and finishing	0.1	Growing and finishing from 175 kg on	0.1
Cows gestation	0.1		
Cows early lactation	0.1		

Bovines: Dairy Cattle

Category - Definition	Co Req. (NRC, 2001) (mg /kg DM)	Category - Definition	Co Req. (CVB, 2007) (mg /kg DM)
Lactating cow: Holstein - 90 days in milk	0.11	Lactating cows (FI: 20 $kg.day^{-1}$)	0.1
Lactating cow: Jersey	0.11	Lactating cows (FI: 40 $kg.day^{-1}$)	0.1
Dry cows: Holstein	0.11	Dry cows, 8 -3 weeks before calving	0.1
		Dry cows, 3 - 0 weeks before calving	0.1

Sheep

Category - Definition	Co Req. (Meschy, 2007) (mg /kg DM)
Sheep	0.07

Category - Definition	Co Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Co Req. (NRC, 2007 (b)) (mg /day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	0.13		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	0.57		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	0.22	Mature ewes; breeding. DM intake: 0.85 kg/day	0.09
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	0.62	Mature ewes; breeding. DM intake: 2.18 kg/day	0.22
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	0.27	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	0.87	Mature ewes; early lact.; DM intake: 2.14 kg/day	0.43
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	0.22	Mature ewes; early lact.; DM intake: 5.29 kg/day	1.06
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	0.52	Mature ewes; late lact.; DM intake: 2.35 kg/day	0.47
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	0.41	Mature ewes; late lact.; DM intake: 4.05 kg/day	0.81
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	0.72		

Goats

Category - Definition	Co Req. (GfE, 2003) (mg /kg DM)	Category - Definition	Co Req. (Meschy, 2007) (mg /kg DM)
Goats	0.15 - 0.20	Goats	0.07

Category - Definition	Co Req. (NRC, 2007 (b)) (mg /day)
Kids; bw: 10 kg; DM intake: 0.35 kg/day	0.04
Kids; bw: 10 kg; DM intake: 0.39 kg/day	0.04
Kids; bw: 40 kg; DM intake: 1.10 kg/day	0.12
Kids; bw: 40 kg; DM intake: 1.41 kg/day	0.16
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	0.11
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	0.29
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	0.17
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	0.46
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	0.08
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	0.23
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	0.14
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	0.29

Category - Definition	Co Req. (NRC, 2007 (b)) (mg /day)
Mature does; breeding; DM intake: 0.60 kg/day	0.07
Mature does; breeding; DM intake: 1.86 kg/day	0.2
Milk yield: 4.65 - 6.43 kg/day	
Dairy does; early lactation; DM intake: 2.81 kg/day	
Dairy does; early lactation; DM intake: 4.83 kg/day	0.31
Milk yield: 6.98 - 9.65 kg/day	0.53
Dairy does; early lactation; DM intake: 3.83 kg/day	
Dairy does; early lactation; DM intake: 5.43 kg/day	0.42
Milk yield: 1.99 - 2.76 kg/day	0.60
Dairy does; late lactation; DM intake: 2.48 kg/day	
Dairy does; late lactation; DM intake: 3.64 kg/day	0.27
Milk yield: 2.99 - 4.13 kg/day	0.4
Dairy does; late lactation; DM intake: 2.51 kg/day	
Dairy does; late lactation; DM intake: 4.53 kg/day	0.28
	0.50

Glossary
Req.: requirement
FI: Feed Intake
lact.: lactation

Annex 3.2: Cobalt Use Levels

Table 1 Supplementation recommendations, calculated background level ranges (information acquired from the industry) and calculated use levels for cobalt

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg/kg)
Pigs (7 – 20 kg)	0	0 - 0.1	0.1	2
Pigs (20 – 30 kg)	0	0 - 0.1	0.1	2
Pigs (30 – 100 kg)	0	0 - 0.1	0.1	2
Sows	0	0 - 0.1	0.1	2
Broilers	0	0 - 0.1	0.1	2
Hens	0	0 - 0.1	0.1	2
Veal	1	0 - 0.1	1.1	2
Cattle	1.5	0 - 0.1	1.6	2
Sheep	1.5	0 - 0.1	1.6	2

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use levels for cobalt

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	0.4 -0.5	0.1	0.6
Pigs (15 - 50 kg)	0.2 - 0.5	0.1	0.6
Pigs (50 - 150 kg)	0.2 - 0.5	0.1	0.6
Gestating sows	0.4 - 0.6	0.1	0.7
Lactating sows	0.4 - 0.6	0.1	0.7

Whittemore *et al.* (2002): summary of supplementation levels found in Denmark, Germany, Netherlands, United Kingdom, United States, Spain and Australia

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Annex 4. Cobalt concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	
Potato prot ASH>10	
Potato starch dried	
Potato sta heat tr	
Potato pulp CP<95	
Potato pulp CP>95	
Potatoes sweet dried	
Bone meal	
Brewers' grains dr	0.1
Brewers' yeast dried	0.21
Sugarb pulp SUG<100	0.3
Sugarb p SUG100-150	0.19
Sugarb p SUG150-200	
Sugarb pulp SUG>200	
Biscuits CFAT<120	
Biscuits CFAT>120	
Blood meal spray dr	0.1
Buckwheat	0.06
Beans phas heat tr	
Bread meal	
Casein	
Chicory pulp dried	0.2
Citrus pulp dried	
Meat meal Dutch	
Meat meal CFAT<100	
Meat meal CFAT>100	
Peas	0.1
Barley	0.25
Barley feed h grade	
Barley mill byprod	
Grass meal CP<140	
Grass meal CP140-160	
Grass meal CP160-200	
Grass meal CP>200	
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	0.3
Peanut exp p with sh	
Peanut exp with sh	
Peanut extr wtht sh	0.2
Peanut extr with sh	
Oats grain	0.23
Oats grain peeled	0.01
Oats husk meal	
Oats mill fd h grade	
Hempseed	
Carob	

INRA	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	0.13	
Maize	0.05	
Oats	0.09	
Oats groats	0.01	
Rice, brown	2	
Rye	0.03	
Sorghum	0.23	
Triticale		
Wheat, durum		
Wheat, soft	0.02	
WHEAT BY-PRODUCTS		
Wheat bran	0.09	
Wheat middlings		
Wheat shorts	0.1	
Wheat feed flour		
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%		
Wheat gluten feed, starch 28%		
MAIZE BY-PRODUCTS		
Corn distillers	0.1	
Corn gluten feed	0.15	
Corn gluten meal	2	
Maize bran		
Maize feed flour		
Maize germ meal, expeller		
Maize germ meal, solvent extracted	0.25	
Hominy feed		
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	0.1	
Brewers' dried grains	0.09	
Rice bran, extracted		
Rice bran, full fat	0.21	
Rice, broken	0.04	
LEGUME AND OIL SEEDS		
Chickpea		
Cottonseed, full fat	0.38	
Faba bean, coloured flowers	0.35	
Faba bean, white flowers		
Linseed, full fat		
Lupin, blue	0.07	
Lupin, white	0.18	
Pea	0.09	
Rapeseed, full fat		
Soybean, full fat, extruded		
Soybean, full fat, toasted		
Sunflower seed, full fat		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	
Cottons exp p with h	
Cottons exp with h	
Cottons extr wtht h	
Cotts extr p with h	
Cottons extr with h	0.21
Coconut exp CFAT<100	0.2
Coconut exp CFAT>100	
Coconut extr	0.2
Linseed	1.99
Linseed exp	0.31
Linseed extr	0.19
Lentils	0.16
Lupins CP<335	
Lupins CP>335	
Alf meal CP<140	2.18
Alf meal CP140-160	1.29
Alf meal CP160-180	1.29
Alf meal CP>180	2.15
Poppyseed	
Macoya fruit exp	
Maize	0.11
Maize chem-h treated	0.11
Maize gluten meal	2.02
Maize glfeed CP<200	
Maize glfd CP200-230	
Maize glfeed CP>230	
Maize germ meal extr	
Maize germ m fd exp	
Maize germ m fd extr	
Dist grains and sol	
Maize feedflour	
Maize feed meal	
Maize feed meal extr	
Maize bran	
Maize starch	
Sugarbeet molasses	0.59
Sugarc mol SUG<475	
Sugarc mol SUG>475	
Milk powder skimmed	
Milk powder whole	
Millet	

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	0.2	
Cottonseed meal, crude fibre 7-14%	0.57	
Cottonseed meal, crude fibre 14-20%	0.52	
Grapeseed oil meal, solvent extracted	0.1	
Groundnut meal, detoxified, crude fibre < 9%	0.28	
Groundnut meal, detoxified, crude fibre > 9%	0.27	
Linseed meal, expeller	0.43	
Linseed meal, solvent extracted	0.37	
Palm kernel meal, expeller	0.13	
Rapeseed meal	0.09	
Sesame meal, expeller	0.71	0.22
Soybean meal, 46		
Soybean meal, 48	0.26	
Soybean meal, 50	0.1	
Sunflower meal, partially decorticated	0.13	
Sunflower meal, undecorticated	0.14	
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	0.04	
Cassava, starch 72%		
Maize starch		
Potato tuber, dried	0.03	
Sweet potato, dried		
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	0.19	
Beet pulp dried, molasses added	0.19	
Beet pulp, pressed		
Brewers' yeast, dried	0.2	
Buckwheat hulls		
Carob pod meal		
Citrus pulp, dried	0.14	
Cocoa hulls		
Grape marc, dried	0.39	
Grape seeds		
Liquid potato feed		
Molasses, beet	0.55	
Molasses, sugarcane	0.9	
Potato protein concentrate		
Potato pulp, dried		
Soybean hulls	0.11	
Vinasse, different origins		
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production		
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	0.1
Malt culms CP>200	0.1
Nigerseed	
Horsebeans	
Horsebeans white	
Palm kernels	
Palm kern exp CF<180	0.1
Palm kern exp CF>180	0.09
Palm kernel extr	
Rapeseed	
Rapeseed exp	0.2
Rapeseed extr CP<380	0.01
Rapeseed extr CP>380	
Rapes meal Mervobest	0.1
Rice wtht hulls	2.03
Rice with hulls	
Rice husk meal	
Rice bran meal extr	
Rice feed m ASH<90	
Rice feed m ASH>90	
Rye	
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	
Semameseed meal extr	0.85
Soybeans heat tr	
Soybeans not heat tr	
Soybean hulls CF<320	
Soyb hulls CF320-360	
Soybean hulls CF>360	
Soybean exp	
Soybm CF<45 CP<480	0.26
Soybm CF<45 CP>480	0.26
Soybm CF45-70 CP<450	0.26
Soybm CF45-70 CP>450	0.26
Soyb meal CF>70	0.26
Soyb meal Mervobest	0.09
Soyb meal Rumi S	0.98
Sorghum	
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	
Tapioca STA 625-675	
Tapioca STA 675-725	
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	0.86	
Alfalfa, dehydrated, protein 17-18% dry matter	0.85	
Alfalfa, dehydrated, protein 18-19% dry matter	0.85	
Alfalfa, dehydrated, protein 22-25% dry matter	0.84	
Grass, dehydrated	0.52	
Wheat straw		
DAIRY PRODUCTS		
Milk powder, skimmed	0.01	
Milk powder, whole	0.01	
Whey powder, acidic	0.1	
Whey powder, sweet	0.1	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	0.09	
Fish meal, protein 65%	0.09	
Fish meal, protein 70%		
Fish solubles, condensed, defatted		
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	0.1	
Feather meal		
Meat and bone meal, fat <7.5%	1.2	
Meat and bone meal, fat >7.5%	1.3	

CVB

COMPOUND FEED INGREDIENTS	mg/kg
Wheat	
Wheat gluten meal	
Wheat glutenfeed	
Wheat middlings	0.11
Wheat germ	0.1
Wheat germfeed	
Wheat feedfl CF<35	0.1
Wheat feedfl CF35-55	0.1
Wheat feed meal	
Wheat bran	0.1
Triticale	
Feather meal hydr	
Fat from Animals	
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	
Vinasse Sugb CP>250	
Fish meal CP<580	1.88
Fish meal CP580-630	1.87
Fish meal CP630-680	1.87
Fish meal CP>680	1.88
Meat bone m CFAT<100	
Meat bone m CFAT>100	
Whey p l lac ASH<210	
Whey p l lac ASH>210	
Whey powder	
Sunflowers deh	
Sunflowers p deh	
Sunflowers w hulls	
Sunfls exp deh	
Sunfls exp p deh	
Sunfls exp w hulls	0.1
Sunfmeal CF<160	
Sunfmeal CF 160-200	
Sunfmeal CF 200-240	
Sunfmeal CF>240	

MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	
Potato pulp pr NL	
Potato pulp pressed	
Potato cut raw	
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	
Pot sta STA 650-775	
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	
Pot s g STA 425-550	
Pot s g STA 550-675	
Pot sta gel STA>675	
Brewers gr 22% DM	
Brewers gr 27% DM	
Brewers yeast CP<400	
Brewers y CP400-500	
Brewers yeast CP>500	
Beetp pressed f+sil	0.21
CCM CF<40	21.02
CCM CF 40-60	
CCM CF>60	
Chicory pulp f+sil	0.26
Distillers sol f	
Cheese whey CP<175	
Cheese w CP175-275	
Cheese whey CP>275	
Maize glutenf f+sil	0.23
Maize solubles	
Wheat st FR STAt 300	
Wheat st STAtot 400	
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	0.33
Beet rests sililed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	0.07
Barley straw	
Grass fr April l y.	0.1
Grass fr April n y.	0.1
Grass fr April h y.	0.1
Grass fr May l y.	0.1
Grass fr May n y.	0.1
Grass fr May h y.	0.1
Grass fr June l y.	0.1
Grass fr June n y.	0.1
Grass fr June h y.	0.1

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	0.1
Grass fr July n y.	0.1
Grass fr July h y.	0.1
Grass fr Aug l y.	0.1
Grass fr Aug n y.	0.1
Grass fr Aug h y.	0.1
Grass fr Sept l y.	0.1
Grass fr Sept n y.	0.1
Grass fr Sept h y.	0.1
Grass fr Oct l y.	0.1
Grass fr Oct n y.	0.1
Grass fr Oct h y.	0.1
Grass average	0.1
Grass horse gr past	0.1
Grass horse same fld	0.1
Grass sil May 2000	0.16
Grass sil May 3500	0.16
Grass sil May 5000	0.16
Grass sil June 2000	0.16
Grass sil June 3000	0.16
Grass sil June 4000	0.16
Grass sil Ju-Au 2000	0.16
Grass sil Ju-Au 3000	0.16
Grass sil Ju-Au 4000	0.16
Grass sil Se-Oc 2000	0.16
Grass sil Se-Oc 3000	0.16
Grass sil average	0.16
Grass sil horse fine	0.16
Grass sil horse midd	0.16
Grass sil horse crs	0.16
Grass hay good qual	0.16
Grass hay av qual	0.16
Grass hay poor qual	0.16
Grass hay horse fine	0.16
Grass hay horse midd	0.16
Grass hay horse crs	0.16
Grass bales ad	0.1
Grass seeds straw	
Oat straw	
Clover red fresh	
Clover red silage	0.15
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	
Lucerne hay	
Lucerne (alfalfa) ad	0.1
Maize Cob with leaves silage	
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	0.43
Maize fod fr DM<240	0.18
Maize f fr DM240-280	0.18
Maize f fr DM280-320	0.18
Maize fod fr DM 320	0.18
Maize sil DM < 240	0.18
Maize sil DM240-280	0.18
Maize sil DM280-320	0.18
Maize sil DM 320	0.18
Maize (Fodder) ad	0.18
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	
Chicory rts not frcd	
Chicory rts frcd cleaned	
Chicory rts frcd dirty	
Carrots	
Sunflower silage	

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	
Calcium carbonate	
Diammonium phosphate	
Difluorinated phosphate	
Dicalcium phosphate	
Mono-dicalcium phosphate	
Monoammonium phosphate	
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of cobalt in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	57.4	69.1	4	4	0.123	0.061
Piglet Starter II (complete feed)	20	50.7	75.7	6	7	0.094	0.053
Pig Grower (complete feed)	19	51.1	81.1	6	8	0.095	0.058
Pig Finisher (complete feed)	18	43.3	80.6	5	7	0.076	0.061
Sows, gestating (complete feed)	18	60.3	75.7	5	8	0.093	0.073
Sows, lactating (complete feed)	20	52.6	69.2	6	7	0.099	0.056
Starter Chicks (complete feed)	15	44.8	83.4	3	4	0.083	0.048
Chicken reared for laying (complete feed)	17	30.5	79.5	4	6	0.042	0.042
Layer Phase I (complete feed)	16	25.9	78.1	2	5	0.037	0.042
Layer Phase II (complete feed)	16	26.3	70.7	2	5	0.038	0.040
Broiler Starter (complete feed)	14	50.9	79.1	3	4	0.131	0.089
Broiler Grower (complete feed)	15	39.3	79.2	4	4	0.105	0.067
Broiler Finisher (complete feed)	15	22.5	77.8	3	3	0.069	0.045
Turkey Starter (complete feed)	14	67.5	87.8	3	3	0.226	0.058
Turkey Grower (complete feed)	13	48.2	88.2	2	3	0.115	0.053
Turkey Finisher (complete feed)	11	51.2	91.2	2	3	0.116	0.053
Turkey Breeder (complete feed)	8	80.8	80.8	2	2	0.106	0.046
Duck, grower/finisher (complete feed)	10	24.0	83.9	2	2	0.049	0.029
Geese, grower/finisher (complete feed)	8	77.0	97.0	3	4	0.148	0.067
Calf, milk replacer (complete feed)	10	10.0	30.7	1	1	0.026	0.031
Calf concentrate (complete feed)	17	73.3	72.5	7	7	0.133	0.297
Calf concentrate (complementary feed)	16	46.6	45.0	6	6	0.107	0.073
Cattle concentrate (complete feed)[4]	9	68.4	88.4	5	6	0.279	0.219
Cattle concentrate (complementary feed)	8	54.8	83.4	4	5	0.330	0.091
Dairy cows TMR (based on corn silage)[4]	15	88.5	97.9	7	9	0.159	0.211
Dairy cows TMR (based on grass silage)[4]	15	86.1	96.2	7	9	0.146	0.337
Dairy concentrate (complementary feed)	13	40.4	82.0	5	7	0.072	0.302
Dairy cows mineral feed (min. 40% crude ash)	8	0.0	0.0	0	0	0.000	0.000
Rabbit, breeder (complete feed)	8	51.0	97.0	3	4	0.544	0.389
Rabbit, grower/finisher (complete feed)	14	75.0	95.0	4	6	0.534	0.373
Salmon feed (wet)[4]	4	55.5	14.9	1	1	1.038	0.003
Salmon feed (dry)	6	72.0	27.4	2	2	1.024	0.021
Trout feed (dry)	12	63.5	69.7	2	3	0.302	0.292
Dog food (dry)	12	39.4	81.1	3	5	0.187	0.658
Cat food (dry)	16	25.8	46.1	4	4	0.102	0.393

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Cobalt: Addendum to the monograph

Abstract

This addendum to the cobalt monograph substantiates the data reported in Annex 5 of the cobalt monograph in which cobalt background levels are reported. The addendum provides the following information for each calculated background level: (1) the cobalt concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no cobalt concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated cobalt content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.25	34.93	0.087	70.81
Maize	0.11	10.00	0.011	8.92
Soybeans heat tr		15.10		
Soybm CF<45 CP>480	0.26	7.50	0.020	15.81
Wheat		16.68		
Wheat middlings	0.11	5.00	0.006	4.46
Fat from Animals		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	0.123	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.25	15.00	0.038	40.09
Maize	0.11	15.81	0.017	18.59
Dist grains and sol		3.00		
Palm kern exp CF<180	0.10	4.00	0.004	4.28
Rapeseed exp	0.20	6.00	0.012	12.83
Soybm CF<45 CP>480	0.26	7.86	0.020	21.86
Wheat		27.50		
Wheat gluten meal		10.00		
Wheat middlings	0.11	2.00	0.002	2.35
Fat from Animals		3.00		
Sunfmeal CF<160		2.55		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate		0.05		
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.094	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		2.00		
Barley	0.25	20.00	0.050	52.53
Maize	0.11	9.42	0.010	10.88
Dist grains and sol		5.00		
Palm kern exp CF<180	0.10	4.00	0.004	4.20
Rapeseed exp	0.20	7.00	0.014	14.71
Soybm CF<45 CP>480	0.26	3.40	0.009	9.28
Wheat		35.00		
Wheat middlings	0.11	7.27	0.008	8.40
Fat from Animals		2.09		
Sunfmeal CF<160		2.32		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.095	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		2.50		
Barley	0.25	20.00	0.050	65.52
Maize	0.11	6.93	0.008	9.98
Dist grains and sol		6.21		
Palm kern exp CF<180	0.10	5.00	0.005	6.55
Rapeseed exp	0.20	1.35	0.003	3.53
Wheat		35.00		
Wheat gluten meal		3.04		
Wheat middlings	0.11	10.00	0.011	14.41
Fat from Animals		2.00		
Sunfmeal CF<160		4.98		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.076	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		5.50		
Barley	0.25	20.00	0.050	54.03
Maize	0.11	15.26	0.017	18.14
Maize germ meal extr		7.50		
Sugarc mol SUG<475		0.10		
Palm kern exp CF<180	0.10	5.00	0.005	5.40
Wheat		11.22		
Wheat glutenfeed		5.00		
Wheat middlings	0.11	7.50	0.008	8.92
Wheat bran	0.10	12.50	0.013	13.51
Fat from Animals		1.91		
Sunfmeal CF<160		6.11		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate		0.07		
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.093	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		2.41		
Barley	0.25	20.00	0.050	50.72
Maize	0.11	10.00	0.011	11.16
Palm kern exp CF<180	0.10	4.00	0.004	4.06
Rapeseed exp	0.20	6.00	0.012	12.17
Soybean exp		1.39		
Soybm CF<45 CP>480	0.26	5.13	0.013	13.52
Wheat		23.43		
Wheat glutenfeed		10.00		
Wheat middlings	0.11	7.50	0.008	8.37
Fat from Animals		2.16		
Sunfmeal CF<160		4.22		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate		0.42		
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.099	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	20.00	0.022	26.36
Rapeseed exp	0.20	5.00	0.010	11.98
Soybeans not heat tr		0.69		
Soybm CF<45 CP>480	0.26	19.79	0.051	61.66
Wheat		35.62		
Wheat gluten meal		5.75		
Fat from Animals		2.00		
Sunfmeal CF<160		7.94		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate		0.56		
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.083	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Chicken reared for laying (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	15.00	0.017	39.59
Dist grains and sol		2.50		
Rapeseed exp	0.20	5.00	0.010	24.00
Soybm CF<45 CP>480	0.26	2.95	0.008	18.42
Wheat		41.54		
Wheat gluten meal		10.00		
Wheat bran	0.10	7.50	0.008	18.00
Fat from Animals		2.00		
Sunfmeal CF<160		10.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.29		
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.042	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	20.00	0.022	58.78
Dist grains and sol		4.00		
Soybeans not heat tr		8.36		
Soybm CF<45 CP>480	0.26	5.93	0.015	41.22
Wheat		38.18		
Wheat gluten meal		0.47		
Fat from Animals		2.87		
Sunfmeal CF<160		10.00		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.55		
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.037	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	20.00	0.022	57.16
Dist grains and sol		4.00		
Soybean exp		7.80		
Soybm CF<45 CP>480	0.26	6.34	0.016	42.84
Wheat		30.36		
Wheat gluten meal		7.41		
Fat from Animals		3.40		
Sunfmeal CF<160		10.00		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate		0.43		
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.038	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	30.00	0.033	25.12
Maize gluten meal	2.02	2.50	0.051	38.44
Soybeans not heat tr		15.00		
Soybm CF<45 CP>480	0.26	18.41	0.048	36.44
Wheat		28.16		
Fat from Animals		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate		0.94		
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.131	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	15.00	0.017	15.64
Maize gluten meal	2.02	1.56	0.031	29.78
Rapeseed exp	0.20	2.50	0.005	4.74
Soybeans not heat tr		10.00		
Soybm CF<45 CP>480	0.26	20.22	0.053	49.83
Wheat		42.41		
Fat from Animals		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate		0.78		
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.105	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize gluten meal	2.02	0.68	0.014	19.99
Rapeseed exp	0.20	2.50	0.005	7.24
Soybeans not heat tr		10.16		
Soybm CF<45 CP>480	0.26	19.32	0.050	72.77
Wheat		57.84		
Fat from Animals		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate		0.39		
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	0.069	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	20.00	0.022	9.74
Soybm CF<45 CP>480	0.26	42.45	0.110	48.87
Wheat		25.35		
Fats/oils vegetable		1.83		
Fish meal CP630-680	1.87	5.00	0.094	41.39
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate		1.90		
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.82	0.226	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	6.94	0.008	6.65
Soybeans not heat tr		2.00		
Soybm CF<45 CP>480	0.26	41.24	0.107	93.35
Wheat		40.00		
Fats/oils vegetable		5.00		
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		2.21		
Salt		0.30		
Total		100.00	0.115	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	11.74	0.013	11.17
Soybm CF<45 CP>480	0.26	39.50	0.103	88.83
Wheat		40.00		
Fats/oils vegetable		4.60		
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		1.77		
Salt		0.30		
Total		100.00	0.116	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.11	69.44	0.076	72.04
Soybm CF<45 CP>480	0.26	11.40	0.030	27.96
Feather meal hydr		2.00		
Calcium carbonate		7.60		
Dicalcium Phosphate		1.00		
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.106	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Soybm CF<45 CP>480	0.26	15.00	0.039	79.75
Wheat		68.91		
Wheat middlings	0.11	9.00	0.010	20.25
Fats/oils veg h %d		3.87		
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate		0.90		
Premix		0.50		
Salt		0.37		
Total		100.02	0.049	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.25	10.00	0.025	16.87
Maize	0.11	34.00	0.037	25.24
Soybm CF<45 CP>480	0.26	33.00	0.086	57.89
Wheat		20.00		
Calcium carbonate		1.20		
Dicalcium Phosphate		0.50		
Premix		1.00		
Salt		0.30		
Total		100.00	0.148	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	0.26	10.00	0.026	100.00
Wheat gluten meal		5.00		
Fat from Animals		6.25		
Whey p l lac ASH<210		15.00		
Whey powder		30.65		
Cheese whey CP>275		11.00		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	0.026	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		5.50		
Citrus pulp, dried		8.00		
Barley	0.25	0.54	0.001	1.01
Linseed	1.99	1.25	0.025	18.66
Sugarbeet molasses	0.59	1.00	0.006	4.43
Palm kern exp CF<180	0.10	5.50	0.006	4.13
Rapeseed		3.50		
Rapeseed extr CP>380		1.94		
Soybeans heat tr		5.37		
Wheat middlings	0.11	7.00	0.008	5.78
Wheat feedfl CF<35	0.10	8.00	0.008	6.00
Vinasse Sugb CP>250		1.50		
Grass hay good qual	0.16	50.00	0.080	60.00
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	0.133	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		11.00		
Citrus pulp, dried		16.00		
Barley	0.25	1.08	0.003	2.53
Linseed	1.99	2.50	0.050	46.65
Sugarbeet molasses	0.59	2.00	0.012	11.06
Palm kern exp CF<180	0.10	11.00	0.011	10.31
Rapeseed		7.00		
Rapeseed extr CP>380		3.88		
Soybeans heat tr		10.74		
Wheat middlings	0.11	14.00	0.015	14.44
Wheat feedfl CF<35	0.10	16.00	0.016	15.00
Vinasse Sugb CP>250		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	0.107	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		10.01		
Barley	0.25	18.90	0.047	16.93
Linseed	1.99	7.51	0.149	53.56
Sugarbeet molasses	0.59	0.98	0.006	2.07
Soybm CF<45 CP>480	0.26	10.99	0.029	10.24
Wheat		17.50		
Fats/oils veg h %d		1.60		
Grass sil average	0.16	30.00	0.048	17.20
Premix		2.50		
Total		99.99	0.279	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		14.30		
Barley	0.25	27.00	0.068	20.48
Linseed	1.99	10.70	0.213	64.62
Sugarbeet molasses	0.59	1.40	0.008	2.51
Soybm CF<45 CP>480	0.26	15.70	0.041	12.39
Wheat		25.00		
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	0.330	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		2.61		
Maize glfd CP200-230		0.95		
Maize feed meal		1.15		
Sugarbeet molasses	0.59	0.24	0.001	0.89
Palm kern exp CF<180	0.10	1.78	0.002	1.12
Rapeseed exp	0.20	0.59	0.001	0.74
Rapeseed extr CP>380		6.18		
Soybm CF<45 CP>480	0.26	7.83	0.020	12.79
Wheat middlings	0.11	0.96	0.001	0.66
Vinasse Sugb CP>250		0.36		
Grass sil average	0.16	26.89	0.043	27.02
Maize sil DM280-320	0.18	50.23	0.090	56.78
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.95	0.159	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		4.72		
Maize glfd CP200-230		1.72		
Maize feed meal		2.08		
Sugarbeet molasses	0.59	0.43	0.003	1.73
Palm kern exp CF<180	0.10	3.22	0.003	2.20
Rapeseed exp	0.20	1.07	0.002	1.46
Rapeseed extr CP>380		4.39		
Soybm CF<45 CP>480	0.26	3.97	0.010	7.05
Wheat middlings	0.11	1.74	0.002	1.31
Vinasse Sugb CP>250		0.64		
Grass sil average	0.16	49.18	0.079	53.73
Maize sil DM280-320	0.18	26.46	0.048	32.52
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		99.94	0.146	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		22.00		
Maize glfd CP200-230		8.00		
Maize feed meal		9.70		
Sugarbeet molasses	0.59	2.00	0.012	16.28
Palm kern exp CF<180	0.10	15.00	0.015	20.69
Rapeseed exp	0.20	5.00	0.010	13.80
Rapeseed extr CP>380		15.00		
Soybm CF<45 CP>480	0.26	10.30	0.027	36.94
Wheat middlings	0.11	8.10	0.009	12.29
Vinasse Sugb CP>250		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	0.072	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)		Dairy cows mineral feed (min. 40% crude ash)		
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate		8.80		
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00		

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.25	2.00	0.005	0.92
Alf meal CP160-180	1.29	40.00	0.516	94.78
Soybm CF<45 CP>480	0.26	9.00	0.023	4.30
Wheat germfeed		46.00		
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	0.544	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG150-200		10.00		
Barley	0.25	23.00	0.058	10.77
Alf meal CP160-180	1.29	35.00	0.452	84.55
Soybm CF<45 CP>480	0.26	5.00	0.013	2.43
Wheat bran	0.10	12.00	0.012	2.25
Fat from Animals		2.00		
Sunfmeal CF 200-240		10.00		
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate		1.90		
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	0.534	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat		14.90		
Fish meal CP630-680	1.87	55.53	1.038	100.00
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		99.99	1.038	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Soybm CF<45 CP>480	0.26	20.00	0.052	5.08
Wheat		7.42		
Fish meal CP630-680	1.87	51.96	0.972	94.92
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	1.024	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	0.26	55.00	0.143	47.36
Wheat		2.87		
Wheat gluten meal		11.80		
Fat from Animals		16.00		
Fish meal CP630-680	1.87	8.50	0.159	52.64
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	0.302	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Sugarb p SUG100-150	0.19	4.30	0.008	4.37
Meat meal CFAT<100		40.62		
Maize	0.11	27.80	0.031	16.36
Maize starch		2.78		
Rice wtht hulls	2.03	7.30	0.148	79.27
Fat from Animals		9.60		
Brewers y CP400-500		1.10		
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.187	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Brewers' yeast dried	0.21	1.80	0.004	3.70
Meat meal Dutch		1.33		
Greaves		29.76		
Linseed	1.99	3.00	0.060	58.43
Wheat		12.21		
Wheat glutenfeed		2.06		
Wheat feedfl CF<35	0.10	20.00	0.020	19.57
Feather meal hydr		18.00		
Fat from Animals		7.97		
Fish meal CP630-680	1.87	1.00	0.019	18.30
Meat bone m CFAT>100		1.00		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.102	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	34.93	0.045	74.14
Maize	0.05	10.00	0.005	8.16
Wheat, soft	0.02	16.68	0.003	5.45
Wheat middlings		5.00		
Soybean, full fat, extruded		15.10		
Soybean meal, 50	0.10	7.50	0.008	12.25
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	0.061	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	15.00	0.020	37.12
Maize	0.05	15.81	0.008	15.05
Wheat, soft	0.02	27.50	0.006	10.47
Wheat middlings		2.00		
Wheat gluten feed, starch 28%		10.00		
Corn distillers	0.10	3.00	0.003	5.71
Palm kernel meal, expeller	0.13	4.00	0.005	9.90
Rapeseed cake		6.00		
Soybean meal, 50	0.10	7.86	0.008	14.97
Sunflower meal, undecorticated	0.14	2.55	0.004	6.79
Tallow		3.00		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate		0.05		
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.053	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	20.00	0.026	44.56
Maize	0.05	9.42	0.005	8.07
Wheat, soft	0.02	35.00	0.007	12.00
Wheat middlings		7.27		
Corn distillers	0.10	5.00	0.005	8.57
Palm kernel meal, expeller	0.13	4.00	0.005	8.91
Rapeseed cake		7.00		
Soybean meal, 50	0.10	3.40	0.003	5.82
Sunflower meal, undecorticated	0.14	2.32	0.003	5.55
Beet pulp, dried	0.19	2.00	0.004	6.51
Tallow		2.09		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.058	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	20.00	0.026	42.70
Maize	0.05	6.93	0.003	5.69
Wheat, soft	0.02	35.00	0.007	11.49
Wheat middlings		10.00		
Wheat gluten feed, starch 28%		3.04		
Corn distillers	0.10	6.21	0.006	10.20
Palm kernel meal, expeller	0.13	5.00	0.007	10.67
Rapeseed cake		1.35		
Sunflower meal, undecorticated	0.14	4.98	0.007	11.45
Beet pulp, dried	0.19	2.50	0.005	7.80
Tallow		2.00		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.061	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	20.00	0.026	35.38
Maize	0.05	15.26	0.008	10.38
Wheat, soft	0.02	11.22	0.002	3.05
Wheat bran	0.09	12.50	0.011	15.31
Wheat middlings		7.50		
Wheat gluten feed, starch 28%		5.00		
Maize germ meal, expeller		7.50		
Palm kernel meal, expeller	0.13	5.00	0.007	8.84
Sunflower meal, undecorticated	0.14	6.11	0.009	11.65
Beet pulp, dried	0.19	5.50	0.010	14.23
Molasses, sugarcane	0.90	0.10	0.001	1.16
Tallow		1.91		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate		0.07		
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.073	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	20.00	0.026	46.02
Maize	0.05	10.00	0.005	8.85
Wheat, soft	0.02	23.43	0.005	8.29
Wheat middlings		7.50		
Wheat gluten feed, starch 28%		10.00		
Soybean, full fat, extruded		1.39		
Palm kernel meal, expeller	0.13	4.00	0.005	9.20
Rapeseed cake		6.00		
Soybean meal, 50	0.10	5.13	0.005	9.07
Sunflower meal, undecorticated	0.14	4.22	0.006	10.45
Beet pulp, dried	0.19	2.41	0.005	8.11
Tallow		2.16		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate		0.42		
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.056	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	20.00	0.010	20.82
Wheat, soft	0.02	35.62	0.007	14.83
Wheat gluten feed, starch 28%		5.75		
Soybean, full fat, extruded		0.69		
Rapeseed cake		5.00		
Soybean meal, 50	0.10	19.79	0.020	41.21
Sunflower meal, undecorticated	0.14	7.94	0.011	23.15
Tallow		2.00		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate		0.56		
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.048	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	15.00	0.008	17.85
Wheat, soft	0.02	41.54	0.008	19.78
Wheat bran	0.09	7.50	0.007	16.07
Wheat gluten feed, starch 28%		10.00		
Corn distillers	0.10	2.50	0.003	5.95
Rapeseed cake		5.00		
Soybean meal, 50	0.10	2.95	0.003	7.03
Sunflower meal, undecorticated	0.14	10.00	0.014	33.33
Tallow		2.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.29		
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.042	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	20.00	0.010	24.06
Wheat, soft	0.02	38.18	0.008	18.37
Wheat gluten feed, starch 28%		0.47		
Corn distillers	0.10	4.00	0.004	9.62
Soybean, full fat, extruded		8.36		
Soybean meal, 50	0.10	5.93	0.006	14.27
Sunflower meal, undecorticated	0.14	10.00	0.014	33.68
Tallow		2.87		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.55		
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.042	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	20.00	0.010	24.74
Wheat, soft	0.02	30.36	0.006	15.02
Wheat gluten feed, starch 28%		7.41		
Corn distillers	0.10	4.00	0.004	9.90
Soybean, full fat, extruded		7.80		
Soybean meal, 50	0.10	6.34	0.006	15.69
Sunflower meal, undecorticated	0.14	10.00	0.014	34.64
Tallow		3.40		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate		0.43		
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.040	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	30.00	0.015	16.85
Wheat, soft	0.02	28.16	0.006	6.33
Corn gluten meal	2.00	2.50	0.050	56.15
Soybean, full fat, extruded		15.00		
Soybean meal, 50	0.10	18.41	0.018	20.68
Tallow		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate		0.94		
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.089	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	15.00	0.008	11.14
Wheat, soft	0.02	42.41	0.008	12.60
Corn gluten meal	2.00	1.56	0.031	46.21
Soybean, full fat, extruded		10.00		
Rapeseed cake		2.50		
Soybean meal, 50	0.10	20.22	0.020	30.04
Tallow		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate		0.78		
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.067	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat, soft	0.02	57.84	0.012	25.97
Corn gluten meal	2.00	0.68	0.014	30.67
Soybean, full fat, extruded		10.16		
Rapeseed cake		2.50		
Soybean meal, 50	0.10	19.32	0.019	43.37
Tallow		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate		0.39		
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	0.045	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	20.00	0.010	17.38
Wheat, soft	0.02	25.35	0.005	8.81
Soybean meal, 50	0.10	42.45	0.042	73.80
Fish meal, protein 70%		5.00		
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate		1.90		
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.82	0.058	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	6.94	0.003	6.58
Wheat, soft	0.02	40.00	0.008	15.18
Soybean, full fat, extruded		2.00		
Soybean meal, 50	0.10	41.24	0.041	78.24
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		2.21		
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	0.053	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	11.74	0.006	11.00
Wheat, soft	0.02	40.00	0.008	14.99
Soybean meal, 50	0.10	39.50	0.040	74.01
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		1.77		
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	0.053	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	69.44	0.035	75.28
Soybean meal, 50	0.10	11.40	0.011	24.72
Feather meal		2.00		
Calcium carbonate		7.60		
Dicalcium Phosphate		1.00		
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.046	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat, soft	0.02	68.91	0.014	47.88
Wheat middlings		9.00		
Soybean meal, 50	0.10	15.00	0.015	52.12
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate		0.90		
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	0.029	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	10.00	0.013	19.40
Maize	0.05	34.00	0.017	25.37
Wheat, soft	0.02	20.00	0.004	5.97
Soybean meal, 50	0.10	33.00	0.033	49.25
Calcium carbonate		1.20		
Dicalcium Phosphate		0.50		
Premix		1.00		
Salt		0.30		
Total		100.00	0.067	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat gluten feed, starch 25%		5.00		
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	0.10	30.65	0.031	100.00
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	0.031	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	0.54	0.001	0.24
Wheat middlings		7.00		
Wheat feed flour		8.00		
Linseed, full fat		1.25		
Rapeseed, full fat		3.50		
Soybean, full fat, toasted		5.37		
Palm kernel meal, expeller	0.13	5.50	0.007	2.41
Rapeseed meal	0.09	1.94	0.002	0.59
Beet pulp, dried	0.19	5.50	0.010	3.52
Citrus pulp, dried	0.14	8.00	0.011	3.77
Molasses, beet	0.55	1.00	0.006	1.85
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	0.52	50.00	0.260	87.62
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	0.297	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	1.08	0.001	1.91
Wheat middlings		14.00		
Wheat feed flour		16.00		
Linseed, full fat		2.50		
Rapeseed, full fat		7.00		
Soybean, full fat, toasted		10.74		
Palm kernel meal, expeller	0.13	11.00	0.014	19.46
Rapeseed meal	0.09	3.88	0.003	4.75
Beet pulp, dried	0.19	11.00	0.021	28.44
Citrus pulp, dried	0.14	16.00	0.022	30.48
Molasses, beet	0.55	2.00	0.011	14.97
Vinasse, different origins		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	0.073	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	18.90	0.025	11.20
Wheat, soft	0.02	17.50	0.004	1.59
Linseed, full fat		7.51		
Soybean meal, 50	0.10	10.99	0.011	5.01
Beet pulp, dried	0.19	10.01	0.019	8.67
Molasses, beet	0.55	0.98	0.005	2.46
Grass silage	0.52	30.00	0.156	71.08
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	0.219	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	27.00	0.035	38.71
Wheat, soft	0.02	25.00	0.005	5.51
Linseed, full fat		10.70		
Soybean meal, 50	0.10	15.70	0.016	17.32
Beet pulp, dried	0.19	14.30	0.027	29.97
Molasses, beet	0.55	1.40	0.008	8.49
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	0.091	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat middlings		0.96		
Corn gluten feed	0.15	0.95	0.001	0.67
Corn gluten meal	2.00	1.15	0.023	10.88
Palm kernel meal, expeller	0.13	1.78	0.002	1.09
Rapeseed meal	0.09	6.18	0.006	2.63
Rapeseed cake		0.59		
Soybean meal, 50	0.10	7.83	0.008	3.70
Beet pulp, dried	0.19	2.61	0.005	2.35
Molasses, beet	0.55	0.24	0.001	0.62
Vinasse, different origins		0.36		
Grass silage	0.52	26.89	0.140	66.16
Corn silage	0.05	50.23	0.025	11.88
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	0.211	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat middlings		1.74		
Corn gluten feed	0.15	1.72	0.003	0.77
Corn gluten meal	2.00	2.08	0.042	12.36
Palm kernel meal, expeller	0.13	3.22	0.004	1.24
Rapeseed meal	0.09	4.39	0.004	1.17
Rapeseed cake		1.07		
Soybean meal, 50	0.10	3.97	0.004	1.18
Beet pulp, dried	0.19	4.72	0.009	2.66
Molasses, beet	0.55	0.43	0.002	0.70
Vinasse, different origins		0.64		
Grass silage	0.52	49.18	0.256	75.98
Corn silage	0.05	26.46	0.013	3.93
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	0.337	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat middlings		8.10		
Corn gluten feed	0.15	8.00	0.012	3.97
Corn gluten meal	2.00	9.70	0.194	64.22
Palm kernel meal, expeller	0.13	15.00	0.020	6.45
Rapeseed meal	0.09	15.00	0.014	4.47
Rapeseed cake		5.00		
Soybean meal, 50	0.10	10.30	0.010	3.41
Beet pulp, dried	0.19	22.00	0.042	13.84
Molasses, beet	0.55	2.00	0.011	3.64
Vinasse, different origins		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	0.302	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)		Dairy cows mineral feed (min. 40% crude ash)		
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate		8.80		
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00		

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	2.00	0.003	0.67
Wheat bran	0.09	46.00	0.041	10.64
Soybean meal, 50	0.10	9.00	0.009	2.31
Alfalfa, dehydrated	0.84	40.00	0.336	86.38
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	0.389	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Barley	0.13	23.00	0.030	8.02
Wheat bran	0.09	12.00	0.011	2.90
Soybean meal, 50	0.10	5.00	0.005	1.34
Sunflower meal, undecorticated	0.14	10.00	0.014	3.76
Beet pulp, dried	0.19	10.00	0.019	5.10
Lard		2.00		
Alfalfa, dehydrated	0.84	35.00	0.294	78.88
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate		1.90		
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	0.373	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat, soft	0.02	14.90	0.003	100.00
Fish meal, protein 70%		55.53		
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	0.003	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat, soft	0.02	7.42	0.001	6.91
Soybean meal, 50	0.10	20.00	0.020	93.09
Fish meal, protein 70%		52.00		
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	0.021	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat, soft	0.02	2.87	0.001	0.20
Corn gluten meal	2.00	11.80	0.236	80.94
Soybean meal, 50	0.10	55.00	0.055	18.86
Maize starch		3.00		
Fish meal, protein 70%		8.50		
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	0.292	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Maize	0.05	27.80	0.014	2.11
Rice, brown	2.00	7.30	0.146	22.20
Maize starch		2.78		
Beet pulp, dried	0.19	4.30	0.008	1.24
Brewers' yeast, dried	0.20	1.10	0.002	0.33
Lard		9.60		
Meat and bone meal, fat <7.5%	1.20	40.62	0.487	74.11
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.658	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Co/kg feed material	% feed material	mg Co/kg complete feedingstuff	Co (% contribution)
Wheat, soft	0.02	12.21	0.002	0.62
Wheat feed flour		20.00		
Wheat gluten feed, starch 25%		2.06		
Linseed, full fat		3.00		
Brewers' yeast, dried	0.20	1.80	0.004	0.91
Fish meal, protein 70%		1.00		
Feather meal		18.00		
Meat and bone meal, fat <7.5%	1.20	29.76	0.357	90.77
Meat and bone meal, fat >7.5%	1.30	2.33	0.030	7.70
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.393	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Copper

Executive summary of the monograph for copper

Several copper compounds are presently authorized as feed and food additives in the EU. Copper is an essential trace element that serves as a cofactor for many important metalloenzymes. The copper dependent enzymes include, e.g., cytochrome oxidase, lysyl oxidase, Cu-Zn superoxide dismutase, ceruloplasmin, tyrosinase. Hence, copper is involved in maturation and stability of collagen and elastin, energy metabolism, the antioxidant defense system, pigmentation, as well as other processes. Copper is known to have a growth stimulating effect in pigs, broilers and probably laying hens. Copper sulphate has been observed to reduce some Gram positive bacterial populations in the gut, e.g., *Streptococcus* spp. Achromotrichia (depigmentation) is the earliest clinical sign of copper deficiency in all species. Other common signs of copper deprivation include anemia, growth depression, bone disorders, demyelination of the spinal cord, fibrosis of the myocardium and diarrhea. In all species, liver and kidney are the organs primarily affected by copper toxicosis. Particularly in young animals, excess of copper leads to a reduced number of erythrocytes and consequently to macrocytic anemia. Livestock species differ greatly in their ability to tolerate excess copper. Dietary copper concentrations that cause toxicosis in nonruminants exceed requirements by at least 25-fold. Contrarily, sheep and nonruminant calves are very susceptible to copper toxicity. Maximum tolerable concentrations of copper for ruminants are greatly affected by dietary concentrations of sulphur and molybdenum. Copper is better absorbed by monogastric and preruminant animals compared to ruminants. Much of the copper released during rumen digestion is likely to be precipitated as copper sulphide. When the diet is enriched with molybdenum as well as sulphur, thiomolybdates are formed which further reduce absorbability. Copper is predominantly absorbed in the upper section of the small intestine. Absorbed copper is transported to the liver where it can be stored, used for the synthesis of copper metalloenzymes e.g., ceruloplasmin or where it can be excreted via bile. The liver is the major storage organ for copper. A high portion of ingested copper appears in the feces which is the combined fraction of unabsorbed copper and endogenous secreted biliary copper. Copper concentrations are highest in the liver. Liver and kidney copper concentrations are related to the dietary copper intake whereas muscle concentrations are more conserved.

Symptoms of acute copper toxicosis include salivation, epigastric pain, nausea, vomiting and diarrhea. Several copper compounds have produced positive results in *in vitro* assays which investigated the genotoxic potential and observed effects included errors in DNA synthesis, reduced DNA synthesis, and increased occurrence of strand breaks. IOM, SCF and EVM selected liver damage, damage to the forestomach and kidneys as critical endpoints to establish upper intake levels (UL). IOM, EVM and SCF established UL values for copper for adults of 10 mg/day, 10 mg/day and 5 mg/day, respectively. In humans, copper is a respiratory irritant. SCAN did not identify risks for the environment consecutive to the use of copper in pig and ruminant diets.

Copper Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Several copper compounds are authorized as feed and food additives. These copper compounds are considered of importance in human and animal nutrition (Chapter 2).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Copper compounds presently authorized in the EU as additives (EC 1334/2003[1], EC 479/2006[2] and EC 1253/2008[3]) are listed in Table 1.

In the US, the following copper compounds are allowed in animal feeds: copper acetate monohydrate, copper carbonate, copper chloride, copper choline citrate complex, copper citrate, copper gluconate, copper hydroxide, copper orthophosphate, copper oxide, copper sulphate, cuprous iodide, copper amino acid complex, copper lysine complex, copper amino acid chelate, copper polysaccharide complex, copper proteinate (AAFCO Official Publication §57: Mineral Products). Copper pyrophosphate is not specifically defined by AAFCO, but was adopted in its publication from the Federal Code of Regulations. It is listed as generally recognised as safe in animal feeds (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

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[1] OJ L 187, 26.7.2003, p.11

[2] OJ L 86, 24.3.2006, p.4

[3] OJ L 337, 16.12.2008, p.78

Table 1 Conditions of use of copper compounds as additives in feedingstuffs according to the Commission Regulations EC 1334/2003[1], EC 479/2006[2] and EC 1253/2008[3])

<table>
<tr><th>Additive</th><th>Chemical formula</th><th>Maximum content of the element in the complete feedingstuff (mg/kg)</th></tr>
<tr><td>Cupric acetate, monohydrate</td><td>$Cu(CH_3COO)_2.H_2O$</td><td rowspan="9">Pigs:
- Piglets up to 12 weeks: 170 (total)
- Other pigs: 25 (total)

Bovine:
- Bovine before start of rumination:
▪ Milk replacers: 15 (total)
▪ Other complete feedingstuffs: 15 (total)
- Other bovine: 35 (total)
Ovine: 15 (total)
Fish: 25 (total)
Crustaceans: 50 (total)
Other species: 25 (total)</td></tr>
<tr><td>Basic cupric carbonate, monohydrate</td><td>$CuCO_3.Cu(OH)2. H_2O$</td></tr>
<tr><td>Cupric chloride, dihydrate</td><td>$CuCl_2. 2H_2O$</td></tr>
<tr><td>Cupric methionate</td><td>$Cu(C_5H_{10}NO_2S)_2$</td></tr>
<tr><td>Cupric oxide</td><td>CuO</td></tr>
<tr><td>Cupric sulphate, pentahydrate</td><td>$CuSO_4.5 H_2O$</td></tr>
<tr><td>Cupric chelate of amino acids, hydrate</td><td>$Cu(X)_{1-3}.n H_2O$
(X: anion of any amino acid derived from hydrolysed soya protein). Molecular weight not exceeding 1500 g/mol</td></tr>
<tr><td>Copper lysine sulphate</td><td>$Cu(C_6H_{13}N_2O_2)_2SO_4$</td></tr>
<tr><td>Cupric chelate of glycine, hydrate [2]</td><td>$Cu(X)_{1-3}.n H_2O$
(X: anion of synthetic glycine)</td></tr>
<tr><td>Copper chelate of hydroxyl analogue of methionine [3]</td><td></td><td>Chickens for fattening: 25</td></tr>
</table>

Table 2 Range of copper guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	**Range (mg/kg)**
Chickens	4 – 125
Turkeys	6 – 125
Swine	6 – 125
Dairy cattle	10 – 100
Beef cattle	4 – 50
Horses	9 – 125
Goats	10 – 40
Ducks and geese	9 – 125
Salmonid fish	5 – 75
Mink	4.5 – 100
Rabbits	10 - 125

2.2 Human nutrition

Copper compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[4]. The authorized copper compounds are cupric carbonate, cupric citrate, cupric gluconate, cupric sulphate, copper lysine complex.

- As food supplements under Regulation EC 1170/2009[5]. The authorized copper compounds are: cupric carbonate, cupric citrate, cupric gluconate, cupric sulphate, copper L-aspartate, copper bisglycinate, copper lysine complex, copper (II) oxide.

- As substances which may be added to foods under Regulation 1925/2006[6] as amended by Regulation 1170/2009[5]. The authorized copper compounds are: cupric carbonate, cupric citrate, cupric gluconate, cupric sulphate, copper lysine complex.

- Directive 2008/100/EC[7] lays down a Recommended Daily Allowance (RDA) for copper of 1 mg.

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[4] OJ L 269, 14.10.2009, p. 9

[5] OJ L 314, 1.12.2009, p. 36

[6] OJ L 404, 30.12.2006, p. 26

[7] OJ L 285, 29.10.2008, p. 9

3 Essential functions

Copper is an essential element that serves as a cofactor for many important metalloenzymes. Copper is only surpassed by zinc in the number of enzymes which it activates (McDowell, 2003; Underwood & Suttle, 1999). A summary of enzymes that require copper, associated physiological functions as well as deficiency symptoms that occur when the copper supply is inadequate, is given in Table 3.

Table 3 Summary of the most important copper dependent enzymes, associated essential functions and deficiency symptoms (adapted from McDowell, 2003; Underwood & Suttle, 1999)

Enzymes	**Physiological functions**	**Deficiency symptoms**
Cytochrome oxidase	Terminal oxidase in the respiratory chain	
Lysyl oxidase	Adds a hydroxyl group to lysine residues in collagen, allowing cross-linking between collagen fibers	Impaired wound healing and blood vessel integrity
Cu – Zn superoxide dismutase	E.g., protection of erythrocytes against oxygen radicals	Anemia
Ceruloplasmin (ferroxidase I) Ferroxidase II	Important in the flow of iron that supports hematopoiesis;	Anemia
Dopamine-β-hydroxylase		
Dopamine-β-monooxygenase	Hydroxylation of dopamine	
Tyrosinase	Melanin formation	Lack of pigmentation (achromotrichia)
Superoxide dismutases Extracellular ceruloplasmin Intracellular Cu thioneins	Antioxidant defense	

4 Other functions

In weaned pigs high copper supplements improve feed conversion and stimulate growth. Although the mechanisms are not fully understood, improvement of appetite contributes to the growth stimulation (Underwood & Suttle, 1999). Copper fed at high levels is only known to have a practical growth promoting effect in pigs, broilers and probably laying hens. For pigs results of copper supplementation, up to 250 mg/kg, on growth and feed conversion are only demonstrated to be significant from weaning to a body weight of approximately 25 kg (SCAN, 2003).

5 Antimicrobial properties

Copper sulphate has been observed to quantitatively reduce some Gram positive bacterial populations in the gut e.g., *Streptococcus* spp. Investigations into the contribution of this antimicrobial property to the growth promoting effect produced inconsistent results (SCAN, 2003).

6 Typical deficiency symptoms

When the diet is deficient in copper, three copper dependent proteins are immediately affected: ceroluplasmin, cytosolic superoxide dismutase and cytochrome C oxidase (McDowell, 2003). Copper deficiency results in a wide range of signs in different animal species. Common signs noted in all animals include anemia, growth depression, bone disorders, depigmentation of hair, wool, fur and feathers, demyelination of the spinal cord, fibrosis of the myocardium, and diarrhea (Leeson, 2009; McDowell, 2003). Achromotrichia (depigmentation) is the earliest clinical sign of copper deprivation in all species, provided the breed has a pigmented coat. Anemia usually develops only when deficiency has been severe or prolonged. One of the hallmarks of severe copper deficiency in mammals is the loss of integrity of elastic and connective tissue, resulting in increased fragility of the blood vessel walls, abnormal elastin, vascular lesions and a greater likelihood of aneurysms (McDowell, 2003; Underwood & Suttle, 1999).

7 Animal requirements, allowances and use levels

Copper requirements of livestock established by scientific bodies are compiled in Annex 3.1. Copper use level are compiled in Annex 3.2.

8 Concentration of the element in feed materials

Copper concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Copper concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Animal species differ greatly in their ability to tolerate excess copper. Sheep and nonruminant calves are very sensitive to copper toxicity. The sensitivity of sheep relates to their inability to increase biliary copper excretion in response to elevated copper intakes. Young ruminants are more susceptible than adults because of higher absorption (NRC, 2005; SCAN, 2003). In nonruminants copper homeostatic control mechanisms generally are efficient in preventing toxicosis (NRC, 2005).

For sheep the range of dietary copper concentrations required under some conditions can overlap with dietary concentrations that cause toxicosis under other conditions. MTL values established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels (MTL) for copper (mg/kg DM) (NRC, 2005)

Species	**MTL**	**Additional remarks**
Rodents	500	
Poultry, swine, horse	250	For ducks the MTL is 100 mg/kg DM
Fish	100	
Cattle	40	Assuming normal concentrations of molybdenum (1 – 2 mg/kg DM) and sulphur (0.15 – 0.25 %). At lower molybdenum and sulphur concentrations copper may become toxic at lower levels
Sheep	15	

Additionally, to the copper MTL values NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Liver and kidney are target organs for copper toxicosis in all species (NRC, 2005; SCAN, 2003). Particularly in young animals, excess of copper leads to a reduced number of erythrocytes and consequently to macrocytic anemia (SCAN, 2003). In sheep copper toxicosis consists of a prehemolytic, and hemolytic phase. During the prehemolytic phase copper accumulates in the liver, liver necrosis occurs and enzymes indicative of liver damage may become elevated in serum. Though, depressed animal performance is generally not observed until shortly before the hemolytic phase. The hemolytic phase is characterized by hemolysis, hemoglobinemia and hemoglobinuria. It is associated with rapid release of copper from the liver and entry of copper into the erythrocytes (NRC, 2005).

12 Bioavailability

12.1 General

Young animals absorb copper better compared to mature animals. Preruminant animals absorb copper as efficiently as monogastric species and more efficiently than the mature ruminant (McDowell, 2003; NRC, 2005). Mature ruminants absorb copper poorly due to processes in the rumen whereby sulphide is formed from organic and inorganic sulphur sources. In particular rumen protozoa are important generators of sulphide. Much of the copper released during rumen digestion is likely to be precipitated as copper sulphide (Underwood & Suttle, 1999). When the diet is enriched with molybdenum as well as sulphur, thiomolybdates are formed which complex copper and further reduce absorbability (McDowell, 2003; Underwood & Suttle, 1999). Research into the influence of the copper compound on copper bioavailability for several livestock species categories has been reviewed by Jongbloed *et al*. (2002) (Table 5). In humans it has been demonstrated that the rate of copper absorption varies inversely with copper intake and can be as low as 12 % with very high copper intakes. In typical diets in developed countries, the average true copper absorption is in the 30 – 40 % range (Wapnir, 1998).

Table 5 Relative bioavailability assessments (%)[1] of copper compounds compared to copper sulphate in livestock (Jongbloed *et al*., 2002)

Copper compound	Pigs	Broilers	Ruminants
Copper sulphate	100	100	100
Copper carbonate	100	64	93
Copper oxide	74	24	76
Copper methionine	100	91	
Copper lysine	94	100	104

[1]:criterion: liver copper concentration

12.2 *Indicators of copper status*

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of copper compounds in livestock (Table 6).

Table 6 Ranking of adequacy of response criterions for assessing the relative biological value of copper compounds[1] (Jongbloed *et al*., 2002)

	Pigs		**Poultry**		**Ruminants**	
Supplementation level →	**Suboptimal**	**Above requirement**	**Suboptimal**	**Above requirement**	**Suboptimal**	**Above requirement**
Criterion						
Liver copper content	4	3	4	3	4	2
Copper absorption	3	1	3	1	2	1
Cu superoxide dismutase	1	1	1	1		
Liver ceruloplasmin content	1	1	1	1		
Animal performance	1	-	1	-		
Kidney copper content					3	2

[1]: the highest values correspond to the best adequacy

The FEEDAP Panel adopted two trials with chickens in their safety and efficacy assessment of a copper chelate of a hydroxyl analogue of methionine as a feed additive. In these trials copper concentrations in liver, bile and tibia were used as response criterions to assess the biological value of the copper chelate in comparison to copper sulphate (EFSA, 2008).

13 Metabolism

Major differences in copper metabolism exist between nonruminant and ruminant species (NRC, 2005). Copper is predominantly absorbed in the upper section of the small intestine (McDowell, 2003; NRC, 2005). Absorbed copper in the portal blood binds to albumin and transcuprein for transport to the liver. In the liver, copper can be excreted via bile, stored or used for the synthesis of ceruloplasmin or other copper metalloenzymes. Copper excreted in bile is poorly reabsorded from the small intestine. Biliary excretion is the major mechanism responsible for copper homeostasis. Biliary copper excretion is less effective in preserving homeostasis and regulating liver copper concentration in ruminants compared to monogastrics. Especially in sheep an increase in dietary copper does not induce an increased biliary copper excretion (NRC, 2005). Copper is transported to extrahepatic tissues bound to ceruloplasmin. Nearly 90 % of the copper in mammalian plasma is bound to ceruloplasmin. Liver is the major storage organ for copper and stored copper is largely bound to metallothionein. A high portion of ingested copper appears in feces which is the combined fraction of unabsorbed copper and endogenous secreted biliary copper (McDowell, 2003; NRC, 2005).

14 Distribution in the animal body

Information related to the distribution of copper in the animal body is given in Chapter 15.

15 Deposition (typical concentration) in edible tissues and products

Copper concentrations are highest in the liver. Liver and kidney copper concentrations are related to the dietary intake whereas muscle concentrations are more conserved (SCAN, 2003). Normal liver copper concentrations are higher in ruminants than in pigs and chickens, and relatively small amounts of dietary copper greatly increase liver copper concentrations in ruminants. In nonruminants, liver copper increases to a much smaller extent with increasing dietary copper unless high levels of copper are fed (> 100 mg/kg) (NRC, 2005). Copper concentrations in edible tissues and products are reported in Annex 1 and copper concentrations in edible tissues and products linked with the dietary intake of several copper compounds and doses are reported in Annex 2.

16 Acute toxicity

Symptoms of acute copper toxicosis include salivation, epigastric pain, nausea, vomiting and diarrhea. Copper ions have an irritant effect on mucosal membranes and daily intakes ranging from 2 – 32 mg in drinking water have been reported to cause symptoms of general gastric irritation (EVM, 2003; SCF, 2003). Ingestion of > 100 g copper sulphate may produce intravascular hemolysis, acute hepatic failure, acute tubular renal failure, shock, coma or death (EVM, 2003).

17 Genotoxicity and Mutagenicity

In vitro various copper salts have been observed to provoke errors in DNA synthesis, reduced DNA synthesis, and increased occurrence of DNA strand breaks. Contrarily, results from reverse mutation testing in *Salmonella* or *Saccharomyces* were mostly negative (Ellingsen *et al*., 2007). Several *in vivo* animal studies have reported an increased occurrence of micronuclei and chromosomal aberrations. In the livers of patients with Wilson's disease an increased load of p53 mutations was observed (Ellingsen *et al*., 2007). SCF (2003) concluded that an adequate evaluation of the genotoxic potential of copper and copper compounds is not possible due to conflict in experimental data.

18 Subchronic toxicity

The ATSDR Toxicological profile for copper includes information on the subchronic toxicity of several copper compounds on several organ systems and by several exposure routes ATSDR (2004).

19 Chronic toxicity, including carcinogenicity

Long term toxicity of copper is not well studied in humans. It rarely occurs with the exception of people suffering from a hereditary defect in copper homeostasis (IOM, 2001).

ATSDR (2004) did not locate any studies regarding carcinogenic effects in humans following oral exposure to copper. In relation to the carcinogenicity of orally ingested copper compounds, ATSDR included three studies in mice and rats were no increase in the occurrence of tumors was found and one study were an increased occurrence of hepatocellular carcinomas were observed in Long-Evans Cinnamon rats (ATSDR, 2004). An elevated incidence of hepatoma has been suggested in untreated Wilson's disease patients and in people recovering from Indian childhood cirrhosis (EVM, 2003).

20 Reproduction toxicity

ATSDR (2004) and SCF (2003) did not locate any studies or evidence regarding reproductive effects nor developmental effects in humans following oral exposure to copper.

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake and Upper Intake Level (UL)

Several scientific bodies established UL for copper. The studies which have been selected, the critical endpoints, NOAEL's and uncertainty factors (UF) are summarized in Table 7.

Table 7 Selected studies, critical endpoints, No Observed Adverse Effect Levels (NOAEL) and Uncertainty Factors (UF) used to establish upper intake levels for copper

Scientific body	Selected study	Species	Critical endpoints	NOAEL	UF
IOM (2001)	Pratt *et al*. (1985)	Human	Liver damage	10 mg/day	1
SCF (2003)	Pratt *et al*. (1985)	Human	Liver damage	10 mg/day	2
EVM (2003)	Hébert *et al*. (1993)	Rats	Damage to forestomach, kidney and liver	16 mg/(kg bw.day)	100

UL values for copper for several live stage groups are given in Table 8.

Table 8 Upper Intake Levels (UL) (mg/day) for copper for several life stage groups

Live stage group	UL (IOM, 2001)	Live stage group	UL (SCF, 2003)
1 - 3 years	1	1 - 3 years	1
4 - 8 years	3	4 - 6 years	2
9 - 13 years	5	7 - 10 years	3
14 - 18 years	8	11 - 17 years	4
Adults (≥ 19 years)	10	Adults	5
Pregnancy: 14 - 18 years	8		
Pregnancy: 19 - 50 years	10		
Lactation: 14 - 18 years	8		
Lactation: 19 - 50 years	10		

EVM (2003) derived an UL for copper of 10 mg/day for adults. BfR (2006) did not establish an UL for copper. As the basis for its derivation of maximum copper levels in food supplements, BfR (2006) upholded the precautionary principle and used the SCF value of 5 mg/day for adults (SCF, 2003).

23 Toxicological risks for user/workers

In humans, copper is a respiratory irritant. A number of symptoms that are suggestive of respiratory irritation, including coughing, sneezing, thoracic pain and runny nose, have been reported in workers exposed to copper dust. Linear pulmonary fibrosis and nodulation has been reported in workers involved in sieving copper (ATSDR, 2004). Anorexia, nausea and occasional diarrhea have occurred in workers involved in grinding and sieving copper dust. These symptoms likely resulted from ingestion of copper particles from mucocilliary clearance of copper particles deposited in the nasopharyngeal and tracheobroncheal regions of the respiratory tract (ATSDR, 2004).

There are no quantitative data from animal or human studies on the extent of absorption of copper compounds after inhalation (Ellingsen *et al*., 2007). Ellingsen *et al*. (2007) reported on two studies with rats where inhalation of copper compounds induced metallothionein synthesis in the lungs.

24 Toxicological risks for the environment

SCAN (2003) did not identify risks for the environment consecutive to the use of copper in pig and ruminant diets at supplementation levels authorized under Council Directive 70/524/ECC [8]. A simulation was made whereby the amount of copper applied per ha was calculated for two different situations: vulnerable areas with a nitrogen application on soil of 170 kg N/(ha.year) and non vulnerable areas with a nitrogen application of 350 kg N/(ha.year) (Table 9) (SCAN, 2003).

Table 9 Calculations of the amount of copper applied (g/(ha.year)) for several species and categories in case of vulnerable (170 kg N/(ha.year)) and non vulnerable areas (350 kg N/(ha.year)) (SCAN, 2003)

Species	**Vulnerable area**	**Non vulnerable area**
Piglets	2434	5011
Fattening pigs	481	990
Fattening steers	535	1101
Dairy cows	524	1079
Broilers	641	1319
Layers	524	1079

These calculated values are well within the maximum limit of copper which may be added annually to agricultural land, based on a 10 year average: 12 kg Cu/(ha.year) (Directive 86/278/EEC [9]).

Copper concentrations in manure from multiple monitoring studies are compiled in Table 10.

[8] OJ L 270, 14.12.1970, p.1

[9] OJ L181, 4.7.1986, p 6

Table 10 Copper content of manure from various species

Species, category	Cu content (mg/kg DM)	Reference
Dairy cattle FYM	37.5	Nicholson *et al*. (1999)
Dairy cattle slurry	62.3	
Beef cattle FYM	16.4	
Beef cattle slurry	33.2	
Pig FYM	374	
Pig slurry	351	
Broiler / turkey	96.8	
Layer	64.8	
Cattle, FYM, Se	29 - 31	Öborn *et al*. (2008)
Cattle, FYM, RF	20 -21	
Broiler	43.6	van Ryssen (2008)
Layer	45.9	
	(g/m^3)	
Pig, gestating	11	Moral *et al*. (2008)
Pig, farrowing	11	
Pig, weaner	55	
Pig, finisher	80	

FYM: Farm yard manure; Se: Sweden; RF: Research facility

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Annex 1. Copper concentrations in edible tissues and products

Table 1.1 Copper concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Hogs	326	1.16	11.1	6.65	Coleman *et al*. (1992)
Boars / sows	280	0.93	18.3	6.73	
Pork		neck steak: 0.92 chop: 0.359 loin: 0.405			Gerber *et al*. (2009)
Pigs	126	0.90	9.0	6.1	Jorhem & Sundström (1993)
Pork	3	saddle: 0.4 loin: 0.5 chump chop: 0.7			Lombardi - Boccia *et al*. (2005)
Pigs (6 m)	62	6.85	14.90	5.63	López-Alonso *et al*. (2007)

Table 1.2 Copper concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Veal	438	0.677	64.6			Alonso *et al*. (2002)
Beef	56	1.70				
Dairy cattle	48				0.052	Anderson (1992)
Calves (6 - 12 m)	195		89.6	4.61		Blanco-Penedo *et al.* (2006) [b]
Calves	327	1.56	138	6.34		Coleman *et al*. (1992)
Heifers / Steers	287	1.77	46.1	4.65		
Bulls / Cows	95	1.41	43.7	8.15		
Lambs	165	1.47	89.8	5.39		
Mature sheep	34	2.32	131.4	3.95		
Lamb		chop: 1.10 loin: 1.32				Gerber *et al*. (2009)
Beef cattle		sirloin: 0.498 - 0.775 braising steak: 0.375 rib-eye: 0.564 - 0.765				
Cattle	7	0.87	39	3.7		Jorhem & Sundström (1993)
Dairy cattle	16				0.12	Leblanc *et al*. (2005)[a]
Veal	3	fillet: 0.3				Lombardi - Boccia *et al*. (2005)
Beef	3	0.4 - 0.9				
Lamb	3	chop: 1.0				
Cattle	100		20.4	3.89		Nriagu *et al*. (2009)
Dairy cattle	3				0.001 - 0.012	Santos *et al*. (2004)[a]
Cattle	97	1.6	80.1	4.97		Waegeneers *et al*. (2009)
Dairy cattle					0.05	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: calves grazing on pastures fertilized with pig slurry

Table 1.3 Copper concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chickens (young)	311	0.44	4.42	2.81		Coleman *et al*. (1992)
Chickens (mature)	308	0.67	4.60	3.07		
Turkeys (young)	60	0.83	7.14	3.68		
Ducks	111	3.03	66.7	5.9		
Chicken		breast with skin: 0.048 breast without skin: 0.003 leg with skin: 0.176				Gerber *et al*. (2009)
Poultry		0.60 b			0.59 c	Leblanc *et al*. (2005)[a]
Chicken	3	breast: 0.5 leg: 0.9 - 1.1 wing: 0.4				Lombardi - Boccia *et al*. (2005)
Turkey	3	0.6 - 1.2				
Ostrich	3	0.8 - 1.0				
Hens, private owners	22				0.604	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.507	
Hens	40				0.43 - 0.52	Waegeneers *et al*. (2008)
Poultry and eggs		0.85			0.62	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Copper concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentarchus labrax*)	3	3.87 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentarchus labrax*)	3	2.96 DM	
Atlantic herring	3	0.57	Engman & Jorhem (1998)
Baltic herring	3	0.79	
Burbot	2	0.30	
Cod	4	0.21	
Eel	3	0.20	
Mackerel	4	0.73	
Perch	3	0.27	
Picked dogfish	2	0.35	
Pike	5	0.18	
Plaice	4	0.16	
Pollack	2	0.40	
Salmon	3	0.50	
Turbot	3	0.29	
Whitefish	3	0.27	
Fish	62	0.41	Leblanc *et al*. (2005) [a]
Shellfish	18	7.05	
Fish	3	0.2	Santos *et al*. (2004) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	1.318 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	2.201 DM	
Gilthead seabream *Sparus aurata*	45	1.239 DM	
Clarias gariepinus	38	0.079	Türkmen *et al*. (2007)
Carasobarbus luteus	23	0.110	

[a]: Total diet study

Table 1.5 Copper concentrations in honey (mg/kg)

Description	n	Honey	Reference
Heather	3	2.117 - 0.554	Fernandez - Torres *et al*. (2005)
Orange-blossom	3	0.548 - < 0.531	
Origin: Holzing (AU)	23	0.13	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.31	
Origin: Hollabrunn (AU)	19	0.12	
Origin: Siena County (It)	51	0.906	Pisani *et al*. (2008)

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Annex 2 Copper concentrations in edible tissues and products linked with the dietary intake of various copper compounds and doses

Table 1 Copper concentrations in edible tissues and products (mg/kg)

Species / category	Source of Cu supplemented	Dose of Cu supplemented (mg Cu/kg)	Cu content of complete feed (mg Cu/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Pigs	$CuSO_4.5H_2O$		7.5	161 d	22.5 DM	32.0 DM	1.92 DM		Bradley *et al*. (1983)
			15		19.7 DM	29.0 DM	1.77 DM		
			30		33.6 DM	28.7 DM	1.72 DM		
			60		33.5 DM	38.5 DM	1.75 DM		
			120		121.9 DM	40.1 DM	1.71 DM		
			240		439.0 DM	44.4 DM	1.73 DM		
Laying hens	$CuSO_4.5H_2O$	0	27 [1]	28 d	13.4 [a]			1.04 [b]	Chiou *et al*. (1997)
		200	195 [1]		24.8 [a]			2.25 [b]	
		400	405 [1]		38.3 [a]			4.7 [b]	
		600	598 [1]		127 [a]			4.16 [b]	
		800	758 [1]		160 [a]			3.13 [b]	
Chicks		0	11.1 DM [1]	21 d	19.4 DM	18.3 DM			Ledoux *et al*. (1991)
	Cu acetate	150			20.9 DM	21.7 DM			
	Cu acetate	300			85.2 DM	18.2 DM			
	Cu acetate	450			263.3 DM	24.2 DM			
	Cu oxide	150			18.1 DM	19.1 DM			
	Cu oxide	300			18.7 DM	20.5 DM			
	Cu oxide	450			19.6 DM	16.7 DM			
	Cu sulphate	150			22.9 DM	19.9 DM			
	Cu sulphate	300			93.2 DM	25.8 DM			
	Cu sulphate	450			263.3 DM	24.2 DM			
	Cu carbonate	150			16.9 DM	22 DM			
	Cu carbonate	300			44.4 DM	21.9 DM			
	Cu carbonate	450			106.0 DM	22.2 DM			

[1]: data from feed analysis

Statistics : Bradley *et al* . (1983): Liver Cu concentrations: treatment effect due to dietary Cu level ($P < 0.01$),
kidney Cu concentrations: treatment effect due to dietary Cu level ($P < 0.05$); Chiou *et al* . (1997): [a]: linear effect of treatment is significant ($P< 0.05$),
[b]: quadratic effect of treatment is significant ($P< 0.05$). Ledoux *et al* . (1991): liver Cu: ANOVA: dietary Cu, Cu source and dietary Cu ×Cu source: $P< 0.001$
kidney Cu: no significant differences ($P> 0.1$).

Table 1 (continued) Copper concentrations in edible tissues and products (mg/kg)

Species / category	Source of Cu supplemented	Dose of Cu supplemented (mg Cu/kg)	Cu content of complete feed [1] (mg Cu/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Laying hens			9.2 DM	56 d	12.6 DM [a]			yolk: 3.57 DM [a] white: 1.46 DM	Skrivan *et al* .(2006)
	$CuSO_4.5H_2O$	25	34 DM		13.6 DM [a]			yolk: 4.50 DM [b] white: 1.52 DM	
		65	72.5 DM		17.9 DM [b]			yolk: 4.78 DM [b] white: 1.60 DM	
		115	124.3 DM		19.7 DM [b]			yolk: 4.85 DM [bc] white: 1.58 DM	
		240	243.7 DM		32.5 DM [c]			yolk: 5.17 DM [c] white: 1.69 DM	
Laying hens			8 DM	28 d				yolk: < 2 DM white: < 2 DM	Huyghebaert *et al.* (2006)
	Copper sulphate	20	35 DM					yolk: < 2 DM white: < 2 DM	
	Bioplex Cu	20	27 DM					yolk: < 2 DM white: < 2 DM	
Steers				177 d	63.2 DM		3.5 DM		Engle *et al* . (2000)
	Cu sulphate	20 DM			290.3 DM		4.2 DM		
	Cu sulphate	40 DM			379.6 DM		3.0 DM		
	Cu citrate	20 DM			253.6 DM		5.5 DM		
	Cu proteinate	20 DM			339.1 DM		3.7 DM		
	tribasic Cu chloride	20 DM			246.6 DM		4.4 DM		

[1]: data from feed analysis

Statistics: Skrivan *et al* . (2006): [a - c] Means within each column with different superscripts differ significantly ANOVA ($P < 0.05$) ;
Engle *et al* . (2000): Liver Cu concentrations: control vs Cu ($P < 0.05$); 20 mg Cu sulphate vs 40 mg Cu sulphate ($P < 0.05$);

Table 1 (continued) Copper concentrations in edible tissues and products (mg/kg)

Species / category	Source of Cu supplemented	Dose of Cu supplemented (mg Cu/kg)	Cu content of complete feed [1] (mg Cu/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Dairy Cows			6.0 DM	60 d					Du *et al*., 1996
Holstein	Cu sulphate	5 DM			181 DM				
		80 DM			448 DM				
	Cu Proteinate	5 DM			153 DM				
		80 DM			429 DM				
Jersey	Cu sulphate	5 DM			195 DM				
		80 DM			489 DM				
	Cu Proteinate	5 DM			148 DM				
		80 DM			551 DM				

[1]: data from feed analysis

Statistics:

Du *et al*. (1996): supplement: 5 versus 80 mg/(kg DM) ($P < 0.05$); Holstein versus Jersey: ($P = 0.077$)

Table 1 (continued) Copper concentrations in milk and plasma

Species / category	Source of Cu supplemented	Dose of Cu supplemented (mg Cu/ (cow.day))	Cu intake from feed (mg Cu/ (cow.day))	Duration of study	Milk (mg/kg)	Plasma (mg/L)	Reference
Dairy cattle			300	42 d	0.12	1.09	Schwarz & Kirchgessner (1978)
	$CuSO_4.5H_2O$	248			0.14	1.10	
		483			0.12	1.18	

Table 1 (continued) Copper concentrations in edible tissues and products (mg/kg)

Species / category	Source of Cu supplemented	Dose of Cu supplemented (mg Cu/kg)	Cu content of complete feed [1] (mg Cu/kg)	Duration of study	Muscle	Liver	Reference
Rainbow trout			11.4	28 d	0.26	38.4	Kamunde *et al*. (2001)
	$CuSO_4.5H_2O$		277.8		0.32	45.18	
			1041.9		0.32 *	100.27 *	

Statistics: *: Significantly different from control, Student-Newman-Keuls pairwise multiple comparison ($P< 0,05$).

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Annex 3.1 : Copper Requirements

Pigs:

Category - Definition	**Cu Req. (NRC, 1998) (mg/kg) (a)**	**Category - Definition**	**Cu Req. (GfE , 2008) (mg/kg DM)**
Pigs: 3 - 5 kg	6.00	Piglets	6
Pigs: 5- 10 kg	6.00		
Pigs: 10 - 20 kg	5.00	Growing - fattening pigs	4 - 5
Pigs: 20 - 50 kg	4.00		
Pigs: 50 - 80 kg	3.50		
Pigs: 80 - 120 kg	3.00		
Sows: gestation	5.00	Breeding sows	8 - 10
Sows: lactation	5.00		
		Boars	8 - 10

Poultry:

Category - Definition	**Cu Req. (NRC, 1994) (mg/kg) (a)**	**Category - Definition**	**Cu Req. (GfE, 1999) (mg/kg DM)**
Broilers (0 - 8 weeks) (a)	8	Broiler (Mast Broiler; Aufzucht Küken)	7
Immature leghorn- Type chickens (0-6 wk) white	5.0	Chickens reared for laying (Junghennen)	6
Immature leghorn- Type chickens (6 wk - first egg) white	4.0		
Immature leghorn- Type chickens (0-6 wk) brown	5.0		
Immature leghorn- Type chickens (6 wk - first egg) brown	4.0		
		Layers (Eiproduction Legehennen)	7
		Female birds reared for breeding (Zuchthennen)	7
Growing turkeys (0 - 8 wk)	8		
Growing turkeys (8 - 24 wk)	6		
Turkey holding hens	6		
Turkey laying hens	8		

Bovines:

Category - Definition	Cu Req. (Meschy, 2007) (mg/kg DM)
Bovines	7

Bovines: Beef Cattle

Category - Definition	Cu Req. (NRC, 2000) (mg/kg DM)	Category - Definition	Cu Req. (GfE, 1995) (mg/kg DM)
Growing and finishing	10.00	Growing and finishing from 175 kg on	8 - 10
Cows gestation	10.00		
Cows early lactation	10.00		

Bovines: Dairy Cattle

Category - Definition	Cu Req. (NRC, 2001) (mg/kg DM)	Category - Definition	Cu Req. (CVB, 2007) (mg/kg DM)
Lactating cow: Holstein - 90 days in milk	11	Lactating cows (FI: 20 kg/day)	12.2
Lactating cow: Jersey	9 - 11	Lactating cows (FI: 40 kg/day)	11.1
Dry cows: Holstein (240 d pregnant)	12	Dry cows, 8 -3 weeks before calving	24.1
Dry cows: Holstein (279 d pregnant)	18	Dry cows, 3 - 0 weeks before calving	25.2

Sheep

Category - Definition	Cu Req. (Meschy, 2007) (mg/kg DM)
Sheep	7

	Cu Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Cu Req. (NRC, 2007 (b)) (mg/day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	3.1		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	14.2		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	6.4	Mature ewes; breeding. DM intake: 0.85 kg/day	3.0
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	17.7	Mature ewes; breeding. DM intake: 2.18 kg/day	10.2
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	9.7	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	23.9	Mature ewes; early lact.; DM intake: 2.14 kg/day	15.7
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	4.8	Mature ewes; early lact.; DM intake: 5.29 kg/day	28.2
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	14.9	Mature ewes; late lact.; DM intake: 2.35 kg/day	10.3
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	9.1	Mature ewes; late lact.; DM intake: 4.05 kg/day	20.3
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	18.4		

Goats

Category - Definition	Cu Req. (GfE, 2003) (mg/kg DM)	Category - Definition	Cu Req. (Meschy, 2007) (mg/kg DM)
Goats	10 - 15	Goats	7

	Cu Req. (NRC, 2007 (b)) (mg/day)	Category - Definition	Cu Req. (NRC, 2007 (b)) (mg/day)
Kids; bw: 10 kg; DM intake: 0.35 kg/day	9	Mature does; breeding; DM intake: 0.60 kg/day	12
Kids; bw: 10 kg; DM intake: 0.39 kg/day	10	Mature does; breeding; DM intake: 1.86 kg/day	37
Kids; bw: 40 kg; DM intake: 1.10 kg/day	28		
Kids; bw: 40 kg; DM intake: 1.41 kg/day	35	***Milk yield: 4.65 - 6.43 kg/day***	
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	14	Dairy does; early lactation; DM intake: 2.81 kg/day	42
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	39	Dairy does; early lactation; DM intake: 4.83 kg/day	72
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	23	***Milk yield: 6.98 - 9.65 kg/day***	
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	62	Dairy does; early lactation; DM intake: 3.83 kg/day	57
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	10	Dairy does; early lactation; DM intake: 5.43 kg/day	81
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	31	***Milk yield: 1.99 - 2.76 kg/day***	
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	19	Dairy does; late lactation; DM intake: 2.48 kg/day	37
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	40	Dairy does; late lactation; DM intake: 3.64 kg/day	55
		Milk yield: 2.99 - 4.13 kg/day	
		Dairy does; late lactation; DM intake: 2.51 kg/day	38
		Dairy does; late lactation; DM intake: 4.53 kg/day	68

Horses

Category - Definition	Cu Req. (NRC, 2007) (mg/day)	Category - Definition	Cu Req. (NRC, 2007) (mg/day)
MBW 200 kg; Adult; no work	40.0	MBW 400 kg; Adult; no work	80.0
MBW 200 kg; Adult; working: light exercise	40.0	MBW 400 kg; Adult; working: light exercise	80.0
MBW 200 kg; Adult; working: moderate exercise	45.0	MBW 400 kg; Adult; working: moderate exercise	90.0
MBW 200 kg; Adult; working: (very) heavy exercise	50.0	MBW 400 kg; Adult; working: (very) heavy exercise	100.0
MBW 200 kg; Stallions nonbreeding; breeding	40.0	MBW 400 kg; Stallions nonbreeding; breeding	80.0
MBW 200 kg; Pregnant mares (till 8 m)	40.0	MBW 400 kg; Pregnant mares (till 8 m)	80.0
MBW 200 kg; Pregnant mares (from 9 m)	50.0	MBW 400 kg; Pregnant mares (from 9 m)	100.0
MBW 200 kg; Lactating mares	50.0	MBW 400 kg; Lactating mares	100.0
MBW 200 kg; Growing animals: 4 m	16.8	MBW 400 kg; Growing animals: 4 m	33.7
MBW 200 kg; Growing animals: 6 m	21.6	MBW 400 kg; Growing animals: 6 m	43.2
MBW 200 kg; Growing animals: 12 m	32.1	MBW 400 kg; Growing animals: 12 m	64.2
MBW 200 kg; Growing animals: 18 m	38.7	MBW 400 kg; Growing animals: 18 m	77.5
MBW 200 kg; Growing animals: 24 m	42.9	MBW 400 kg; Growing animals: 24 m	85.8

Horses

Category - Definition	Cu Req. (NRC, 2007) (mg/day)	Category - Definition	Cu Req. (NRC, 2007) (mg/day)
MBW 500 kg; Adult; no work	100.0	MBW 600 kg; Adult; no work	120.0
MBW 500 kg; Adult; working: light exercise	100.0	MBW 600 kg; Adult; working: light exercise	120.0
MBW 500 kg; Adult; working: moderate exercise	112.5	MBW 600 kg; Adult; working: moderate exercise	135.0
MBW 500 kg; Adult; working: (very) heavy exercise	125.0	MBW 600 kg; Adult; working: (very) heavy exercise	150.0
MBW 500 kg; Stallions nonbreeding; breeding	100.0	MBW 600 kg; Stallions nonbreeding; breeding	120.0
MBW 500 kg; Pregnant mares (till 8 m)	100.0	MBW 600 kg; Pregnant mares (till 8 m)	120.0
MBW 500 kg; Pregnant mares (from 9 m)	125.0	MBW 600 kg; Pregnant mares (from 9 m)	150.0
MBW 500 kg; Lactating mares	125.0	MBW 600 kg; Lactating mares	150.0
MBW 500 kg; Growing animals: 4 m	42.0	MBW 600 kg; Growing animals: 4 m	50.4
MBW 500 kg; Growing animals: 6 m	54.0	MBW 600 kg; Growing animals: 6 m	64.8
MBW 500 kg; Growing animals: 12 m	80.3	MBW 600 kg; Growing animals: 12 m	96.3
MBW 500 kg; Growing animals: 18 m	96.8	MBW 600 kg; Growing animals: 18 m	116.1
MBW 500 kg; Growing animals: 24 m	107.3	MBW 600 kg; Growing animals: 24 m	128.7
MBW 900 kg; Adult; no work	180.0		
MBW 900 kg; Adult; working: light exercise	180.0		
MBW 900 kg; Adult; working: moderate exercise	202.5		
MBW 900 kg; Adult; working: (very) heavy exercise	225.0		
MBW 900 kg; Stallions nonbreeding; breeding	180.0		
MBW 900 kg; Pregnant mares (till 8 m)	180.0		
MBW 900 kg; Pregnant mares (from 9 m)	225.0		
MBW 900 kg; Lactating mares	225.0		
MBW 900 kg; Growing animals: 4 m	75.6		
MBW 900 kg; Growing animals: 6 m	97.2		
MBW 900 kg; Growing animals: 12 m	144.5		
MBW 900 kg; Growing animals: 18 m	174.2		
MBW 900 kg; Growing animals: 24 m	193.1		

Salmonids

Category - Definition	Cu Req. (NRC, 1993) (mg/kg)
Pacific salmon	not tested
Rainbow trout	3

Dogs

Category - Definition	Cu Req. (NRC, 2006) (mg/kg DM)	Adequate intake (NRC, 2006) (mg/kg DM)	Rec. Allowance (NRC, 2006) (mg/kg DM)
Puppies after weaning		11	11
Adult dogs for maintenance		6	6
Bitches for late gestation and peak lactation		12.4	12.4

Cats

Category - Definition	Cu Req. (NRC, 2006) (mg/kg DM)	Adequate intake (NRC, 2006) (mg/kg DM)	Rec. Allowance (NRC, 2006) (mg/kg DM)
Kittens after weaning	4.5		8.4
Adult cats		5.0	5.0
Queens in late gestation and peak lactation		8.8	8.8

Glossary

Req.: requirement

(a): 90 % dry matter

MBW: Mature body weight

FI: Feed Intake

lact.: lactation

Annex 3.2 Copper Use Levels

Table 1 Supplementation recommendations, calculated background level ranges (information acquired from the industry) and calculated use levels for copper

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg /kg)
Pigs (7 – 20 kg)	160	6 – 8	168	170
Pigs (20 – 30 kg)	160	6 – 8	168	170
Pigs (30 – 100 kg)	15	7 – 10	25	25
Sows	15	8 – 10	25	25
Broilers	15	6 – 10	25	25
Hens	15	6 – 10	25	25
Veal	5	8 – 12	17	15
Cattle	15	10 – 15	30	35
Sheep	0	8 - 14	14	15

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use levels for copper

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	6 - 20	8	28
Pigs (15 - 50 kg)	6 - 15	10	35
Pigs (50 - 150 kg)	6 - 15	10	35
Gestating sows	6 - 20	10	30
Lactating sows	6 - 20	10	30

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Annex 4. Copper concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	33
Potato prot ASH>10	23
Potato starch dried	1
Potato sta heat tr	1
Potato pulp CP<95	6
Potato pulp CP>95	6
Potatoes sweet dried	6
Bone meal	4
Brewers' grains dr	20
Brewers' yeast dried	9
Sugarb pulp SUG<100	7
Sugarb p SUG100-150	8
Sugarb p SUG150-200	4
Sugarb pulp SUG>200	5
Biscuits CFAT<120	2
Biscuits CFAT>120	3
Blood meal spray dr	11
Buckwheat	10
Beans phas heat tr	9
Bread meal	1
Casein	1
Chicory pulp dried	6
Citrus pulp dried	5
Meat meal Dutch	32
Meat meal CFAT<100	50.4
Meat meal CFAT>100	15
Peas	7
Barley	4
Barley feed h grade	9
Barley mill byprod	6
Grass meal CP<140	8.4
Grass meal CP140-160	8.3
Grass meal CP160-200	8.3
Grass meal CP>200	8.2
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	21
Peanut exp p with sh	21
Peanut exp with sh	21
Peanut extr wtht sh	34
Peanut extr with sh	33
Oats grain	4
Oats grain peeled	3
Oats husk meal	2
Oats mill fd h grade	
Hempseed	
Carob	3

INRA	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	9	5
Maize	2	1
Oats	3	1
Oats groats	3	
Rice, brown	2	
Rye	5	
Sorghum	4	2
Triticale	6	3
Wheat, durum	7	
Wheat, soft	5	10
WHEAT BY-PRODUCTS		
Wheat bran	17	25
Wheat middlings	12	2
Wheat shorts	14	
Wheat feed flour	6	
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%	7	
Wheat gluten feed, starch 28%	7	
MAIZE BY-PRODUCTS		
Corn distillers	10	
Corn gluten feed	5	4
Corn gluten meal	11	4
Maize bran	26	
Maize feed flour		
Maize germ meal, expeller	13	
Maize germ meal, solvent extracted	12	
Hominy feed	7	
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	10	
Brewers' dried grains	18	5
Rice bran, extracted	14	
Rice bran, full fat	7	4
Rice, broken	1.4	
LEGUME AND OIL SEEDS		
Chickpea	6	
Cottonseed, full fat	10	1
Faba bean, coloured flowers	12	2
Faba bean, white flowers	11	
Linseed, full fat	12	
Lupin, blue	5	
Lupin, white	4	
Pea	7	1
Rapeseed, full fat	3	
Soybean, full fat, extruded	34	
Soybean, full fat, toasted	34	
Sunflower seed, full fat	21	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	5
Greaves	7
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	16
Cottons exp p with h	16
Cottons exp with h	16
Cottons extr wtht h	15
Cotts extr p with h	15
Cottons extr with h	15
Coconut exp CFAT<100	32
Coconut exp CFAT>100	29
Coconut extr	31
Linseed	12
Linseed exp	18
Linseed extr	17
Lentils	10
Lupins CP<335	5
Lupins CP>335	6
Alf meal CP<140	7
Alf meal CP140-160	6
Alf meal CP160-180	9
Alf meal CP>180	7
Poppyseed	
Macoya fruit exp	17
Maize	1
Maize chem-h treated	2
Maize gluten meal	7
Maize glfeed CP<200	5
Maize glfd CP200-230	5
Maize glfeed CP>230	6
Maize germ meal extr	7
Maize germ m fd exp	6
Maize germ m fd extr	5
Dist grains and sol	5
Maize feedflour	2
Maize feed meal	
Maize feed meal extr	3
Maize bran	
Maize starch	
Sugarbeet molasses	9
Sugarc mol SUG<475	6
Sugarc mol SUG>475	6
Milk powder skimmed	1
Milk powder whole	5
Millet	6

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	32	
Cottonseed meal, crude fibre 7-14%	19	
Cottonseed meal, crude fibre 14-20%	10	
Grapeseed oil meal, solvent extracted	21	
Groundnut meal, detoxified, crude fibre < 9%	17	
Groundnut meal, detoxified, crude fibre > 9%	15	1
Linseed meal, expeller	18	
Linseed meal, solvent extracted	19	
Palm kernel meal, expeller	21	9
Rapeseed meal	7	6
Sesame meal, expeller	34	
Soybean meal, 46		
Soybean meal, 48	18	7
Soybean meal, 50	17	
Sunflower meal, partially decorticated	62	
Sunflower meal, undecorticated	27	2
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	4	
Cassava, starch 72%	4	
Maize starch		
Potato tuber, dried	4	
Sweet potato, dried	5	
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	5	2
Beet pulp dried, molasses added	4	
Beet pulp, pressed	1	0
Brewers' yeast, dried	47	
Buckwheat hulls		
Carob pod meal	3	
Citrus pulp, dried	3	2
Cocoa hulls		
Grape marc, dried	75	
Grape seeds	14	
Liquid potato feed	2	
Molasses, beet	13	
Molasses, sugarcane	29	
Potato protein concentrate	38	
Potato pulp, dried	7	
Soybean hulls	8	3
Vinasse, different origins		
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production	9	
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	12.8
Malt culms CP>200	12.8
Nigerseed	13
Horsebeans	13
Horsebeans white	13
Palm kernels	13
Palm kern exp CF<180	24
Palm kern exp CF>180	22.8
Palm kernel extr	
Rapeseed	3
Rapeseed exp	7
Rapeseed extr CP<380	6
Rapeseed extr CP>380	5
Rapes meal Mervobest	4.4
Rice wtht hulls	1
Rice with hulls	
Rice husk meal	
Rice bran meal extr	11
Rice feed m ASH<90	7
Rice feed m ASH>90	8
Rye	3
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	
Semameseed meal extr	43
Soybeans heat tr	12
Soybeans not heat tr	12
Soybean hulls CF<320	8
Soyb hulls CF320-360	8
Soybean hulls CF>360	8
Soybean exp	18
Soybm CF<45 CP<480	14.8
Soybm CF<45 CP>480	14.9
Soybm CF45-70 CP<450	14.9
Soybm CF45-70 CP>450	14.9
Soyb meal CF>70	14.9
Soyb meal Mervobest	11.3
Soyb meal Rumi S	14
Sorghum	3
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	4
Tapioca STA 625-675	2
Tapioca STA 675-725	3
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	9	
Alfalfa, dehydrated, protein 17-18% dry matter	5	1
Alfalfa, dehydrated, protein 18-19% dry matter	5	1
Alfalfa, dehydrated, protein 22-25% dry matter	7	1
Grass, dehydrated	7	1
Wheat straw	3	
DAIRY PRODUCTS		
Milk powder, skimmed	3	
Milk powder, whole	1.5	
Whey powder, acidic	1.6	
Whey powder, sweet	2	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	9	
Fish meal, protein 65%	7	1
Fish meal, protein 70%	7	
Fish solubles, condensed, defatted	36	
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	5	0
Feather meal	9	1
Meat and bone meal, fat <7.5%	20	
Meat and bone meal, fat >7.5%	20	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	3
Wheat gluten meal	6
Wheat glutenfeed	7
Wheat middlings	10
Wheat germ	10
Wheat germfeed	9.8
Wheat feedfl CF<35	6
Wheat feedfl CF35-55	6
Wheat feed meal	11
Wheat bran	31
Triticale	5
Feather meal hydr	13
Fat from Animals	2
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	8
Vinasse Sugb CP>250	8
Fish meal CP<580	7
Fish meal CP580-630	7
Fish meal CP630-680	8
Fish meal CP>680	6
Meat bone m CFAT<100	8.2
Meat bone m CFAT>100	8.6
Whey p l lac ASH<210	3
Whey p l lac ASH>210	3
Whey powder	1
Sunflowers deh	
Sunflowers p deh	14
Sunflowers w hulls	14
Sunfls exp deh	27.9
Sunfls exp p deh	28.4
Sunfls exp w hulls	28.1
Sunfmeal CF<160	33
Sunfmeal CF 160-200	33
Sunfmeal CF 200-240	36
Sunfmeal CF>240	28
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	47
Potato pulp pr NL	4
Potato pulp pressed	6
Potato cut raw	
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	11
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	10
Pot sta STA 650-775	
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	15
Pot s g STA 425-550	15
Pot s g STA 550-675	15
Pot sta gel STA>675	15
Brewers gr 22% DM	7
Brewers gr 27% DM	16
Brewers yeast CP<400	15
Brewers y CP400-500	15
Brewers yeast CP>500	15
Beetp pressed f+sil	5
CCM CF<40	2
CCM CF 40-60	2
CCM CF>60	3
Chicory pulp f+sil	10
Distillers sol f	
Cheese whey CP<175	13
Cheese w CP175-275	18
Cheese whey CP>275	19
Maize glutenf f+sil	5
Maize solubles	14
Wheat st FR STAt 300	6
Wheat st STAtot 400	7
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	10
Beet rests sililed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	4.7
Barley straw	
Grass fr April l y.	8.9
Grass fr April n y.	8.9
Grass fr April h y.	8.9
Grass fr May l y.	8.9
Grass fr May n y.	8.9
Grass fr May h y.	8.9
Grass fr June l y.	8.9
Grass fr June n y.	8.9
Grass fr June h y.	8.9

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	8.9
Grass fr July n y.	8.9
Grass fr July h y.	8.9
Grass fr Aug l y.	8.9
Grass fr Aug n y.	8.9
Grass fr Aug h y.	8.9
Grass fr Sept l y.	8.9
Grass fr Sept n y.	8.9
Grass fr Sept h y.	8.9
Grass fr Oct l y.	8.9
Grass fr Oct n y.	8.9
Grass fr Oct h y.	8.9
Grass average	8.9
Grass horse gr past	8.9
Grass horse same fld	8.9
Grass sil May 2000	7.8
Grass sil May 3500	7.8
Grass sil May 5000	7.8
Grass sil June 2000	7.8
Grass sil June 3000	7.8
Grass sil June 4000	7.8
Grass sil Ju-Au 2000	7.8
Grass sil Ju-Au 3000	7.8
Grass sil Ju-Au 4000	7.8
Grass sil Se-Oc 2000	7.8
Grass sil Se-Oc 3000	7.8
Grass sil average	7.8
Grass sil horse fine	7.8
Grass sil horse midd	7.8
Grass sil horse crs	7.8
Grass hay good qual	7.8
Grass hay av qual	7.8
Grass hay poor qual	7.8
Grass hay horse fine	7.8
Grass hay horse midd	7.8
Grass hay horse crs	7.8
Grass bales ad	7.6
Grass seeds straw	4
Oat straw	
Clover red fresh	
Clover red silage	10.6
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	2
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	
Lucerne hay	
Lucerne (alfalfa) ad	8.6
Maize Cob with leaves silage	
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	6.1
Maize fod fr DM<240	3.9
Maize f fr DM240-280	3.9
Maize f fr DM280-320	3.9
Maize fod fr DM 320	3.9
Maize sil DM < 240	3.9
Maize sil DM240-280	3.9
Maize sil DM280-320	3.9
Maize sil DM 320	3.9
Maize (Fodder) ad	3.9
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	
Chicory rts not frcd	
Chicory rts frcd cleaned	
Chicory rts frcd dirty	
Carrots	
Sunflower silage	

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	16.3
Calcium carbonate	24
Diammonium phosphate	80
Difluorinated phosphate	22
Dicalcium phosphate	80
Mono-dicalcium phosphate	70
Monoammonium phosphate	80
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of copper in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	90.0	89.2	7	6	5.44	11.19
Piglet Starter II (complete feed)	20	97.2	88.2	13	11	6.13	7.29
Pig Grower (complete feed)	19	97.5	88.4	12	10	5.77	7.26
Pig Finisher (complete feed)	18	97.0	93.7	12	10	6.50	8.25
Sows, gestating (complete feed)	18	98.1	96.2	14	13	10.43	10.18
Sows, lactating (complete feed)	20	97.7	89.5	14	12	7.52	8.76
Starter Chicks (complete feed)	15	98.7	91.7	10	8	8.37	9.04
Chicken reared for laying (complete feed)	17	98.6	91.6	11	9	9.21	8.44
Layer Phase I (complete feed)	16	98.1	95.3	10	9	9.07	11.54
Layer Phase II (complete feed)	16	98.2	94.8	10	9	9.81	11.60
Broiler Starter (complete feed)	14	98.1	96.6	8	7	6.94	11.56
Broiler Grower (complete feed)	15	98.3	91.3	9	7	6.88	10.30
Broiler Finisher (complete feed)	15	98.3	89.8	8	6	6.78	10.31
Turkey Starter (complete feed)	14	96.7	96.7	6	6	9.49	11.04
Turkey Grower (complete feed)	13	93.5	93.5	6	6	9.48	11.65
Turkey Finisher (complete feed)	11	94.3	94.3	5	5	8.75	10.50
Turkey Breeder (complete feed)	8	91.4	91.4	5	5	5.28	6.13
Duck, grower/finisher (complete feed)	10	95.0	95.0	5	5	6.21	8.08
Geese, grower/finisher (complete feed)	8	98.7	98.7	6	6	6.95	8.88
Calf, milk replacer (complete feed)	10	77.9	35.7	6	2	4.76	0.84
Calf concentrate (complete feed)	17	99.6	98.1	14	13	8.37	9.01
Calf concentrate (complementary feed)	16	99.2	96.2	13	12	8.94	11.02
Cattle concentrate (complete feed)[4]	9	95.9	95.9	7	7	6.65	8.07
Cattle concentrate (complementary feed)	8	94.1	94.1	6	6	6.15	8.53
Dairy cows TMR (based on corn silage)[4]	15	98.7	98.9	12	11	6.31	5.49
Dairy cows TMR (based on grass silage)[4]	15	97.7	98.0	12	11	7.09	6.47
Dairy concentrate (complementary feed)	13	88.9	90.6	10	9	8.86	9.87
Dairy cows mineral feed (min. 40% crude ash)	8	45.7	45.7	3	3	19.48	19.48
Rabbit, breeder (complete feed)	8	99.1	99.1	5	5	10.03	12.83
Rabbit, grower/finisher (complete feed)	14	98.9	96.9	8	7	14.10	12.13
Salmon feed (wet)[4]	4	70.4	70.4	2	2	4.89	4.63
Salmon feed (dry)	6	79.4	79.4	3	3	7.36	7.41
Trout feed (dry)	12	94.2	78.2	5	4	9.99	11.39
Dog food (dry)	12	91.5	81.9	7	6	21.72	9.75
Cat food (dry)	16	98.1	90.2	11	9	7.41	11.27

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Copper: Addendum to the monograph

Abstract

This addendum to the copper monograph substantiates the data reported in Annex 5 of the copper monograph in which copper background levels are reported. The addendum provides the following information for each calculated background level: (1) the copper concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no copper concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated copper content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	4.0	34.93	1.40	25.67
Maize	1.0	10.00	0.10	1.84
Soybeans heat tr	12.0	15.10	1.81	33.29
Soybm CF<45 CP>480	14.9	7.50	1.12	20.53
Wheat	3.0	16.68	0.50	9.19
Wheat middlings	10.0	5.00	0.50	9.19
Fat from Animals	2.0	0.80	0.02	0.29
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	5.44	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	4.0	15.00	0.60	9.79
Maize	1.0	15.81	0.16	2.58
Dist grains and sol	5.0	3.00	0.15	2.45
Palm kern exp CF<180	24.0	4.00	0.96	15.67
Rapeseed exp	7.0	6.00	0.42	6.85
Soybm CF<45 CP>480	14.9	7.86	1.17	19.12
Wheat	3.0	27.50	0.83	13.46
Wheat gluten meal	6.0	10.00	0.60	9.79
Wheat middlings	10.0	2.00	0.20	3.26
Fat from Animals	2.0	3.00	0.06	0.98
Sunfmeal CF<160	33.0	2.55	0.84	13.72
Phytase		1.50		
Calcium carbonate	24.0	0.45	0.11	1.77
L-Lysine HCl		0.49		
Monocalciumphosphate	70.0	0.05	0.03	0.56
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	6.13	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	2.00	0.08	1.39
Barley	4.0	20.00	0.80	13.87
Maize	1.0	9.42	0.09	1.63
Dist grains and sol	5.0	5.00	0.25	4.33
Palm kern exp CF<180	24.0	4.00	0.96	16.64
Rapeseed exp	7.0	7.00	0.49	8.49
Soybm CF<45 CP>480	14.9	3.40	0.51	8.78
Wheat	3.0	35.00	1.05	18.20
Wheat middlings	10.0	7.27	0.73	12.60
Fat from Animals	2.0	2.09	0.04	0.72
Sunfmeal CF<160	33.0	2.32	0.76	13.24
Calcium carbonate	24.0	0.02	0.01	0.10
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	5.77	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	2.50	0.10	1.54
Barley	4.0	20.00	0.80	12.31
Maize	1.0	6.93	0.07	1.07
Dist grains and sol	5.0	6.21	0.31	4.78
Palm kern exp CF<180	24.0	5.00	1.20	18.47
Rapeseed exp	7.0	1.35	0.09	1.45
Wheat	3.0	35.00	1.05	16.16
Wheat gluten meal	6.0	3.04	0.18	2.80
Wheat middlings	10.0	10.00	1.00	15.39
Fat from Animals	2.0	2.00	0.04	0.62
Sunfmeal CF<160	33.0	4.98	1.64	25.29
Calcium carbonate	24.0	0.04	0.01	0.13
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	6.50	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	5.50	0.22	2.11
Barley	4.0	20.00	0.80	7.67
Maize	1.0	15.26	0.15	1.46
Maize germ meal extr	7.0	7.50	0.53	5.03
Sugarc mol SUG<475	6.0	0.10	0.01	0.05
Palm kern exp CF<180	24.0	5.00	1.20	11.50
Wheat	3.0	11.22	0.34	3.23
Wheat glutenfeed	7.0	5.00	0.35	3.35
Wheat middlings	10.0	7.50	0.75	7.19
Wheat bran	31.0	12.50	3.88	37.14
Fat from Animals	2.0	1.91	0.04	0.37
Sunfmeal CF<160	33.0	6.11	2.02	19.34
Phytase		1.50		
Calcium carbonate	24.0	0.48	0.12	1.11
L-Lysine HCl		0.24		
Monocalciumphosphate	70.0	0.07	0.05	0.44
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	10.43	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	2.41	0.10	1.28
Barley	4.0	20.00	0.80	10.64
Maize	1.0	10.00	0.10	1.33
Palm kern exp CF<180	24.0	4.00	0.96	12.77
Rapeseed exp	7.0	6.00	0.42	5.59
Soybean exp	18.0	1.39	0.25	3.33
Soybm CF<45 CP>480	14.9	5.13	0.76	10.16
Wheat	3.0	23.43	0.70	9.35
Wheat glutenfeed	7.0	10.00	0.70	9.31
Wheat middlings	10.0	7.50	0.75	9.97
Fat from Animals	2.0	2.16	0.04	0.57
Sunfmeal CF<160	33.0	4.22	1.39	18.50
Phytase		1.50		
Calcium carbonate	24.0	1.02	0.25	3.26
L-Lysine HCl		0.34		
Monocalciumphosphate	70.0	0.42	0.30	3.95
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	7.52	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	20.00	0.20	2.39
Rapeseed exp	7.0	5.00	0.35	4.18
Soybeans not heat tr	12.0	0.69	0.08	0.99
Soybm CF<45 CP>480	14.9	19.79	2.95	35.25
Wheat	3.0	35.62	1.07	12.77
Wheat gluten meal	6.0	5.75	0.34	4.12
Fat from Animals	2.0	2.00	0.04	0.48
Sunfmeal CF<160	33.0	7.94	2.62	31.32
Calcium carbonate	24.0	1.34	0.32	3.84
L-Lysine HCl		0.07		
Monocalciumphosphate	70.0	0.56	0.39	4.65
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	8.37	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Chicken reared for laying (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	15.00	0.15	1.63
Dist grains and sol	5.0	2.50	0.13	1.36
Rapeseed exp	7.0	5.00	0.35	3.80
Soybm CF<45 CP>480	14.9	2.95	0.44	4.78
Wheat	3.0	41.54	1.25	13.53
Wheat gluten meal	6.0	10.00	0.60	6.51
Wheat bran	31.0	7.50	2.33	25.24
Fat from Animals	2.0	2.00	0.04	0.43
Sunfmeal CF<160	33.0	10.00	3.30	35.83
Calcium carbonate	24.0	1.79	0.43	4.65
L-Lysine HCl		0.23		
Monocalciumphosphate	70.0	0.29	0.21	2.23
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	9.21	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	20.00	0.20	2.21
Dist grains and sol	5.0	4.00	0.20	2.21
Soybeans not heat tr	12.0	8.36	1.00	11.07
Soybm CF<45 CP>480	14.9	5.93	0.88	9.75
Wheat	3.0	38.18	1.15	12.63
Wheat gluten meal	6.0	0.47	0.03	0.31
Fat from Animals	2.0	2.87	0.06	0.63
Sunfmeal CF<160	33.0	10.00	3.30	36.39
Calcium carbonate	24.0	7.78	1.87	20.60
L-Lysine HCl		0.23		
Monocalciumphosphate	70.0	0.55	0.38	4.21
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	9.07	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	20.00	0.20	2.04
Dist grains and sol	5.0	4.00	0.20	2.04
Soybean exp	18.0	7.80	1.40	14.32
Soybm CF<45 CP>480	14.9	6.34	0.94	9.64
Wheat	3.0	30.36	0.91	9.29
Wheat gluten meal	6.0	7.41	0.44	4.53
Fat from Animals	2.0	3.40	0.07	0.69
Sunfmeal CF<160	33.0	10.00	3.30	33.65
Calcium carbonate	24.0	8.48	2.04	20.76
L-Lysine HCl		0.20		
Monocalciumphosphate	70.0	0.43	0.30	3.03
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	9.81	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	30.00	0.30	4.32
Maize gluten meal	7.0	2.50	0.18	2.52
Soybeans not heat tr	12.0	15.00	1.80	25.93
Soybm CF<45 CP>480	14.9	18.41	2.74	39.52
Wheat	3.0	28.16	0.84	12.17
Fat from Animals	2.0	1.50	0.03	0.43
Calcium carbonate	24.0	1.62	0.39	5.60
L-Lysine HCl		0.44		
Monocalciumphosphate	70.0	0.94	0.66	9.50
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	6.94	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	15.00	0.15	2.18
Maize gluten meal	7.0	1.56	0.11	1.58
Rapeseed exp	7.0	2.50	0.18	2.54
Soybeans not heat tr	12.0	10.00	1.20	17.43
Soybm CF<45 CP>480	14.9	20.22	3.01	43.76
Wheat	3.0	42.41	1.27	18.48
Fat from Animals	2.0	4.44	0.09	1.29
Calcium carbonate	24.0	1.38	0.33	4.82
L-Lysine HCl		0.33		
Monocalciumphosphate	70.0	0.78	0.54	7.91
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	6.88	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize gluten meal	7.0	0.68	0.05	0.71
Rapeseed exp	7.0	2.50	0.18	2.58
Soybeans not heat tr	12.0	10.16	1.22	17.99
Soybm CF<45 CP>480	14.9	19.32	2.88	42.46
Wheat	3.0	57.84	1.74	25.59
Fat from Animals	2.0	6.00	0.12	1.77
Calcium carbonate	24.0	1.38	0.33	4.90
L-Lysine HCl		0.28		
Monocalciumphosphate	70.0	0.39	0.27	4.01
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	6.78	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	20.00	0.20	2.11
Soybm CF<45 CP>480	14.9	42.45	6.33	66.63
Wheat	3.0	25.35	0.76	8.01
Fats/oils vegetable		1.83		
Fish meal CP630-680	8.0	5.00	0.40	4.21
Calcium carbonate	24.0	1.99	0.48	5.04
L-Lysine HCl		0.34		
Monocalciumphosphate	70.0	1.90	1.33	14.01
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.82	9.49	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	6.94	0.07	0.73
Soybeans not heat tr	12.0	2.00	0.24	2.53
Soybm CF<45 CP>480	14.9	41.24	6.14	64.84
Wheat	3.0	40.00	1.20	12.66
Fats/oils vegetable		5.00		
Calcium carbonate	24.0	1.15	0.28	2.91
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	70.0	2.21	1.55	16.32
Salt		0.30		
Total		100.00	9.48	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	11.74	0.12	1.34
Soybm CF<45 CP>480	14.9	39.50	5.89	67.23
Wheat	3.0	40.00	1.20	13.71
Fats/oils vegetable		4.60		
Calcium carbonate	24.0	1.30	0.31	3.56
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	70.0	1.77	1.24	14.15
Salt		0.30		
Total		100.00	8.75	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	1.0	69.44	0.69	13.16
Soybm CF<45 CP>480	14.9	11.40	1.70	32.19
Feather meal hydr	13.0	2.00	0.26	4.93
Calcium carbonate	24.0	7.60	1.82	34.57
Dicalcium Phosphate	80.0	1.00	0.80	15.16
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	5.28	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Soybm CF<45 CP>480	14.9	15.00	2.24	35.99
Wheat	3.0	68.91	2.07	33.29
Wheat middlings	10.0	9.00	0.90	14.49
Fats/oils veg h %d		3.87		
Calcium carbonate	24.0	1.20	0.29	4.64
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	80.0	0.90	0.72	11.59
Premix		0.50		
Salt		0.37		
Total		100.02	6.21	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	4.0	10.00	0.40	5.76
Maize	1.0	34.00	0.34	4.90
Soybm CF<45 CP>480	14.9	33.00	4.92	70.80
Wheat	3.0	20.00	0.60	8.64
Calcium carbonate	24.0	1.20	0.29	4.15
Dicalcium Phosphate	80.0	0.50	0.40	5.76
Premix		1.00		
Salt		0.30		
Total		100.00	6.95	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	14.9	10.00	1.49	31.29
Wheat gluten meal	6.0	5.00	0.30	6.30
Fat from Animals	2.0	6.25	0.13	2.63
Whey p l lac ASH<210	3.0	15.00	0.45	9.45
Whey powder	1.0	30.65	0.31	6.44
Cheese whey CP>275	19.0	11.00	2.09	43.89
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	4.76	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	5.50	0.22	2.63
Citrus pulp, dried	5.0	8.00	0.40	4.78
Barley	4.0	0.54	0.02	0.26
Linseed	12.0	1.25	0.15	1.79
Sugarbeet molasses	9.0	1.00	0.09	1.08
Palm kern exp CF<180	24.0	5.50	1.32	15.77
Rapeseed	3.0	3.50	0.11	1.25
Rapeseed extr CP>380	5.0	1.94	0.10	1.16
Soybeans heat tr	12.0	5.37	0.64	7.70
Wheat middlings	10.0	7.00	0.70	8.36
Wheat feedfl CF<35	6.0	8.00	0.48	5.73
Vinasse Sugb CP>250	8.0	1.50	0.12	1.43
Grass hay good qual	7.8	50.00	3.90	46.59
Calcium carbonate	24.0	0.51	0.12	1.47
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	8.37	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	11.00	0.44	4.92
Citrus pulp, dried	5.0	16.00	0.80	8.95
Barley	4.0	1.08	0.04	0.48
Linseed	12.0	2.50	0.30	3.35
Sugarbeet molasses	9.0	2.00	0.18	2.01
Palm kern exp CF<180	24.0	11.00	2.64	29.52
Rapeseed	3.0	7.00	0.21	2.35
Rapeseed extr CP>380	5.0	3.88	0.19	2.17
Soybeans heat tr	12.0	10.74	1.29	14.42
Wheat middlings	10.0	14.00	1.40	15.66
Wheat feedfl CF<35	6.0	16.00	0.96	10.74
Vinasse Sugb CP>250	8.0	3.00	0.24	2.68
Calcium carbonate	24.0	1.02	0.25	2.75
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	8.94	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	10.01	0.40	6.02
Barley	4.0	18.90	0.76	11.37
Linseed	12.0	7.51	0.90	13.56
Sugarbeet molasses	9.0	0.98	0.09	1.33
Soybm CF<45 CP>480	14.9	10.99	1.64	24.63
Wheat	3.0	17.50	0.53	7.90
Fats/oils veg h %d		1.60		
Grass sil average	7.8	30.00	2.34	35.20
Premix		2.50		
Total		99.99	6.65	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	14.30	0.57	9.30
Barley	4.0	27.00	1.08	17.56
Linseed	12.0	10.70	1.28	20.87
Sugarbeet molasses	9.0	1.40	0.13	2.05
Soybm CF<45 CP>480	14.9	15.70	2.34	38.03
Wheat	3.0	25.00	0.75	12.19
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	6.15	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	2.61	0.10	1.65
Maize glfd CP200-230	5.0	0.95	0.05	0.75
Maize feed meal		1.15		
Sugarbeet molasses	9.0	0.24	0.02	0.34
Palm kern exp CF<180	24.0	1.78	0.43	6.77
Rapeseed exp	7.0	0.59	0.04	0.65
Rapeseed extr CP>380	5.0	6.18	0.31	4.89
Soybm CF<45 CP>480	14.9	7.83	1.17	18.48
Wheat middlings	10.0	0.96	0.10	1.52
Vinasse Sugb CP>250	8.0	0.36	0.03	0.46
Grass sil average	7.8	26.89	2.10	33.22
Maize sil DM280-320	3.9	50.23	1.96	31.03
Calcium carbonate	24.0	0.06	0.01	0.23
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.95	6.31	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	4.72	0.19	2.66
Maize glfd CP200-230	5.0	1.72	0.09	1.21
Maize feed meal		2.08		
Sugarbeet molasses	9.0	0.43	0.04	0.55
Palm kern exp CF<180	24.0	3.22	0.77	10.90
Rapeseed exp	7.0	1.07	0.07	1.06
Rapeseed extr CP>380	5.0	4.39	0.22	3.10
Soybm CF<45 CP>480	14.9	3.97	0.59	8.34
Wheat middlings	10.0	1.74	0.17	2.45
Vinasse Sugb CP>250	8.0	0.64	0.05	0.72
Grass sil average	7.8	49.18	3.84	54.09
Maize sil DM280-320	3.9	26.46	1.03	14.55
Calcium carbonate	24.0	0.11	0.03	0.37
Premix		0.21		
Magnesiumoxide		0.06		
Total		99.94	7.09	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	22.00	0.88	9.93
Maize glfd CP200-230	5.0	8.00	0.40	4.51
Maize feed meal		9.70		
Sugarbeet molasses	9.0	2.00	0.18	2.03
Palm kern exp CF<180	24.0	15.00	3.60	40.61
Rapeseed exp	7.0	5.00	0.35	3.95
Rapeseed extr CP>380	5.0	15.00	0.75	8.46
Soybm CF<45 CP>480	14.9	10.30	1.53	17.31
Wheat middlings	10.0	8.10	0.81	9.14
Vinasse Sugb CP>250	8.0	3.00	0.24	2.71
Calcium carbonate	24.0	0.50	0.12	1.35
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	8.86	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize starch		0.17		
Calcium carbonate	24.0	30.50	7.32	37.58
Dicalcium Phosphate	80.0	8.80	7.04	36.14
Salt		22.60		
Diammonium phosphate	80.0	6.40	5.12	26.28
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	19.48	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	4.0	2.00	0.08	0.80
Alf meal CP160-180	9.0	40.00	3.60	35.88
Soybm CF<45 CP>480	14.9	9.00	1.34	13.37
Wheat germfeed	9.8	46.00	4.51	44.93
Calcium carbonate	24.0	2.10	0.50	5.02
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	10.03	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG150-200	4.0	10.00	0.40	2.84
Barley	4.0	23.00	0.92	6.53
Alf meal CP160-180	9.0	35.00	3.15	22.35
Soybm CF<45 CP>480	14.9	5.00	0.75	5.29
Wheat bran	31.0	12.00	3.72	26.39
Fat from Animals	2.0	2.00	0.04	0.28
Sunfmeal CF 200-240	36.0	10.00	3.60	25.54
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	80.0	1.90	1.52	10.78
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	14.10	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat	3.0	14.90	0.45	9.14
Fish meal CP630-680	8.0	55.53	4.44	90.86
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		99.99	4.89	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Soybm CF<45 CP>480	14.9	20.00	2.98	40.49
Wheat	3.0	7.42	0.22	3.02
Fish meal CP630-680	8.0	51.96	4.16	56.48
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	7.36	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	14.9	55.00	8.20	82.04
Wheat	3.0	2.87	0.09	0.86
Wheat gluten meal	6.0	11.80	0.71	7.09
Fat from Animals	2.0	16.00	0.32	3.20
Fish meal CP630-680	8.0	8.50	0.68	6.81
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	9.99	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Sugarb p SUG100-150	8.0	4.30	0.34	1.58
Meat meal CFAT<100	50.4	40.62	20.47	94.27
Maize	1.0	27.80	0.28	1.28
Maize starch		2.78		
Rice wtht hulls	1.0	7.30	0.07	0.34
Fat from Animals	2.0	9.60	0.19	0.88
Brewers y CP400-500	15.0	1.10	0.17	0.76
Calcium carbonate	24.0	0.80	0.19	0.88
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	21.72	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Brewers' yeast dried	9.0	1.80	0.16	2.19
Meat meal Dutch	32.0	1.33	0.43	5.75
Greaves	7.0	29.76	2.08	28.13
Linseed	12.0	3.00	0.36	4.86
Wheat	3.0	12.21	0.37	4.95
Wheat glutenfeed	7.0	2.06	0.14	1.95
Wheat feedfl CF<35	6.0	20.00	1.20	16.20
Feather meal hydr	13.0	18.00	2.34	31.59
Fat from Animals	2.0	7.97	0.16	2.15
Fish meal CP630-680	8.0	1.00	0.08	1.08
Meat bone m CFAT>100	8.6	1.00	0.09	1.16
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	7.41	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	34.93	3.14	28.10
Maize	2.0	10.00	0.20	1.79
Wheat, soft	5.0	16.68	0.83	7.46
Wheat middlings	12.0	5.00	0.60	5.36
Soybean, full fat, extruded	34.0	15.10	5.13	45.89
Soybean meal, 50	17.0	7.50	1.28	11.40
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	11.19	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	15.00	1.35	18.52
Maize	2.0	15.81	0.32	4.34
Wheat, soft	5.0	27.50	1.38	18.87
Wheat middlings	12.0	2.00	0.24	3.29
Wheat gluten feed, starch 28%	7.0	10.00	0.70	9.60
Corn distillers	10.0	3.00	0.30	4.12
Palm kernel meal, expeller	21.0	4.00	0.84	11.52
Rapeseed cake		6.00		
Soybean meal, 50	17.0	7.86	1.34	18.34
Sunflower meal, undecorticated	27.0	2.55	0.69	9.44
Tallow		3.00		
Phytase		1.50		
Calcium carbonate	24.0	0.45	0.11	1.49
L-Lysine HCl		0.49		
Monocalciumphosphate	70.0	0.05	0.03	0.47
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	7.29	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	20.00	1.80	24.80
Maize	2.0	9.42	0.19	2.59
Wheat, soft	5.0	35.00	1.75	24.11
Wheat middlings	12.0	7.27	0.87	12.02
Corn distillers	10.0	5.00	0.50	6.89
Palm kernel meal, expeller	21.0	4.00	0.84	11.57
Rapeseed cake		7.00		
Soybean meal, 50	17.0	3.40	0.58	7.96
Sunflower meal, undecorticated	27.0	2.32	0.63	8.61
Beet pulp, dried	5.0	2.00	0.10	1.38
Tallow		2.09		
Calcium carbonate	24.0	0.02	0.01	0.08
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	7.26	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	20.00	1.80	21.82
Maize	2.0	6.93	0.14	1.68
Wheat, soft	5.0	35.00	1.75	21.21
Wheat middlings	12.0	10.00	1.20	14.54
Wheat gluten feed, starch 28%	7.0	3.04	0.21	2.58
Corn distillers	10.0	6.21	0.62	7.53
Palm kernel meal, expeller	21.0	5.00	1.05	12.73
Rapeseed cake		1.35		
Sunflower meal, undecorticated	27.0	4.98	1.34	16.30
Beet pulp, dried	5.0	2.50	0.13	1.52
Tallow		2.00		
Calcium carbonate	24.0	0.04	0.01	0.10
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	8.25	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	20.00	1.80	17.68
Maize	2.0	15.26	0.31	3.00
Wheat, soft	5.0	11.22	0.56	5.51
Wheat bran	17.0	12.50	2.13	20.87
Wheat middlings	12.0	7.50	0.90	8.84
Wheat gluten feed, starch 28%	7.0	5.00	0.35	3.44
Maize germ meal, expeller	13.0	7.50	0.98	9.58
Palm kernel meal, expeller	21.0	5.00	1.05	10.31
Sunflower meal, undecorticated	27.0	6.11	1.65	16.21
Beet pulp, dried	5.0	5.50	0.28	2.70
Molasses, sugarcane	29.0	0.10	0.03	0.27
Tallow		1.91		
Phytase		1.50		
Calcium carbonate	24.0	0.48	0.12	1.13
L-Lysine HCl		0.24		
Monocalciumphosphate	70.0	0.07	0.05	0.45
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	10.18	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	20.00	1.80	20.56
Maize	2.0	10.00	0.20	2.28
Wheat, soft	5.0	23.43	1.17	13.38
Wheat middlings	12.0	7.50	0.90	10.28
Wheat gluten feed, starch 28%	7.0	10.00	0.70	7.99
Soybean, full fat, extruded	34.0	1.39	0.47	5.40
Palm kernel meal, expeller	21.0	4.00	0.84	9.59
Rapeseed cake		6.00		
Soybean meal, 50	17.0	5.13	0.87	9.95
Sunflower meal, undecorticated	27.0	4.22	1.14	13.00
Beet pulp, dried	5.0	2.41	0.12	1.38
Tallow		2.16		
Phytase		1.50		
Calcium carbonate	24.0	1.02	0.25	2.80
L-Lysine HCl		0.34		
Monocalciumphosphate	70.0	0.42	0.30	3.39
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	8.76	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	20.00	0.40	4.43
Wheat, soft	5.0	35.62	1.78	19.71
Wheat gluten feed, starch 28%	7.0	5.75	0.40	4.45
Soybean, full fat, extruded	34.0	0.69	0.23	2.60
Rapeseed cake		5.00		
Soybean meal, 50	17.0	19.79	3.36	37.23
Sunflower meal, undecorticated	27.0	7.94	2.14	23.73
Tallow		2.00		
Calcium carbonate	24.0	1.34	0.32	3.56
L-Lysine HCl		0.07		
Monocalciumphosphate	70.0	0.56	0.39	4.31
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	9.04	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	15.00	0.30	3.56
Wheat, soft	5.0	41.54	2.08	24.61
Wheat bran	17.0	7.50	1.28	15.11
Wheat gluten feed, starch 28%	7.0	10.00	0.70	8.30
Corn distillers	10.0	2.50	0.25	2.96
Rapeseed cake		5.00		
Soybean meal, 50	17.0	2.95	0.50	5.95
Sunflower meal, undecorticated	27.0	10.00	2.70	32.00
Tallow		2.00		
Calcium carbonate	24.0	1.79	0.43	5.08
L-Lysine HCl		0.23		
Monocalciumphosphate	70.0	0.29	0.21	2.44
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	8.44	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	20.00	0.40	3.47
Wheat, soft	5.0	38.18	1.91	16.54
Wheat gluten feed, starch 28%	7.0	0.47	0.03	0.29
Corn distillers	10.0	4.00	0.40	3.47
Soybean, full fat, extruded	34.0	8.36	2.84	24.63
Soybean meal, 50	17.0	5.93	1.01	8.74
Sunflower meal, undecorticated	27.0	10.00	2.70	23.39
Tallow		2.87		
Calcium carbonate	24.0	7.78	1.87	16.18
L-Lysine HCl		0.23		
Monocalciumphosphate	70.0	0.55	0.38	3.30
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	11.54	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	20.00	0.40	3.45
Wheat, soft	5.0	30.36	1.52	13.09
Wheat gluten feed, starch 28%	7.0	7.41	0.52	4.47
Corn distillers	10.0	4.00	0.40	3.45
Soybean, full fat, extruded	34.0	7.80	2.65	22.87
Soybean meal, 50	17.0	6.34	1.08	9.29
Sunflower meal, undecorticated	27.0	10.00	2.70	23.28
Tallow		3.40		
Calcium carbonate	24.0	8.48	2.04	17.54
L-Lysine HCl		0.20		
Monocalciumphosphate	70.0	0.43	0.30	2.56
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	11.60	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	30.00	0.60	5.19
Wheat, soft	5.0	28.16	1.41	12.18
Corn gluten meal	11.0	2.50	0.28	2.38
Soybean, full fat, extruded	34.0	15.00	5.10	44.11
Soybean meal, 50	17.0	18.41	3.13	27.08
Tallow		1.50		
Calcium carbonate	24.0	1.62	0.39	3.36
L-Lysine HCl		0.44		
Monocalciumphosphate	70.0	0.94	0.66	5.70
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	11.56	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	15.00	0.30	2.91
Wheat, soft	5.0	42.41	2.12	20.58
Corn gluten meal	11.0	1.56	0.17	1.66
Soybean, full fat, extruded	34.0	10.00	3.40	32.99
Rapeseed cake		2.50		
Soybean meal, 50	17.0	20.22	3.44	33.35
Tallow		4.44		
Calcium carbonate	24.0	1.38	0.33	3.22
L-Lysine HCl		0.33		
Monocalciumphosphate	70.0	0.78	0.54	5.28
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	10.30	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat, soft	5.0	57.84	2.89	28.05
Corn gluten meal	11.0	0.68	0.08	0.73
Soybean, full fat, extruded	34.0	10.16	3.45	33.51
Rapeseed cake		2.50		
Soybean meal, 50	17.0	19.32	3.28	31.85
Tallow		6.00		
Calcium carbonate	24.0	1.38	0.33	3.22
L-Lysine HCl		0.28		
Monocalciumphosphate	70.0	0.39	0.27	2.63
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	10.31	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	20.00	0.40	3.62
Wheat, soft	5.0	25.35	1.27	11.48
Soybean meal, 50	17.0	42.45	7.22	65.36
Fish meal, protein 70%	7.0	5.00	0.35	3.17
Calcium carbonate	24.0	1.99	0.48	4.33
L-Lysine HCl		0.34		
Monocalciumphosphate	70.0	1.90	1.33	12.04
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.82	11.04	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	6.94	0.14	1.19
Wheat, soft	5.0	40.00	2.00	17.16
Soybean, full fat, extruded	34.0	2.00	0.68	5.84
Soybean meal, 50	17.0	41.24	7.01	60.17
Calcium carbonate	24.0	1.15	0.28	2.37
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	70.0	2.21	1.55	13.28
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	11.65	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	11.74	0.23	2.24
Wheat, soft	5.0	40.00	2.00	19.05
Soybean meal, 50	17.0	39.50	6.72	63.95
Calcium carbonate	24.0	1.30	0.31	2.97
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	70.0	1.77	1.24	11.80
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	10.50	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	69.44	1.39	22.65
Soybean meal, 50	17.0	11.40	1.94	31.61
Feather meal	9.0	2.00	0.18	2.94
Calcium carbonate	24.0	7.60	1.82	29.75
Dicalcium Phosphate	80.0	1.00	0.80	13.05
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	6.13	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat, soft	5.0	68.91	3.45	42.62
Wheat middlings	12.0	9.00	1.08	13.36
Soybean meal, 50	17.0	15.00	2.55	31.55
Calcium carbonate	24.0	1.20	0.29	3.56
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	80.0	0.90	0.72	8.91
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	8.08	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	10.00	0.90	10.14
Maize	2.0	34.00	0.68	7.66
Wheat, soft	5.0	20.00	1.00	11.26
Soybean meal, 50	17.0	33.00	5.61	63.19
Calcium carbonate	24.0	1.20	0.29	3.24
Dicalcium Phosphate	80.0	0.50	0.40	4.51
Premix		1.00		
Salt		0.30		
Total		100.00	8.88	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat gluten feed, starch 25%	7.0	5.00	0.35	41.65
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	1.6	30.65	0.49	58.35
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	0.84	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	0.54	0.05	0.54
Wheat middlings	12.0	7.00	0.84	9.32
Wheat feed flour	6.0	8.00	0.48	5.33
Linseed, full fat	12.0	1.25	0.15	1.67
Rapeseed, full fat	3.0	3.50	0.11	1.17
Soybean, full fat, toasted	34.0	5.37	1.83	20.27
Palm kernel meal, expeller	21.0	5.50	1.16	12.82
Rapeseed meal	7.0	1.94	0.14	1.51
Beet pulp, dried	5.0	5.50	0.28	3.05
Citrus pulp, dried	3.0	8.00	0.24	2.66
Molasses, beet	13.0	1.00	0.13	1.44
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	7.0	50.00	3.50	38.85
Calcium carbonate	24.0	0.51	0.12	1.36
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	9.01	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	1.08	0.10	0.88
Wheat middlings	12.0	14.00	1.68	15.25
Wheat feed flour	6.0	16.00	0.96	8.71
Linseed, full fat	12.0	2.50	0.30	2.72
Rapeseed, full fat	3.0	7.00	0.21	1.91
Soybean, full fat, toasted	34.0	10.74	3.65	33.15
Palm kernel meal, expeller	21.0	11.00	2.31	20.97
Rapeseed meal	7.0	3.88	0.27	2.47
Beet pulp, dried	5.0	11.00	0.55	4.99
Citrus pulp, dried	3.0	16.00	0.48	4.36
Molasses, beet	13.0	2.00	0.26	2.36
Vinasse, different origins		3.00		
Calcium carbonate	24.0	1.02	0.25	2.23
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	11.02	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	18.90	1.70	21.07
Wheat, soft	5.0	17.50	0.88	10.84
Linseed, full fat	12.0	7.51	0.90	11.16
Soybean meal, 50	17.0	10.99	1.87	23.14
Beet pulp, dried	5.0	10.01	0.50	6.20
Molasses, beet	13.0	0.98	0.13	1.58
Grass silage	7.0	30.00	2.10	26.01
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	8.07	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	27.00	2.43	28.49
Wheat, soft	5.0	25.00	1.25	14.65
Linseed, full fat	12.0	10.70	1.28	15.05
Soybean meal, 50	17.0	15.70	2.67	31.29
Beet pulp, dried	5.0	14.30	0.72	8.38
Molasses, beet	13.0	1.40	0.18	2.13
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	8.53	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat middlings	12.0	0.96	0.12	2.10
Corn gluten feed	5.0	0.95	0.05	0.87
Corn gluten meal	11.0	1.15	0.13	2.30
Palm kernel meal, expeller	21.0	1.78	0.37	6.81
Rapeseed meal	7.0	6.18	0.43	7.88
Rapeseed cake		0.59		
Soybean meal, 50	17.0	7.83	1.33	24.25
Beet pulp, dried	5.0	2.61	0.13	2.38
Molasses, beet	13.0	0.24	0.03	0.57
Vinasse, different origins		0.36		
Grass silage	7.0	26.89	1.88	34.29
Corn silage	2.0	50.23	1.00	18.30
Calcium carbonate	24.0	0.06	0.01	0.26
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	5.49	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat middlings	12.0	1.74	0.21	3.23
Corn gluten feed	5.0	1.72	0.09	1.33
Corn gluten meal	11.0	2.08	0.23	3.54
Palm kernel meal, expeller	21.0	3.22	0.68	10.45
Rapeseed meal	7.0	4.39	0.31	4.75
Rapeseed cake		1.07		
Soybean meal, 50	17.0	3.97	0.67	10.43
Beet pulp, dried	5.0	4.72	0.24	3.65
Molasses, beet	13.0	0.43	0.06	0.86
Vinasse, different origins		0.64		
Grass silage	7.0	49.18	3.44	53.19
Corn silage	2.0	26.46	0.53	8.18
Calcium carbonate	24.0	0.11	0.03	0.41
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	6.47	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat middlings	12.0	8.10	0.97	9.85
Corn gluten feed	5.0	8.00	0.40	4.05
Corn gluten meal	11.0	9.70	1.07	10.81
Palm kernel meal, expeller	21.0	15.00	3.15	31.91
Rapeseed meal	7.0	15.00	1.05	10.64
Rapeseed cake		5.00		
Soybean meal, 50	17.0	10.30	1.75	17.74
Beet pulp, dried	5.0	22.00	1.10	11.14
Molasses, beet	13.0	2.00	0.26	2.63
Vinasse, different origins		3.00		
Calcium carbonate	24.0	0.50	0.12	1.22
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	9.87	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize starch		0.17		
Calcium carbonate	24.0	30.50	7.32	37.58
Dicalcium Phosphate	80.0	8.80	7.04	36.14
Salt		22.60		
Diammonium phosphate	80.0	6.40	5.12	26.28
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	19.48	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	2.00	0.18	1.40
Wheat bran	17.0	46.00	7.82	60.93
Soybean meal, 50	17.0	9.00	1.53	11.92
Alfalfa, dehydrated	7.0	40.00	2.80	21.82
Calcium carbonate	24.0	2.10	0.50	3.93
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	12.83	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Barley	9.0	23.00	2.07	17.07
Wheat bran	17.0	12.00	2.04	16.82
Soybean meal, 50	17.0	5.00	0.85	7.01
Sunflower meal, undecorticated	27.0	10.00	2.70	22.26
Beet pulp, dried	5.0	10.00	0.50	4.12
Lard		2.00		
Alfalfa, dehydrated	7.0	35.00	2.45	20.20
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	80.0	1.90	1.52	12.53
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	12.13	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat, soft	5.0	14.90	0.75	16.08
Fish meal, protein 70%	7.0	55.53	3.89	83.92
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	4.63	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat, soft	5.0	7.42	0.37	5.01
Soybean meal, 50	17.0	20.00	3.40	45.88
Fish meal, protein 70%	7.0	52.00	3.64	49.12
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	7.41	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat, soft	5.0	2.87	0.14	1.26
Corn gluten meal	11.0	11.80	1.30	11.40
Soybean meal, 50	17.0	55.00	9.35	82.11
Maize starch		3.00		
Fish meal, protein 70%	7.0	8.50	0.60	5.23
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	11.39	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Maize	2.0	27.80	0.56	5.70
Rice, brown	2.0	7.30	0.15	1.50
Maize starch		2.78		
Beet pulp, dried	5.0	4.30	0.22	2.21
Brewers' yeast, dried	47.0	1.10	0.52	5.30
Lard		9.60		
Meat and bone meal, fat <7.5%	20.0	40.62	8.12	83.32
Calcium carbonate	24.0	0.80	0.19	1.97
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	9.75	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Cu/kg feed material	% feed material	mg Cu/kg complete feedingstuff	Cu (% contribution)
Wheat, soft	5.0	12.21	0.61	5.42
Wheat feed flour	6.0	20.00	1.20	10.65
Wheat gluten feed, starch 25%	7.0	2.06	0.14	1.28
Linseed, full fat	12.0	3.00	0.36	3.19
Brewers' yeast, dried	47.0	1.80	0.85	7.51
Fish meal, protein 70%	7.0	1.00	0.07	0.62
Feather meal	9.0	18.00	1.62	14.38
Meat and bone meal, fat <7.5%	20.0	29.76	5.95	52.82
Meat and bone meal, fat >7.5%	20.0	2.33	0.47	4.14
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	11.27	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Fluorine

Executive summary of the monograph for fluorine

EU legislation governs the maximum content for fluorine in products intended for animal feed. In the EU several fluorine compounds are presently authorized as substances which may be added to foods and as food supplements. In nature, fluorine does not occur in the elemental state bur forms organic or inorganic compounds as fluorides. Fluorine is considered an essential element for animals and humans by some scientific bodies while others consider the available evidence for indispensability to be insufficient. In mammals, low fluorine diets have been reported to cause growth retardation and impairment of fertility. Additionally, fluorine is beneficial in the prevention of dental caries. In humans, fluorine deficiency results in early tooth decay and osteoporosis. The principal sources of fluorine for livestock are commercial feeds that contain fluorine-rich phosphate supplements. Animal by products containing bone may contribute significant quantities of fluorine to animal diets. Cattle are most sensitive to fluorine intoxication, i.e., fluorosis, followed by sheep, horses, pigs, rats and poultry. Maximum tolerable levels established by NRC vary between 150 mg/kg DM for pigs, poultry and rodents and 40 mg/kg DM for cattle and horses. Fluorosis is initially manifested as dental fluorosis and, at higher levels of intake, skeletal fluorosis. The pathological results of skeletal fluorosis include dissociation of the normal sequences in osteogenesis, acceleration of bone remodelling, production of abnormal bone and in some cases bone resorption. In monogastric species, fluorine compounds with low solubility, e.g., calcium-, magnesium or aluminium fluorines are poorly absorbed. Contrarily, fluorine from readily soluble fluorine compounds, e.g., sodium or hydrogen fluoride, fluorosilicic acid and monofluorophosphate are almost completely absorbed from the gastrointestinal tract. Ruminants were reported to absorb approximately 75 % of fluorine compounds present in plants or sodium fluoride. Following absorption fluorine forms calcium fluoride in plasma or fluorine coordinates with macromolecules such as proteins. Fluorine is retained only in calcified tissues. In laboratory animals and humans, approximately 99 % of fluorine is retained in bones and teeth. Fluorine is predominantly excreted via urine. Fluorine concentration in urine, plasma and saliva can be used as biomarkers for acute exposure to fluorine but do not well reflect the fluorine body burden. Bone fluorine levels can be used to quantify long-term fluorine exposure. The genotoxicity of fluorine has been examined numerously and the results of these studies indicate that, in general, fluorine is not mutagenic in prokaryotic cells and positive genotoxicity findings occurred at doses that are highly toxic to cells and whole animals. Long-term excessive exposure to fluorine may lead to skeletal fluorosis. In all stages of the pathology the mineralization of bone is deficient and osteomalacia may be present. IOM and EFSA established upper intake levels for fluorine for adults of 10 mg/day and 7 mg/day, respectively. The major health risk of chronic inhalation exposure to fluorine is skeletal fluorosis, which has been reported in cases of exposure to fluoride dusts and hydrogen fluoride, either individually or in combination. The implementation of the actual EU legislation, fixing maximum fluorine contents in products intended for animal feed, limits the contribution of fluorine originating from animal excreta in the soil and the aquatic environment.

Fluorine Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

In nature, fluorine does not occur in the elemental state but forms organic or inorganic compounds as fluorides. Fluorides are natural components in phosphate and super-phosphate fertilizers used in agricultural practice. Fluoride bearing rock phosphate is used in mineral supplements for livestock. For this reason, rock phosphates should be de-fluorinated. Uptake of fluorides by plants from the soil occurs via the roots and uptake from air occurs through the stomata of the leaves. Fluorides are retained in roots and only poorly transported to other parts of the plant. Soluble fluorides taken up from the soil are converted into carbon-fluorine compounds, including mono-fluoroacetic acid, monofluorooleic acid, monofluoropalmitinic acid and monofluoromyristic acid. The significance of this conversion remains unknown (EFSA, 2004; NRC, 2005).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal nutrition

Presently, in the EU the Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2] on undesirable substances in animal feed governs the maximum tolerable levels of fluorine in feedingstuffs (Table 1).

Table 1 Maximum allowed fluorine (*) content in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2]

Products intended for animal feed	**Maximum content in mg/kg (ppm) relative to a feedingstuff with a moisture content of 12 %**
Feed materials with the exception of :	150
– Feedingstuffs of animal origin with the exception of marine crustaceans such as marine krill	500
– Marine crustaceans such as marine krill	3000
– Phosphates	2000
– Calcium carbonate	350
– Magnesium oxide	600
– Calcareaous marine algae	1000

[1] OJ L 140, 30.5.2002, p. 10

[2] OJ L 318, 6.12.2005, p. 19

Table 1 (continued) Maximum allowed fluorine (*) content in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2]

Products intended for animal feed	**Maximum content in mg/kg (ppm) relative to a feedingstuff with a moisture content of 12 %**
Vermiculite (E 561)	3000 (**)
Complementary feedingstuffs: Containing ≤ 4 % phosphorus	500
Complementary feedingstuffs: Containing > 4 % phosphorus	125 per 1 % phosphorus
Complete feedingstuffs with the exception of	150
– Complete feedingstuffs for cattle, sheep and goats: in lactation	30
– Complete feedingstuffs for cattle, sheep and goats: other	50
– Complete feedingstuffs for pigs	100
– Complete feedingstuffs for poultry	350
– Complete feedingstuffs for chicks	250

(*): Maximum levels refer to an analytical determination of fluorine, whereby extraction is performed with hydrochloric acid 1 N for 20 minutes at ambient temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency

(**): The levels shall be reviewed on 31 December 2007 with the aim of reducing the maximum levels

In the US, the AAFCO published a 'Model Bill and Regulations' which represents the official policy of the association, although it has not been passed into law in all the states. Section 7 on 'Adulteration' governs when a feed shall be deemed to be adultered. This section is further completed with Model Regulation 10 on adultrants under the 'Model Bill and Regulations'. It contains the following on fluorine substantiating the terms " poisonous or deleterious substances":

(1) Fluorine and any mineral or mineral mixture which is to be used directly for the feeding of domestic animals and in which the fluorine exceeds 0.20 % for breeding and dairy cattle; 0.30 % for slaughter cattle; 0.30 % for sheep; 0.35 % for lambs; 0.45 % for swine; and 0.60 % for poultry. (2) Fluorine bearing ingredients when used in such amounts that they raise the fluorine content of the total ration (exclusive of roughage) above the following amounts: 0.004 % for breeding and dairy cattle; 0.009 % for slaughter cattle; 0.006 % for sheep; 0.01 % for lambs; 0.015 % for swine; and 0.03 % for poultry. (3) Fluorine bearing ingredients incorporated in any feed that is fed directly to cattle, sheep or goats consuming roughage (with or without) limited amounts of grain, that results in a daily fluorine intake in excess of 50 milligrams of fluorine per 100 pounds of body weight.

2.2 *Human nutrition*

Fluorine compounds are presently authorized in the EU:

– As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[3]. The authorized fluorine compounds are potassium fluoride and sodium fluoride.

– As food supplements under Regulation EC 1170/2009[4]. The authorized fluorine compounds are: calcium fluoride, potassium fluoride, sodium fluoride, sodium monofluorophosphate.

– As substances which may be added to foods under Regulation EC 1925/2006[5] as amended by Regulation EC 1170/2009[5]. The authorized fluorine compounds are: sodium fluoride, potassium fluoride.

– Directive 2008/100/EC[6] lays down a Recommended Daily Allowance (RDA) for fluoride of 3.5 mg.

3 Essential functions

Fluorine is considered to be an essential element (EFSA, 2004; NRC, 2005). In mammals, low fluorine diets have been reported to cause growth retardation and impairment of fertility. Contrarily, EFSA (2005) considered the available evidence for the indispensability of fluorine to be insufficient.

4 Other functions

Fluorine is beneficial in the prevention of dental caries (tooth decay) when ingested in amounts of about 0.05 mg/(kg bw.day) and when applied topically with dental products such as toothpaste. Dental enamel which contains fluorine is less likely to develop caries, because of greater resistance to ingested acids or to acids generated from ingested sugars by oral bacteria. In addition, fluorine inhibits sugar metabolism by oral bacteria (EFSA, 2005).

5 Antimicrobial properties

No information was available on antimicrobial properties of fluorine in principal literature sources.

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[3] OJ L 269, 14.10.2009, p. 9

[4] OJ L 314, 1.12.2009, p. 36

[5] OJ L 404, 30.12.2006, p. 26

[6] OJ L 285, 29.10.2008, p. 9

6 Typical deficiency symptoms

In humans, fluorine deficiency results in early tooth decay and probably in osteoporosis. However, caries is not a fluorine deficiency disease and no specific fluorine deficiency syndrome has yet been found (EFSA, 2004; EFSA, 2005).

7 Animal requirements, allowances and use levels

Established scientific bodies did not publish any fluorine requirements for livestock species.

8 Concentration of the element in feed materials

Concentrations of fluorine in soils vary considerably depending on geographic conditions as well as industrial pollution. In contrast to many heavy metals, mobility of fluorine in soil is very limited. Furthermore many plant species have a limited capacity to absorb fluorine from the soil, even when fluorine containing fertilizers are applied. The principal sources of fluorine for livestock are commercial feeds that contain fluorine-rich phosphate supplements (Underwood & Suttle, 1999). Fluorine is a normal component of calcified animal and fish tissues. Animal by-products containing bone may contribute significant quantities of fluorine to animal diets, depending upon the amount of by-product used and the dietary history of the animals from which the by-products were derived (NRC, 2005). Fluorine concentrations in feedmaterials are compiled in Table 2.

Table 2 Mean fluorine concentrations in feed materials

Feed material	**n**	**F conc. (mg/kg DM)**	**Reference**
Fish meal	5	159	EFSA (2004)
Meat and bone meal	7	180	
Palm kernel expeller meal	1	46	
Rapeseed meal	5	10	
Soya bean meal	7	11	
Sugar beet pulp (fresh and dried)	192	244	
Forage		2 - 20	NRC (2005)
Cereal grains and by-products		1 - 3	Underwood & Suttle (1999)

Table 2 Mean fluorine concentrations in feed materials

Feed material	n	F conc. (g/kg DM)	Reference
Monocalcium phosphate		1.4 - 1.6	Thompson (1980)
Defluorinated phosphate		1.6	
Monammonium phosphate, feed grade		1.8	
Diammonium phosphate, feed grade		1.6	
Bone meal		0.2 – 3.5	

9 Concentration of the element in complete feedingstuffs

Fluorine concentrations in complete feedingstuffs are compiled in Table 3.

Table 3 Mean fluorine concentrations (mg/kg DM) in commercial complete feedingstuffs for livestock and fish reported by EU member states (EFSA, 2004)

	n	F concentration
Poultry - layers	9	24
Poultry - broilers	7	24
Poultry - unspecified	2	32
Fish	354	30
Pigs < 17 weeks	4	14
Pigs > 16 weeks	7	23
Pigs - unspecified	37	16
Ruminants - unspecified	8	17

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Cattle are most sensitive to fluorosis followed by sheep, horses, pigs, rats, guinea pigs and poultry. Young animals are most affected by fluorosis. The dietary concentration at which fluorine ingestion becomes harmful in farm animals is not clearly defined. Diagnosis of fluorine toxicosis at low dietary intakes is difficult because there is an extended interval of time between ingestion of elevated levels and the appearance of toxic signs. The MTL values established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels (MTL) for fluorine (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Pigs, Poultry, Rodents	150	
Sheep	60	
Cattle	40	
Horses	40	Value derived from interspecies extrapolation
Fish		Available data were considered insufficient to establish a MTL

Additionally to the fluorine MTL values, NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

The toxicity of fluorine in animals via excessive fluorine ingestion from water or from industrial exposure is referred to as fluorosis, chronic fluorine toxicity, or fluorine toxicosis. The toxicosis is initially manifested as dental fluorosis and, at higher levels of intake, skeletal fluorosis. The pathological results of skeletal fluorosis include dissociation of the normal sequences in osteogenesis, acceleration of bone remodelling, production of abnormal bone (exostosis, sclerosis) and in some cases accelerated bone resorption (osteoporosis). Clinical signs comprise stiffness and lameness and in severe cases animals refuse to stand, moving instead on their knees. The stiffness and lameness are primarily associated with osteofluorotic lesions and calcification of peri-articular structures and tendons preceding skeletal deformation (EFSA, 2004; NRC, 2005). Excess fluorine intake produces dental fluorosis in animals affecting the teeth during development. Specific ameloblastic and odontoblastic damage may be caused by high fluorine intake and varies directly with the levels consumed. Faulty materialization results when the matrix laid down by damaged ameloblasts and odontoblasts fails to accept minerals normally. Once a tooth is fully formed, the ameloblasts have lost their constructive ability and the enamel lesions cannot be repaired (EFSA, 2004).

12 Bioavailability

12.1 General

In monogastric species, fluorine compounds with low solubility, e.g., calcium-, magnesium or aluminium fluorides are poorly absorbed. Contrarily, fluorine from readily soluble fluorine compounds, e.g., sodium or hydrogen fluoride, fluorosilicic acid and monofluorophosphate are almost completely absorbed from the gastrointestinal tract by passive diffusion in monogastric species. Conditions of high gastric acidity favour absorption, whereas alkalinity decreases fluorine absorption. Ruminants absorb approximately 75 % of fluorine compounds present in plants or sodium fluoride. Assessments of the absorbable fractions of fluorine contained in soil in sheep and bovine species ranged between 4.5 – 23% and 30 – 41 %, respectively (EFSA, 2004). In humans, readily soluble fluorides are rapidly almost completely absorbed, in contrast to the low soluble fluorine compounds. In its assessments, the ANS Panel concluded that monofluorophosphate and calcium fluoride are equally and less bioavailable compared to sodium fluoride, respectively (EFSA, 2008; EFSA, 2008b).

12.2 *Fluorine status indicators*

Urine, plasma and saliva fluorine concentrations can be used as biomarkers for acute exposure to fluorine but do not well reflect the fluorine body burden. Fluorine concentrations can peak within one hour after exposure since fluorine is rapidly absorbed from all routes of exposure. The concentration of fluorine in nails and hair appears to be proportional to fluorine exposure over longer periods of time taking into account their growth rate. Bone fluorine levels can be used to quantify long-term fluorine exposure as fluorine concentrations in calcified tissues reflect the historical body burden. However, this requires a bone biopsy, so bone fluorine levels are most frequently measured after clinical signs appear (ATSDR, 2003; EFSA, 2005).

13 Metabolism

Following absorption the concentration of ionic fluoride increases in plasma where it reacts with calcium ions to form calcium fluoride. Some ionic fluorine may become non-ionic by coordinating with macromolecules such as proteins. Fluorine is retained only in calcified tissues. Removal of fluorine from circulation occurs principally through two mechanisms: renal excretion and calcified tissue deposition. Urinary fluorine excretion accounts for approximately 90 percent of total excretion (EFSA, 2005; NRC, 2005).

14 Distribution in the animal body

In laboratory animals and humans, approximately 99 % of fluorine is retained in bones and teeth (NRC, 2005). In bones and teeth fluorine interacts with the hydroxyapatite of calcified tissues. Fluorine retention in bone and dentine is proportional to the long-term fluorine exposure and, moreover, dependent on the turnover rate of bone, on age, gender and the type of bone. Only minor concentrations of fluorine are measurable in body fluid and soft tissues. Tendons, the aorta and the placenta have higher fluorine concentrations than other soft tissues (EFSA, 2004; EFSA, 2005; NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

Fluorine mainly accumulates in bone and teeth. In soft tissues fluorine levels are very low, generally, < 2.5 mg/kg (EFSA, 2004). A compilation of fluorine concentrations in edible tissues and products is given in Annex 1. Fluorine concentrations in edible tissues and products linked with the dietary intake of various fluorine compounds and doses is reported in Annex 2.

16 Acute toxicity

Acute high oral exposure to fluorine may lead to nausea, vomiting, abdominal pain, diarrhea, drowsiness, headaches, polyuria and polydipsia, coma, convulsions, cardiac arrest and death. In autopsy reports the following observations are described: hemorrhagic edema of the lungs, hemorrhagic gastritis, and cerebral edema. For adults the lethal fluorine dose is reported to be between 40 - 80 mg/(kg bw) and the minimum acute fluorine dose leading to gastrointestinal effects was described to be 0.4 - 5 mg/(kg bw) (EFSA, 2005; ATSDR, 2003). Oral LD_{50} values are compiled in Table (5).

Table 5 Oral LD_{50}- values for fluorine (mg/kg bw) (ATSDR, 2003; WHO, 2002)

Species	**Fluorine compound**	**LD_{50}**
Rats	Sodium fluoride	31 – 126.3
Rats	Sodium monofluorophosphate	84.3 – 146.3
Mice	Sodium fluoride	44.3 - 58
Mice	Sodium monofluorophosphate	54 - 94

17 Genotoxicity and Mutagenicity

The genotoxicity of fluorine has been examined in a large number of *in vitro* and *in vivo* assays, in which a wide range of end-points has been assessed. The results of these studies indicate that, in general, fluorine is not mutagenic in prokaryotic cells and positive genotoxicity findings occurred at doses that are highly toxic to cells and whole animals (ATSDR, 2003; EFSA, 2005, WHO, 2002). Sodium fluoride was clastogenic in many but not all, *in vitro* cytogenetic assays. The frequency of chromosomal aberrations was increased following exposure to sodium fluoride of Chinese hamster lung cells, Syrian hamster embryo cells, rat bone marrow cells, human peripheral blood lymphocytes, human fibroblasts, human amnion cells, human and chimpanzee lymphoid cells and human oral keratinocytes. The chromosomal aberrations consisted primarily of breaks/deletions and gaps, with very few exchanges. Contrarily, no significant increase in chromosomal aberrations was observed to sodium fluoride exposure at or below concentrations of 10 mg/L in human fibroblasts, Chinese hamster ovary cells, or human diploid lung cells nor in Chinese hamster lung cells at concentrations at or below 500 mg/L (WHO, 2002).

In most *in vivo* studies in which sodium fluoride was administered orally to rodents, there was no effect observed upon sperm morphology, the frequency of chromosomal aberrations, micronuclei and sister chromatid exchange or DNA strand breaks (WHO, 2002).

18 Subchronic toxicity

WHO (2002) reported on short- and medium-term oral toxicity studies of fluorine compounds. Observed clinical symptoms include reduced survival, effects on the skeleton, stomach and liver. A concise summary is given in Table 6.

Table 6 Short and medium term oral toxicity of fluorine (WHO, 2002)

Species	**Exposure route**	**Concentration**	**Duration**	**Effects**
F344/N rats	Drinking water	363.2 mg F/L	14 d	Reduced survival
Female Wistar rats	Drinking water	113.5 or 136.2 mg F/L	5 w	Inhibition of trabecular bone mineralization
Male Holtzman rats	Drinking water	85.5 mg F/L	21 d	Inhibition of endosteal bone formation, reduced cancellous bone volume
Male albino rats		14 mg F/(kg bw.day)	30 d	Delayed fracture healing, reduced collagen synthesis
Female Wistar rats	Drinking water	100 – 150 mg F/L	90 d	Reduced vertebral bone quality
Female $B6C3F_1$ mice	Drinking water	22.7 – 45.5 mg F/L	6 m	Altered bone remodelling
F344/N rats	Drinking water	45.5 – 136 mg F/L	6 m	Hyperplasia of the stomach and pathological effects in the glandular stomach

19 Chronic toxicity, including carcinogenicity

Skeletal fluorosis may arise from long-term excessive exposure to fluorine both by oral ingestion and by inhalation. The development of this pathology and its severity is directly related to the level and duration of fluorine exposure. In the preclinical stage of fluorosis the patient may be asymptomatic and have an increase in bone density on radiography. With increasing fluorine incorporation into bone, clinical stage I and II develop with pain and stiffness of joints, osteosclerosis of both cortical and cancellous bone, osteophytes and calcification of ligaments. Crippling skeletal fluorosis (clinical stage III) may be associated with movement restriction of joints, skeletal deformities, severe calcification of ligaments, muscle wasting and neurological symptoms. All stages are accompanied by disturbed or deficient mineralization of bone and osteomalacia may be present, particularly when the calcium intake is insufficient (EFSA, 2005; IOM, 1997).

Overall, based on the results of the most adequate long-term carcinogenicity studies, there is equivocal evidence of carcinogenicity in male rats and no evidence of carcinogenicity in mice (EFSA, 2005). Numerous epidemiologic studies have examined the issue of a connection between fluoridated water and cancer. Most studies have not found significant increases in cancer mortality or site-specific cancer incidence (ATSDR, 2003).

20 Reproduction and developmental toxicity

There are limited data on the potential of fluorine to induce reproductive effects in humans following oral exposure. ATSDR reported on a meta-analysis that found a statistically significant association between decreasing total fertility rate and increasing fluorine levels in municipal drinking water (ATSDR, 2003). Fluorine readily crosses the placenta and is found in fetal and placental tissue (ATSDR, 2003). A Non observed adverse effect level (NOAEL) for maternal toxicity from fluorine in drinking water was 8.1 mg/(kg bw.day) for both rats and rabbits. The NOAEL for developmental toxicity from fluorine in drinking water administered during organogenesis was 12.2 and 13.1 mg/(kg bw.day) for rats and rabbits, respectively (EFSA, 2005). A summary of some of the reported studies on the reproduction toxicity of oral fluorine exposure reported by ATSDR (2003) and WHO (2002) are given in Table 7.

Table 7 Studies assessing reproductive effects of oral fluorine exposure as sodium fluoride (adapted from ATSDR, 2003; WHO, 2002)

Species	**Dose**	**Duration**	**Effect**
Male rats	16 mg F/(kg bw.day)	14 w	No alterations in mean serum levels of testosterone, luteinizing hormone, or follicle stimulating hormone
Rats	4.5 mg F/(kg bw.day)	50 d	Decreases in serum testosterone levels
Rats	4.5 mg F/(kg bw.day)	50 d	Decreases in Leydig cell diameter
Rabbits	4.5 mg F/(kg bw.day)	18 – 23 m	Decreases in Leydig cell diameter
Female mice	19 mg F/(kg bw.day)	25 w	Nearly complete infertility

21 Non Observed Adverse Effect Level (NOAEL) and LOAEL (Lowest Observed Adverse Effect Level)

NOAEL and LOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

IOM (1997) and EFSA (2005) established UL values for fluorine for several live stage categories. The selected critical endpoint , identified LOAEL and NOAEL values and the uncertainty assessment are given in Table 8. A summary of the established UL values for different live stage groups is reported in Table 9. ATSDR (2003) derived a chronic-duration oral minimal risk level for fluorine of 0.05 mg/(kg bw.day). BfR (2006) did not establish an UL. As a conclusion of their risk assessment of fluorine, BfR recommended that fluorine should not be used in food supplements and that the addition of fluorine to conventional foods should be restricted to table salt (BfR, 2006).

Table 8 Critical end points, Non observed adverse effects levels (NOAEL) and Lowest observed adverse effect levels (LOAEL) and uncertainty factors (UF) for fluorine

IOM (1997)		**EFSA (2005)**	
Live stage group: children up to eight years:		*Live stage group: children up to eight years:*	
Critical endpoint:	Moderate dental fluorosis	Critical endpoint:	Moderate dental fluorosis
LOAEL:	0.1 mg/(kg bw.day)	LOAEL:	0.1 mg/(kg bw.day)
UF:	1	UF:	1
Live stage group: children > 8 years and adults:		*Live stage group: children > 8 years and adults:*	
Critical endpoint:	Skeletal fluorosis	Critical endpoint:	Increased risk for skeletal fractures
NOAEL:	10 mg/day	LOAEL:	0.6 mg/(kg bw.day)
UF:	1	UF	5

Table 9 Upper Intake Levels (UL) (mg/day) for fluorine for several live stage groups

Live stage group	**UL (IOM, 1997)**	**Live stage group**	**UL (EFSA, 2005)**
0- 6 months	0.7		
7 - 12 months	0.9		
1 – 3 years	1.3	1 - 3 years	1.5
4 – 8 years	2.2	4 - 8 years	2.5
		9 – 14 years	5
> 8 years and adults	10	≥ 15 years	7
Pregnancy and Lactation	10	Pregnancy and lactation	7

23 Toxicological risks for user/workers

The major health effect of chronic inhalation exposure to fluorine is skeletal fluorosis, which has been reported in cases of exposure to fluorine dusts and hydrogen fluoride, either individually or in combination. In several case reports the incidence of radiological alterations, namely, thickening of the bone, has been described in workers exposed to sodium fluoride, rock phosphate dust contining fluoride or cryolite (ATSDR, 2003). ATSDR (2003) did not establish a minimal risk level for inhalation exposure to fluorides because the available studies are often difficult to interpret due to co-exposure to hydrogen fluoride and other chemicals such as aluminium.

24 Toxicological risks for the environment

WHO (2002) ranked anthropogenic fluorine emissions into the environment. Fluorine is released via exhaust fumes, process waters and waste from various industrial processes, including steel manufacture, primary aluminium, copper and nickel production, phosphate fertilizer production and use, glass, brick, and ceramic manufacturing, and glue and adhesive production. The use of fluorine containing pesticides as well as the fluoridation of drinking water supplies also contribute to the release of fluorine from antropogenic sources. In Canada, phosphate fertilizer production contributed 48 % the the total fluorine emissions of antropogenic sources (WHO, 2002). No information was found in principal literature sources on the emissions of fluorine related to animal husbandry.

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Annex 1: Fluorine concentrations in edible tissues and products

Table 1 Fluorine concentrations in edible tissues and products (mg/kg)

Product description	n	Muscle	Liver	Kidney	Eggs	Milk	Reference
Milk and milk products	12					0.189	Dabeka & McKenzie (1995)
Meat and poultry	17	0.251					
Fish	4	2.118					
Pork	6	Loin chop: 0.4					Greenfield *et al* . (2009)
Pork	24	< 0.2 - 0.4					
Milk and milk products						0.045 - 0.51 [b]	WHO (2002) [a]
Milk and milk products						0.019 - 0.16 [b]	
Meat and poultry		0.01 - 1.7					
Meat and poultry		0.29					
Fish		0.06 - 1.7					

[a]: References herein; [b]: mg/L

Annex 1: References

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Annex 2: Fluorine concentrations in edible tissues and products linked with the dietary intake of fluorine

Table 1 Fluorine concentrations in edible tissues, edible products and bone (mg/kg)

Species / category	Source of F supplemented	Dose of F supplemented (mg F /kg)	F content of complete feed [1] (mg F/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Bone	Reference
Laying hens			72 [3]	16 w	4.14 [a]		1.47 [a]	0.72 [a]	149 [a]	Górecki *et al*. (2006)
	Phosphogypsum[2]	46.30	123		4.35 [a]		1.89 [b]	0.85 [b]	210 [b]	
	Phosphogypsum[2]	138.9	225		7.34 [b]		3.70 [c]	0.89 [c]	464 [c]	
Laying hens			16.2 [4]	16 w	5.2 DM [ab]	3.4 DM [a]	P: 4.0 DM [a] T: 4.9 DM [a]	Y: 4.3 DM [a] W: 0.6 [a]	538 DM [a]	Hahn & Guenter (1986) [5]
	NaF	100	115		5.5 DM [ab]	3.8 DM [a]	P: 4.0 DM [a] T: 9.4 DM [ab]	Y: 3.3 DM [a] W: 0.4 [a]	2247 DM [bc]	
	NaF	1300	1540		19.2 DM [c]	31.8 DM [b]	P: 6.7 DM [c] T: 13.2 DM [b]	Y: 18.4 DM [d] W: 1.0 [b]	2600 DM [c]	

[1]: Data from feed analysis; [2]: main component is $CaSO_4.2H_2O$, the product contains F impurities including CaF_2, $CaSiF_6$, K_2SiF_6, Na_2SiF_6; [3]: F content of drinking water: 0.3 mg/L

[4]: F content of drinking water: 1 mg/L; [5]: DM-values are expressed on dry, fat-free basis

Statistics:

Górecki *et al*. (2006): Means within each column with different superscripts differ significantly, $P \leq 0.05$

Hahn & Guenter (1986): Means within a column with different superscripts differ significantly , $P< 0.01$, Anova

Annex 2: References

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Iodine

Executive summary of the monograph for iodine

Iodine compounds are presently authorized as feed and food additives in the EU. Iodine is an essential trace element for animals and humans as it is incorporated into thyroid hormones: thyroxine (T4), triiodothyronine (T3) and into the precursors iodothyrosines. Iodine deficiency reduces the production of thyroid hormones and consequently leads to a slowing down of many metabolic processes, especially oxidation at cellular level. Iodine deficiency reduces the capacity of reproduction as well as growth and development of the progeny. An obvious clinical manifestation of iodine deficiency is an enlarged thyroid gland (goiter). For all species the minimum requirement appears to be far below the maximum tolerable level. Horses are more sensitive to excess iodine compared to other farm animals. The maximum tolerable levels established by NRC range between 5 and 400 mg I/kg DM. Exposure to excess iodine results in hypothyroidism, because of feedback inhibition of T3 synthesis. Most iodine compounds present in food and iodine additives are highly absorbable (90 – 100 %) with the exception of diiodosalicylic acid which is poorly absorbed by ruminants. Iodine is concentrated primarily in the thyroid and the kidney. In thyroid follicular cells, iodine is transformed through a series of metabolic steps into the thyroid hormones, T4 and T3. The iodine pool is in a dynamic equilibrium with the thyroid and the kidneys. Approximately 80 - 90 % of ingested iodine is excreted via the kidneys.

Lethal doses of iodine in humans are reported to range between 7 and 120 mg I/kg bw. Iodine compounds have generally produced negative results in mutagenic assays. Results of epidemiological studies in which the relationship between iodine intake and the incidence of thyroid cancer was investigated, suggested that iodine intake may be a risk factor in populations residing in iodine deficient areas. Chronic exposure to excess iodine causes iodism which is manifested in clinical symptoms that resemble coryza and e.g., salvary gland swelling. Additionally, it may cause disruptions of reproductive function secondary to thyroid gland dysfunction. IOM and SCF selected thyroid dysfunction shown as elevated TSH concentrations as a toxicological endpoint for setting an upper intake level (UL). UL values of 1100 µg I/day and 600 µg I/day for adults were set by IOM and SCF, respectively. ATSDR did not locate any studies in humans and animals after inhalation exposure to iodine. Recently the FEEDAP Panel concluded that the input of iodine in the environment through the spreading of sludge is not expected to pose an environmental risk.

Iodine Monograph

Table of contents

1 Forms/Sources of the element of importance in human and animal nutrition

The only natural iodine sources for humans and animals are the iodides in food and water (SCF, 2002; WHO, 2009). Additionally, various iodine compounds are authorized as feed and food additives for which the reader is referred to Chapter 2.

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Iodine compounds presently authorized in the EU as additives (EC 1459/2005[1]) are listed in Table 1.

Table 1 Conditions of use of iodine compounds as additives in feedingstuffs according to the Commission Regulations EC 1459/2005[1]

Additive	**Chemical formula**	**Maximum content of the element in the complete feedingstuff with a moisture content of 12% (mg/kg)**
Calcium iodate, hexahydrate	$Ca(IO_3)_2 . 6H_2O$	Equines: 4 (total) Dairy cows and laying hens: 5 (total) Fish: 20 (total) Other species or categories of animals: 10 (total)
Calcium iodate, anhydrous	$Ca(IO_3)_2$	
Sodium iodide	NaI	
Potassium iodide	KI	

In the US, the following iodine compounds are allowed in animal feeds: calcium iodate, calcium iodobehenate, cuprous iodide, diiodosalicylic acid, ethylenediamine dihydroiodide, potassium iodate, potassium iodide, iodized salt, sodium iodate, sodium iodide, thymol iodide (AAFCO Official Publication §57: Mineral Products) (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

[1] OJ L 1459, 9.9.2005, p.8

Table 2 Range of iodine guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	Range (mg/kg)
Chickens	0.4 - 10
Turkeys	0.4 -10
Swine	0.2 - 10
Dairy cattle	0.25 - 10
	0.5 – 10 (lactating)
Beef cattle	0.1 - 10
Sheep	0.1 - 10
	0.8 – 10 (lactating)
Horses	0.1 - 2.5
Goats	0.2 - 10
Ducks and geese	0.4 - 10
Salmonid fish	5 - 20
Mink	0.2 - 20
Rabbits	0.2 - 10

2.2 *Human nutrition*

Iodine compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Commission Regulation 953/2009[2]. The authorized iodine compounds are: potassium iodide, potassium iodate, sodium iodide, sodium iodate.

- As food supplements under Regulation 1170/2009[3]. The authorized iodine compounds are: potassium iodide, potassium iodate, sodium iodide, sodium iodate.

- As substances which may be added to foods under Regulation 1925/2006[4] as amended by regulation 1170/2009[3]. The authorized iodine compounds are: potassium iodide, potassium iodate, sodium iodide, sodium iodate.

[2] OJ L 269, 14.10.2009, p.9

[3] OJ L 314, 1.12.2009, p.36

[4] OJ L 404, 30.12.2006, p. 26

- Directive 2008/100/EC[5] lays down a Recommended Daily Allowance (RDA) for iodine of 150 μg.

In the U.S. the Code of Federal Regulations grants a generally recognized as safe status for the use as nutrient and or dietary supplement (Part 582; Subpart F) to potassium iodide.

3 Essential functions

Iodine is an essential trace element for animals and humans (EFSA, 2005; NRC, 2005; WHO, 2009). The only known role of iodine in the metabolism is its incorporation into thyroid hormones, namely, thyroxine (T_4, 3,5,3',5'-tetraiodothyronine) and triiodothyronine (T_3, 3,5,3'-triiodothyronine) and into the precursor iodothyrosines. Both thyroid hormones have multiple functions which include regulation of cell activity (energy metabolism) and growth, transmission of nervous stimuli and they are important factors in brain development (EFSA, 2005).

4 Other functions

There was no information available on other functions of iodine in principal literature sources.

5 Antimicrobial properties

Iodophore teat dipping is used as biocide/disinfectant to decrease intramammary infections (Galton, 2004).

6 Typical deficiency symptoms

Iodine deficiency in humans and animals reduces the production of thyroid hormones. Hence, it leads to a slowing down of many metabolic processes, especially oxidation at cellular level. Iodine deficiency also reduces the capacity of reproduction as well as growth and development of the progeny. Iodine deficiency occurring during the critical period of fetal and early postnatal brain development results in severe thyroid failure and irreversible brain damage (EFSA, 2005; Schöne & Rajkumar Rajendram, 2009). An obvious clinical manifestation of iodine deficiency is an enlarged thyroid gland (goiter). The degree of the enlargement increases with the degree and duration of iodine deprivation. The main unspecific manifestations of iodine deficiency include: sluggishness, decreased feed intake, decreased body weight gain of young animals, reduced production / performance, dry hair/wool, puffy appearance, decreased resistance to cold, decreased resistance to infections, stunted growth, dwarfism. In dairy cows reductions in

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[5] OJ L 285, 29.10.2008, p. 9

milk yield are an important feature of iodine deficiency (EFSA, 2005; Underwood & Suttle, 1999; Schöne & Rajkumar Rajendram, 2009).

7 Animal requirements, allowances and use levels

Iodine requirements of livestock established by scientific bodies are compiled in Annex 3.1, iodine use levels are listed in Annex 3.2.

8 Concentration of the element in feed materials

Iodine concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Iodine concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Significant species differences exist in the tolerance to high levels of dietary iodine because of the differences in basal metabolic rate and iodine metabolism. All species appear to have a wide margin of safety for this element, e.g., the safety margin is 1000 times the minimal requirement of chickens and pigs (NRC, 2005). Horses are less tolerant to excess iodine compared to other farm animals (EFSA, 2005). MTL values established by NRC (2005) are compiled in Table 3.

Table 3 Maximum Tolerable Levels (MTL) (mg/kg DM) (NRC, 2005)

Species	**MTL**	**Additional remarks**
Swine	400	
Poultry	300	
Cattle, sheep	50	
Horses	5	
Rodents, fish	-	Data were insufficient to set a MTL

Additionally, to the iodine MTL values NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Exposure to excess iodine paradoxically results in hypothyroidism, because of feedback inhibition of T_3 synthesis (Underwood & Suttle, 1999). In cattle clinical signs include excessive nasal and ocular discharge, coughing, nervousness, tachycardia, decrease of appetite, dermatitis and alopecia, exophtalmos, weight loss, decreased milk production, susceptibility to infectious and respiratory diseases, and increased mortality of dams. In pigs depressed growth rate, feed intake and hemoglobin levels have been observed. In poultry depressed growth and neurological clinical were reported. Additionally, decreased egg production, egg size, and hatchability, low fertility and enlarged thyroids in hatching chicks are provoked by high dietary iodine in chicken and turkey laying hens (EFSA, 2005; NRC, 2005; Schöne & Rajkumar Rajendram, 2009).

12 Bioavailability

12.1 General

Iodine occurs in foods and feeds largely as inorganic iodide. A form in which it is almost completely absorbed. The bioavailability of potassium iodide, sodium iodide, ethylenediamine dihydroiodide, pentacalcium orthoperiodate and calcium iodide is reported to be in the 90 - 100 % range for poultry, cattle and rats. Diiodosalisylic acid is a stable compound which is well absorbed by rats but not by ruminants (NRC, 2005). Relative differences in bioavailability between these iodine compounds reported by Jongbloed *et al*. (2002) are listed in Table 4.

Table 4 Relative bioavailability assessments (%) of iodine compounds compared to potassium iodide in livestock (Jongbloed *et al*., 2002)

	Pigs	**Poultry**	**Ruminants**
Potassium iodide	100	100	100
Calcium iodate		95	106
Calcium iodide			110
Ethylenediamine dihydroiodide	99		111
Iodine humate	71		
Diiodosalicylic acid			36
Pentacalcium orthoperiodate			111

12.2 *Indicators of iodine status*

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of iodine compounds in livestock (Table 5).

Table 5 Ranking of adequacy of response criterions for assessing the relative biological value of iodine compounds [1] (Jongbloed *et al*., 2002)

	Pigs		**Poultry**		**Ruminants**	
Supplementation level →	Suboptimal	Above requirement	Suboptimal	Above requirement	Suboptimal	Above requirement
Criterion						
Iodine absorption	3	1	3	1	3	1
Thyroid weight	2	2	2	2	2	2
Thyroid iodine content	2	2	2	2	2	2
Performance	1	-	1	-		
Milk iodine content					2	1

[1]: the highest values correspond to the best adequacy

Urinary iodine excretion, blood levels of T4 or thyroid stimulating hormone (TSH) can be used to estimate iodine status (EVM, 2003). The best parameter is the TSH serum level especially if hypothyroidism is to be detected in pregnant women and neonates. The sensitivity can be increased by previous stimulation with TRH. An exaggerated response to TRH suggests an inadequate hormone availability, hypothyroidism and iodine deficiency (SCF, 2002).

13 Metabolism

Ingested inorganic iodine and iodate are reduced to iodide and absorbed almost completely from the gastrointestinal tract. In the ruminant, the rumen is the major site of absorption of iodine and the abomasum is the major site of endogenous secretion (NRC, 2005). After absorption, the iodide is rapidly distributed throughout the body. Iodine is concentrated primarily in the thyroid and the kidney. Additionally, the salivary glands, mammary glands, gastric mucosa, placenta, ovary, skin, and hair are sites of iodine deposition (NRC, 2005). In thyroid follicular cells, iodine is transformed through a series of metabolic steps into the thyroid hormones, T_4 and T_3. The iodine pool is replenished continuously, exogenously from the diet and endogenously from saliva, gastric juice, and breakdown of thyroid hormones and iodothyronines by deiodination. The pool is in a dynamic equilibrium with the thyroid gland and kidneys. Approximately 80 - 90 % of iodine intake is excreted via the kidneys. Other routes include saliva, bile, sweat, and feces. In lactating animals, milk is also a major route of iodine excretion. Undigested organic iodine is excreted via the feces (NRC, 2005). It should be noted that glucosinolates, thiocyanates, nitrates and nitrites are strong iodine antagonists (Schöne & Rajkumar Rajendram, 2009).

14 Distribution in the animal body

In a study in which human subjects were exposed via ingestion to tracer levels of radio-labelled iodine as sodium iodide, approximately 20–30% of the iodine was distributed to the thyroid, and 30–60% was excreted in the urine in about 10 h (WHO, 2009). It is assumed that normally approximately 80% of the total iodine content of the animal body is contained in the thyroid gland and the rest in soft tissues, particularly liver, kidney and muscles (Downer *et al*., 1981).

15 Deposition (typical concentration) in edible tissues and products

A compilation of iodine concentrations in edible tissues and products is given in Annex 1. Iodine concentrations in edible tissues and products linked with the dietary intake of various iodine compounds is given in Annex 2.

Among food from terrestrial animals milk and eggs contain the highest iodine concentrations, followed by inner organs. Much higher levels of iodine are present in marine fish, shell fish, sea salt and kelp products (EFSA, 2005; EVM, 2003). The iodine content of milk and eggs is related to the dietary iodine intake. Iodophor medication, iodine-containing sterilizers of milking equipment, teat dips, and udder washes may contribute to the total iodine content of milk and dairy products (SCF, 2002; Galton, 2004).

16 Acute toxicity

ATSDR (2004) reported on clinical case literature from attempted suicides in which adults had ingested iodine tinctures, i.e., mixtures of molecular iodine and sodium triiodide. The symptoms of acute oral iodine toxicity included abdominal cramps, bloody diarrhea, gastrointestinal ulceration, edema of face and neck, pneumonitis, hemolytic anemia, metabolic acidosis, fatty degeneration of the liver and renal failure. Lethal doses ranged from 17 - 120 mg I/kg bw (ATSDR, 2004).

17 Genotoxicity and Mutagenicity

The mutagenicity data for iodine are generally negative. Both iodine deficiency and excess can promote tumor formation in animals pre-exposed to known carcinogens. The observed effects were thought to be provoked via a non-genotoxic proliferation dependent mechanism (EVM, 2003). A concise overview of mutagenicity tests reported by ATSDR (2004) is given in Table 6.

Table 6 Results of *in vitro* genotoxicity and mutagenicity tests with iodine compounds (ATSDR, 2004)

Iodine compound	**Test system**	**Result**
Potassium iodide, I_2	Mutagenic effects in L5178Y mouse lymphoma cells, transforming activity in Balb/c 3T3 cells grown in culture	-
I_2	Mutagenic activity in His+ revertant assay in *Saccharomyces cerevisiae*	-
Sodium iodate	Bacterial Ames assay; mouse bone marrow micronucleus test	-

18 Subchronic toxicity

Normal subjects receiving 50 - 250 mg I/day for 10 - 14 days were reported to show subtle changes in thyroid function. These consisted of small but significant decreases in serum levels of T4, T3 and concurrent small compensatory increases in basal serum TSH concentrations and exaggerated serum TSH responses to i.v. thyrotropin-releasing hormone (TRH) (SCF, 2002).

19 Chronic toxicity, including carcinogenicity

Chronic exposure to iodine causes iodism. The symptoms resemble coryza as well as salivary gland swelling, gastrointestinal irritation, acneform dermatitis, metallic taste, gingivitis, increased salivation, conjunctivitis and oedema of eyelids (SCF, 2002).

ATSDR (2004) reported on several epidemiological studies that investigated the relationship between iodine intake and the incidence of thyroid cancer. The results of these studies suggest that an increased iodine intake may be a risk factor in populations residing in iodine deficient areas. Studies of populations in which iodine intakes are sufficient have not found significant associations between iodine intake and thyroid cancer. However, in otherwise iodine-deficient populations an apparent shift in the histopathology towards a higher prevalence of papillary cancers, relative to follicular cancers after increased iodine intake has been recurrently observed (ATSDR, 2004).

20 Reproduction toxicity

Oral exposure to excess iodine may produce hypothyroidism or hyperthyroidism and may cause disruptions of reproductive function secondary to thyroid gland dysfunction. Hypothyroidism can produce changes in the menstrual cycle in humans including menorrhagia and anovulation. Abortions, stillbirths, and premature births have also been associated with hypothyroidism. Reproductive impairments associated with hyperthyroidism include amenorrhea, alterations in gonadotropin release and sex hormone-binding globulin and changes in the levels and metabolism of steroid hormones in both females and males (ATSDR, 2004).

Hypothyroidism and hyperthyroidism could give rise to developmental defects. Hypothyroidism may be associated with impairment in neurological development of the fetus, growth retardation, goiter and transient hypothyroidism (ATSDR, 2004).

21 Non observed effect level (NOAEL)

NOAEL and LOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

For setting an UL, IOM has selected thyroid dysfunction shown by elevated TSH concentrations as a critical toxicological endpoint. Based on two supplementation studies in humans a LOAEL was identified of 1700 µg I/day. An uncertainty factor of 1.5 was applied to derive a NOAEL from the LOAEL. No other uncertainty factor was considered to calculate the UL because of the mild, reversible nature of elevated TSH over baseline (IOM, 2001). SCF (2002) also selected changes in TSH levels as toxicological endpoint for the basis of their assessment. In agreement with the IOM (2001) a LOAEL of 1700 µg I/day to 1800 µg I/day was identified. An uncertainty factor of 3 was considered adequate (SCF, 2002). UL values for various live stage groups established by IOM (2001) and SCF (2002) are compiled in Table 7.

Table 7 Upper Intake Levels for iodine (UL) (µg I/day) for several life stage groups

	UL (IOM, 2001)		**UL (SCF, 2002)**
1 - 3 years	200	1 – 3 years	200
4 – 8 years	300	4 – 6 years	250
9 – 13 years	600	7 – 10 years	300
		11 – 14 years	450
14 – 18 years	900	15 – 17 years	500
Adults	1100	Adults	600
Pregnancy and lactation 14 – 18 years	900		
Pregnancy and lactation 19 – 50 years	1100		

EVM (2003) considered the available data from human and animal studies insufficient to establish an UL for iodine. For guidance purposes only, EVM, put forward that a supplemental intake of 0.5 mg I/day, in addition to the iodine present in the diet would not be expected to have any significant adverse effects in adults. BfR (2006) recommended a maximum level of iodine for food supplements of 100 µg I/day and that only iodised salt is used as a carrier. This should guarantee that foreseeable amounts of iodine can be ingested by the general population and that an intake level of 500 µg I/day is not exceeded (BfR, 2006).

23 Toxicological risks for user/workers

Iodine is absorbed in humans when I_2 or methyl iodide vapors are inhaled. Once absorbed, iodide would be expected to exert effects that are similar to that of iodide absorbed after ingestion, including effects on the thyroid gland and thyroid hormone status. Exposure to high air concentrations of I_2 vapor could potentially produce upper respiratory tract irritation and possibly oxidative injury (ATSDR, 2004). ATSDR (2004) did not locate any studies in humans and animals after inhalation exposure to iodine.

24 Toxicological risks for the environment

Iodine present in feed can enter the environment via direct excretion of feces and urine on pasture or spreading of sludge and slurry collected from intensively reared animals. The FEEDAP Panel calculated that the maximum increase of iodine in soil for the main categories of target animals is around 80 µg I/kg. This simulation was done using an application rate of 170 kg N/ha for one year and starting from the assumption that 100% of a dietary concentration of 4 mg I/kg will be excreted. This concentration is well below the background concentration (3-5 mg I/kg soil) and it is therefore not expected to pose an environmental risk (EFSA, 2005).

25 References

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Glossary

T3: 3,5,3'-triiodothyronine

T4: 3,4,3',5'-tetraiodothyronine

TRH: thyrotropin-releasing hormone

TSH: Thyroid stimulating hormone

Annex 1 Iodine concentrations in edible tissues and products

Table 1 Iodine concentrations in edible tissues and products (mg/kg)

Species - category	n	Muscle	Liver	Kidney	Milk	Eggs	Reference
	86	Red meat : 0.059 DM					Haldimann *et al* . (2005) [a]
		Carcass meat: 0.09					Rose *et al* . (2001)[a]
Poultry	30	Poultry: 0.066 DM					Haldimann *et al* . (2005) [a]
		Poultry: 0.1					Rose *et al* . (2001)[a]
	4					Yolk: 1.413 DM	Haldimann *et al* . (2005) [a]
	14					White: 0.219 DM	
						0.48	Rose *et al* . (2001)[a]
Dairy	22				0.690 DM		Haldimann *et al* . (2005) [a]
					0.32		Rose *et al* . (2001)[a]
Fish	34	Fish, marine: 2.112 DM					Haldimann *et al* . (2005) [a]
	17	Fish, freshwater: 0.375 DM					
		Fish: 1.3					Rose *et al* . (2001)[a]

[a] Total diet study

<u>**Annex 1: References**</u>

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Annex 2: Iodine concentrations in edible tissues and products linked with the dietary intake of various iodine compounds and doses

Table 1 Iodine concentrations in edible tissues and products of pigs (µg/kg)

Species / category	Source of I supplemented	Dose of I supplemented (mg I/kg)	I content of complete feed [1] (mg I/kg)	Duration of study	Liver	Kidney	Muscle	Reference
Piglets			1.05	11 d	27.3 [b]	31.4 [b]	*M. psoas* : 15.5 [b] *M. longissimus dorsi* : 19.9 [b]	Dierick *et al.* (2009)
	Seaweed *Ascophyllum nodosum*	9	10		117.7 [a]	214.3 [a]	*M. psoas* : 59.5 [a] *M. longissimus dorsi* : 55.4 [a]	
Pigs			PI: 0.25 PII: 0.09	97 - 125 d [2]			3.9 [c]	Franke *et al* . (2008) [3]
	Calcium iodate	0.5	PI: 0.31 PII: 0.51				6.0 [c]	
		1	PI: 1.24 PII: 0.73				8.5 [b]	
		2	PI: 1.98 PII: 2.43				10.8 [b]	
		5	PI: 4.19 PII: 4.56				17.1 [a]	
Piglets			0.22		53.3 [a]	56.6 [a]	32.0 [a]	He *et al* . (2002)
	Potassium iodide	5		90 d	86.1 [b]	94.1 [b]	38.5 [b]	
	Potassium iodide	8			115.1 [c]	104.6 [b]	50.6 [bc]	
	Algae *Laminaria digitata*	5			126.6 [c]	97.2 [b]	86.1 [bc]	
	Algae *Laminaria digitata*	8			163.6 [d]	127.8 [c]	94.1 [c]	
Pigs	KI	0.125	0.140	105 d			*M. longissimus:* 3.4	Schöne *et al* . (2006)
	KI	0.250					*M. longissimus* : 4.1	

[1]: Data from feed analysis; Franke *et al* . (2008): PI: diet from 27 - 70 kg bw; PII: diet from 70 - 115 kg bw; [2]: trial covered a live weight period from 27 to 115 kg.

[3]: reported muscle concentrations are concentrations in the combined fraction 'muscle + fat'

Statistics : Dierick *et al* . (2009): means with different superscripts within a column differ significantly ($P < 0.001$)

Franke *et al* . (2008): means with different superscripts within a column differ significantly ($P < 0.05$)

He *et al* . (2002): means with different superscripts within a column differ significantly ($P < 0.05$), Anova

Schöne *et al* . (2006): means did not differ significantly, Newman-Keuls test

Table 1 (continued) Iodine concentrations in edible tissues and products of poultry (µg/kg)

Species / category	Source of I supplemented	Dose of I supplemented (mg I/kg)	I content of complete feed [1] (mg I/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Laying hens			0.80	210 d				albumen: 48 [e] yolk: 443 [e]	Yalçin *et al*. (2004)
	Calcium iodate	3	2.90					albumen: 107 [d] yolk: 664 [d]	
	Calcium iodate	6	5.20					albumen: 180 [c] yolk: 1122 [c]	
	Calcium iodate	12	11.10					albumen: 290 [b] yolk: 1953 [b]	
	Calcium iodate	24	21.50					albumen: 511 [a] yolk: 3352 [a]	
Poultry			0.03 DM		30 DM	88 DM	32 DM		EFSA (2005)[2]
	KIO_3	0.1 DM			45 DM	97 DM	57 DM		
	KIO_3	1 DM			71 DM	126 DM	73 DM		
	KIO_3	10 DM			525 DM	558 DM	385 DM		
	KI	10 DM			901 DM	646 DM	302 DM		
	KIO_3	100 DM			5872 DM	5913 DM	1114 DM		
	KI	100 DM			9184 DM	6385 DM	1248 DM		

[1]: Data from feed analysis; [2]: reference herein

Statistics: Yalcin *et al*. (2004): means with the same superscripts do not differ significantly ($P < 0.05$)

Table 1 (continued) Iodine concentrations in edible tissues and products of ruminants (µg/kg)

Species / category	Source of I supplemented	Dose of I supplemented (mg I/kg)	I content of complete feed [1] (mg I/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Goats		0.04 DM			37 DM	64 DM	108 DM		EFSA (2005)[2]
		0.40 DM			180 DM	261 DM	202 DM		
		0.06 DM			60 DM	80 DM	104 DM		
		0.11 DM			93 DM	129 DM	112 DM		
		0.63 DM			214 DM	301 DM	211 DM		
Sheep		0.1 DM			46 DM	67 DM			
		0.36 DM			117 DM	206 DM			
Dairy cattle			0.18 DM	21 d				83^{D}	Franke *et al*. (2009)
	KI	0.5 DM	0.61 DM					158^{D}	
	KI	1 DM	1.37 DM					214^{D}	
	KI	2 DM	1.98 DM					550^{C}	
	KI	3 DM	2.69 DM					638^{C}	
	KI	4 DM	3.93 DM					1085^{B}	
	KI	5 DM	4.81 DM					1464^{A}	
			0.18 DM					72^{D}	
	$Ca(IO_3)_2$	0.5 DM	0.71 DM					188^{D}	
	$Ca(IO_3)_2$	1 DM	1.37 DM					231^{D}	
	$Ca(IO_3)_2$	2 DM	1.84 DM					584^{C}	
	$Ca(IO_3)_2$	3 DM	2.98 DM					930^{B}	
	$Ca(IO_3)_2$	4 DM	3.58 DM					1188^{B}	
	$Ca(IO_3)_2$	5 DM	4.78 DM					1578^{A}	
Dairy cattle			0.2 DM	14 d				107	Schöne *et al*. (2009)
	$Ca(IO_3)_2.6H_2O$		1.3 DM					357	
	$Ca(IO_3)_2.6H_2O$		5.0 DM					1145	
	$Ca(IO_3)_2.6H_2O$		10.1 DM					2698	

[1]: Data from feed analysis; [2]: Reference herein

Statistics: Franke *et al*. (2009): values with different superscripts (same supplement) are significantly different ($P < 0.05$)

Annex 2: References

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Annex 3.1 Iodine Requirements

Pigs:

Category - Definition	I Req. (NRC, 1998) (mg/kg) (a)	Category - Definition	I Req. (GFE, 2008) (mg/kg DM) (b)
Pigs: 3 - 5 kg	0.14	Piglets	0.15
Pigs: 5- 10 kg	0.14		
Pigs: 10 - 20 kg	0.14	Growing - fattening pigs	0.15
Pigs: 20 - 50 kg	0.14		
Pigs: 50 - 80 kg	0.14		
Pigs: 80 - 120 kg	0.14		
Sows: gestation	0.14	Breeding sows	0.6
Sows: lactation	0.14		
		Boars	0.6

Poultry:

Category - Definition	I Req. (NRC, 1994) (mg/kg) (a)	Category - Definition	I Req. (GfE, 1999) (mg /kg DM)
Broilers (0 - 8 weeks)	0.35	Broiler (Mast Broiler; Aufzucht Küken)	0.5
Immature leghorn- Type chickens (0-6 wk) white	0.35	Chickens reared for laying (Junghennen)	0.4
Immature leghorn- Type chickens (6 wk - first egg) white	0.35		
Immature leghorn- Type chickens (0-6 wk) brown	0.33		
Immature leghorn- Type chickens (6 wk - first egg) brown	0.33		
Leghorn-Type white egg layers (80 g FI/day)	0.044	Layers (Eiproduction Legehennen)	0.5
Leghorn-Type white egg layers (100 g FI/day)	0.035		
Leghorn-Type white egg layers (120 g FI/day)	0.029		
		Female birds reared for breeding (Zuchthennen)	0.5
Growing turkeys (0 - 24 wk)	0.4		
Turkey holding hens	0.4		
Turkey laying hens	0.4		

Bovines:

Category - Definition	I Req. (Meschy, 2007) (mg/kg DM)
Bovines	0.15

Bovines: Beef Cattle

Category - Definition	I Req. (NRC, 2000) (mg/kg DM)	Category - Definition	I Req. (GfE, 1995) (mg/kg DM)
Growing and finishing	0.50	Growing and finishing from 175 kg on	0.25 (**)
Cows gestation	0.50		
Cows early lactation	0.50		

Bovines: Dairy Cattle

Category - Definition	I Req. (NRC, 2001) (mg/kg DM)	Category - Definition	I Req. (CVB, 2007) (mg/kg DM)
Lactating cow: Holstein - 90 days in milk	0.4 - 0.6	Lactating cows (FI: 20 kg/day)	0.5
Lactating cow: Jersey	0.35 - 0.44	Lactating cows (FI: 40 kg/day)	0.5
Dry cows: Holstein (240 d pregnant)	0.4	Dry cows. 8 -3 weeks before calving	0.1
Dry cows: Holstein (279 d pregnant)	0.5	Dry cows. 3 - 0 weeks before calving	0.1

Sheep

Category - Definition	I Req. (Meschy, 2007) (mg/kg DM)
Sheep	0.15

	I Req. (NRC, 2007 (b)) (mg/day)	Category - Definition	I Req. (NRC, 2007 (b)) (mg /day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	0.3		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	1.4		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	0.9	Mature ewes; breeding. DM intake: 0.85 kg/day	0.4
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	2.5	Mature ewes; breeding. DM intake: 2.18 kg/day	1.1
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	1.1	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	3.5	Mature ewes; early lact.; DM intake: 2.14 kg/day	1.7
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	0.9	Mature ewes; early lact.; DM intake: 5.29 kg/day	4.2
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	2.1	Mature ewes; late lact.; DM intake: 2.35 kg/day	1.9
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	1.7	Mature ewes; late lact.; DM intake: 4.05 kg/day	3.2
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	2.9		

Goats

Category - Definition	I Req. (GfE, 2003) (mg/kg DM)	Category - Definition	I Req. (Meschy, 2007) (mg/kg DM)
Goats	0.30 - 0.80	Goats	0.15

	I Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	I Req. (NRC, 2007 (b)) (mg /day)
Kids; bw: 10 kg; DM intake: 0.35 kg/day	0.18	Mature does; breeding; DM intake: 0.60 kg/day	0.30
Kids; bw: 10 kg; DM intake: 0.39 kg/day	0.19	Mature does; breeding; DM intake: 1.86 kg/day	0.93
Kids; bw: 40 kg; DM intake: 1.10 kg/day	0.55		
Kids; bw: 40 kg; DM intake: 1.41 kg/day	0.71	***Milk yield: 4.65 - 6.43 kg/day***	
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	0.76	Dairy does; early lactation; DM intake: 2.81 kg/day	2.25
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	2.10	Dairy does; early lactation; DM intake: 4.83 kg/day	3.86
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	1.23	***Milk yield: 6.98 - 9.65 kg/day***	
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	3.32	Dairy does; early lactation; DM intake: 3.83 kg/day	3.06
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	0.56	Dairy does; early lactation; DM intake: 5.43 kg/day	4.34
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	1.64	***Milk yield: 1.99 - 2.76 kg/day***	
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	1.00	Dairy does; late lactation; DM intake: 2.48 kg/day	1.98
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	2.12	Dairy does; late lactation; DM intake: 3.64 kg/day	2.91
		Milk yield: 2.99 - 4.13 kg/day	
		Dairy does; late lactation; DM intake: 2.51 kg/day	2.01
		Dairy does; late lactation; DM intake: 4.53 kg/day	3.63

Horses

Category - Definition	I Req. (NRC, 2007) (mg/day)	Category - Definition	I Req. (NRC, 2007) (mg/day)
MBW 200 kg; Adult; no work	1.4	MBW 400 kg; Adult; no work	2.8
MBW 200 kg; Adult; working: light exercise	1.4	MBW 400 kg; Adult; working: light exercise	2.8
MBW 200 kg; Adult; working: moderate exercise	1.6	MBW 400 kg; Adult; working: moderate exercise	3.2
MBW 200 kg; Adult; working: (very) heavy exercise	1.8	MBW 400 kg; Adult; working: (very) heavy exercise	3.6
MBW 200 kg; Stallions nonbreeding; breeding	1.4	MBW 400 kg; Stallions nonbreeding; breeding	2.8
MBW 200 kg; Pregnant mares (till 8 m)	1.4	MBW 400 kg; Pregnant mares (till 8 m)	2.8
MBW 200 kg; Pregnant mares (from 9 m)	1.6	MBW 400 kg; Pregnant mares (from 9 m)	3.2
MBW 200 kg; Lactating mares	1.8	MBW 400 kg; Lactating mares	3.6
MBW 200 kg; Growing animals: 4 m	0.6	MBW 400 kg; Growing animals: 4 m	1.2
MBW 200 kg; Growing animals: 6 m	0.8	MBW 400 kg; Growing animals: 6 m	1.6
MBW 200 kg; Growing animals: 12 m	1.1	MBW 400 kg; Growing animals: 12 m	2.2
MBW 200 kg; Growing animals: 18 m	1.4	MBW 400 kg; Growing animals: 18 m	2.8
MBW 200 kg; Growing animals: 24 m	1.5	MBW 400 kg; Growing animals: 24 m	3.0

Horses

Category - Definition	I Req. (NRC, 2007) (mg/day)	Category - Definition	I Req. (NRC, 2007) (mg/day)
MBW 500 kg; Adult; no work	3.5	MBW 600 kg; Adult; no work	4.2
MBW 500 kg; Adult; working: light exercise	3.5	MBW 600 kg; Adult; working: light exercise	4.2
MBW 500 kg; Adult; working: moderate exercise	4.0	MBW 600 kg; Adult; working: moderate exercise	4.8
MBW 500 kg; Adult; working: (very) heavy exercise	4.5	MBW 600 kg; Adult; working: (very) heavy exercise	5.4
MBW 500 kg; Stallions nonbreeding; breeding	3.5	MBW 600 kg; Stallions nonbreeding; breeding	4.2
MBW 500 kg; Pregnant mares (till 8 m)	3.5	MBW 600 kg; Pregnant mares (till 8 m)	4.2
MBW 500 kg; Pregnant mares (from 9 m)	4.0	MBW 600 kg; Pregnant mares (from 9 m)	4.8
MBW 500 kg; Lactating mares	4.5	MBW 600 kg; Lactating mares	5.4
MBW 500 kg; Growing animals: 4 m	1.5	MBW 600 kg; Growing animals: 4 m	1.8
MBW 500 kg; Growing animals: 6 m	2.0	MBW 600 kg; Growing animals: 6 m	2.4
MBW 500 kg; Growing animals: 12 m	2.8	MBW 600 kg; Growing animals: 12 m	3.3
MBW 500 kg; Growing animals: 18 m	3.5	MBW 600 kg; Growing animals: 18 m	4.2
MBW 500 kg; Growing animals: 24 m	3.8	MBW 600 kg; Growing animals: 24 m	4.5
MBW 900 kg; Adult; no work	6.3		
MBW 900 kg; Adult; working: light exercise	6.3		
MBW 900 kg; Adult; working: moderate exercise	7.2		
MBW 900 kg; Adult; working: (very) heavy exercise	8.1		
MBW 900 kg; Stallions nonbreeding; breeding	6.3		
MBW 900 kg; Pregnant mares (till 8 m)	6.3		
MBW 900 kg; Pregnant mares (from 9 m)	7.2		
MBW 900 kg; Lactating mares	8.1		
MBW 900 kg; Growing animals: 4 m	2.7		
MBW 900 kg; Growing animals: 6 m	3.6		
MBW 900 kg; Growing animals: 12 m	5.0		
MBW 900 kg; Growing animals: 18 m	6.3		
MBW 900 kg; Growing animals: 24 m	6.8		

Salmonids

Category - Definition	I Req. (NRC, 1993) (mg/kg)
Pacific salmon	0.6 - 1.1
Rainbow trout	1.1

Dogs

Category - Definition	I Req. (NRC, 2006) (µg/kg DM)	I adequate intake (NRC, 2006) (µg/kg DM)	I Rec. Allowance (NRC, 2006) (µg/ kg DM)
Puppies after weaning		880	880
Adult dogs at maintenance	700		880
Bitches for late gestation and peak lactation		880	880

Cats

Category - Definition	Nut. Req. (NRC, 2006) (µg/kg DM)	Adequate intake (NRC, 2006) (µg/kg DM)	Rec. Allowance (NRC, 2006) (µg/kg DM)
Kittens after weaning		1800	1800
Adult cats	1300		1400
Queens in late gestation and peak lactation		1800	1800

Glossary

(a): 90 % dry matter
(b): increase necessary for feeds containing glucosinolates
(**) Bei Kältestress und bei Rationen. die stark mit goitrogenen Stoffen (Glucosinolate.cyanogene Glycoside) belasted sind. empfiehlt sich eine höhere Jodzufuhr
MBW: Mature body weight
FI: Feed intake
lact.: lactation

Annex 3.2 Iodine Use Levels

Table 1 Supplementation recommendations, calculated background level ranges and calculated use levels for iodine (information acquired from the industry)

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg /kg)
Pigs (7 – 20 kg)	2	0.0 - 0.2	2.2	10
Pigs (20 – 30 kg)	2	0.0 - 0.2	2.2	10
Pigs (30 – 100 kg)	2	0.0 - 0.2	2.2	10
Sows	2	0.0 - 0.1	2.1	10
Broilers	2	0.0 - 0.1	2.1	10
Hens	2	0.0 - 0.2	2.2	5
Veal	1	0.0 - 0.1	1.1	10
Cattle	1.5	0.0 - 0.1	1.6	10
Dairy Cattle	1.5	0.0 - 0.1	1.6	5
Sheep	1	0.0 - 0.1	1.1	10

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use level for iodine

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	0.5 - 1.0	0.2	1.2
Pigs (15 - 50 kg)	0.4 - 1.0	0.2	1.2
Pigs (50 - 150 kg)	0.4 - 1.0	0.2	1.2
Gestating sows	0.5 - 1.0	0.1	1.1
Lactating sows	0.5 - 1.0	0.1	1.1

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Annex 4. Iodine concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB

COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	
Potato prot ASH>10	
Potato starch dried	
Potato sta heat tr	
Potato pulp CP<95	
Potato pulp CP>95	
Potatoes sweet dried	
Bone meal	
Brewers' grains dr	
Brewers' yeast dried	
Sugarb pulp SUG<100	1.85
Sugarb p SUG100-150	
Sugarb p SUG150-200	
Sugarb pulp SUG>200	
Biscuits CFAT<120	
Biscuits CFAT>120	
Blood meal spray dr	0.8
Buckwheat	
Beans phas heat tr	
Bread meal	
Casein	
Chicory pulp dried	
Citrus pulp dried	
Meat meal Dutch	
Meat meal CFAT<100	
Meat meal CFAT>100	
Peas	0.1
Barley	0.15
Barley feed h grade	
Barley mill byprod	
Grass meal CP<140	1.02
Grass meal CP140-160	1.01
Grass meal CP160-200	1.01
Grass meal CP>200	1
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	0.5
Peanut exp p with sh	
Peanut exp with sh	
Peanut extr wtht sh	
Peanut extr with sh	
Oats grain	0.16
Oats grain peeled	
Oats husk meal	
Oats mill fd h grade	
Hempseed	
Carob	

INRA

	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	0.09	
Maize	0.09	
Oats	0.1	
Oats groats		
Rice, brown	0.02	
Rye	0.08	
Sorghum	0.02	
Triticale	0.09	
Wheat, durum		
Wheat, soft	0.06	
WHEAT BY-PRODUCTS		
Wheat bran	0.08	
Wheat middlings	0.09	
Wheat shorts	0.11	
Wheat feed flour		
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%	0.18	
Wheat distillers' grains, starch >7%	0.18	
Wheat gluten feed, starch 25%		
Wheat gluten feed, starch 28%		
MAIZE BY-PRODUCTS		
Corn distillers	0.03	
Corn gluten feed	0.12	
Corn gluten meal		
Maize bran	0.09	
Maize feed flour		
Maize germ meal, expeller		
Maize germ meal, solvent extracted		
Hominy feed		
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried		
Brewers' dried grains		
Rice bran, extracted	0.32	
Rice bran, full fat		
Rice, broken	0.05	
LEGUME AND OIL SEEDS		
Chickpea		
Cottonseed, full fat		
Faba bean, coloured flowers		
Faba bean, white flowers		
Linseed, full fat	0.4	
Lupin, blue		
Lupin, white		
Pea	0.26	
Rapeseed, full fat		
Soybean, full fat, extruded	0.09	
Soybean, full fat, toasted		
Sunflower seed, full fat		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	
Cottons exp p with h	
Cottons exp with h	
Cottons extr wtht h	
Cotts extr p with h	
Cottons extr with h	
Coconut exp CFAT<100	
Coconut exp CFAT>100	
Coconut extr	1.29
Linseed	0.4
Linseed exp	0.91
Linseed extr	0.87
Lentils	
Lupins CP<335	
Lupins CP>335	
Alf meal CP<140	
Alf meal CP140-160	
Alf meal CP160-180	
Alf meal CP>180	
Poppyseed	
Macoya fruit exp	
Maize	0.2
Maize chem-h treated	0.2
Maize gluten meal	
Maize glfeed CP<200	
Maize glfd CP200-230	
Maize glfeed CP>230	
Maize germ meal extr	
Maize germ m fd exp	
Maize germ m fd extr	
Dist grains and sol	
Maize feedflour	
Maize feed meal	
Maize feed meal extr	
Maize bran	
Maize starch	
Sugarbeet molasses	0.69
Sugarc mol SUG<475	
Sugarc mol SUG>475	
Milk powder skimmed	1.1
Milk powder whole	1.14
Millet	

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	1.3	
Cottonseed meal, crude fibre 7-14%	0.1	
Cottonseed meal, crude fibre 14-20%		
Grapeseed oil meal, solvent extracted		
Groundnut meal, detoxified, crude fibre < 9%	0.44	
Groundnut meal, detoxified, crude fibre > 9%	0.06	
Linseed meal, expeller	0.31	
Linseed meal, solvent extracted	0.9	
Palm kernel meal, expeller	0.13	
Rapeseed meal	0.09	
Sesame meal, expeller	0.17	
Soybean meal, 46		
Soybean meal, 48	0.15	
Soybean meal, 50	0.25	
Sunflower meal, partially decorticated	0.09	
Sunflower meal, undecorticated	0.09	
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%		
Cassava, starch 72%		
Maize starch		
Potato tuber, dried	0.13	
Sweet potato, dried	0.07	
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	2	
Beet pulp dried, molasses added		
Beet pulp, pressed		
Brewers' yeast, dried	0.02	
Buckwheat hulls		
Carob pod meal		
Citrus pulp, dried	0.09	
Cocoa hulls		
Grape marc, dried		
Grape seeds		
Liquid potato feed		
Molasses, beet	1.1	
Molasses, sugarcane		
Potato protein concentrate		
Potato pulp, dried		
Soybean hulls		
Vinasse, different origins		
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production		
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	
Malt culms CP>200	
Nigerseed	
Horsebeans	
Horsebeans white	
Palm kernels	
Palm kern exp CF<180	0.1
Palm kern exp CF>180	0.09
Palm kernel extr	
Rapeseed	
Rapeseed exp	
Rapeseed extr CP<380	
Rapeseed extr CP>380	
Rapes meal Mervobest	
Rice wtht hulls	
Rice with hulls	
Rice husk meal	
Rice bran meal extr	
Rice feed m ASH<90	
Rice feed m ASH>90	
Rye	0.1
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	
Semameseed meal extr	0.42
Soybeans heat tr	
Soybeans not heat tr	
Soybean hulls CF<320	
Soyb hulls CF320-360	
Soybean hulls CF>360	
Soybean exp	
Soybm CF<45 CP<480	0.09
Soybm CF<45 CP>480	0.09
Soybm CF45-70 CP<450	0.09
Soybm CF45-70 CP>450	0.09
Soyb meal CF>70	0.09
Soyb meal Mervobest	
Soyb meal Rumi S	
Sorghum	
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	
Tapioca STA 625-675	
Tapioca STA 675-725	
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter		
Alfalfa, dehydrated, protein 17-18% dry matter		
Alfalfa, dehydrated, protein 18-19% dry matter		
Alfalfa, dehydrated, protein 22-25% dry matter		
Grass, dehydrated	0.65	
Wheat straw		
DAIRY PRODUCTS		
Milk powder, skimmed	0.82	
Milk powder, whole	0.69	
Whey powder, acidic		
Whey powder, sweet		
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	3	
Fish meal, protein 65%	2	
Fish meal, protein 70%	3	
Fish solubles, condensed, defatted		
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	0.34	0.05
Feather meal	0.55	0.07
Meat and bone meal, fat <7.5%	1.2	
Meat and bone meal, fat >7.5%	1.2	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	0.1
Wheat gluten meal	
Wheat glutenfeed	
Wheat middlings	
Wheat germ	
Wheat germfeed	
Wheat feedfl CF<35	
Wheat feedfl CF35-55	
Wheat feed meal	
Wheat bran	
Triticale	
Feather meal hydr	
Fat from Animals	
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	
Vinasse Sugb CP>250	
Fish meal CP<580	
Fish meal CP580-630	
Fish meal CP630-680	
Fish meal CP>680	
Meat bone m CFAT<100	
Meat bone m CFAT>100	
Whey p l lac ASH<210	
Whey p l lac ASH>210	
Whey powder	
Sunflowers deh	
Sunflowers p deh	
Sunflowers w hulls	
Sunfls exp deh	
Sunfls exp p deh	
Sunfls exp w hulls	
Sunfmeal CF<160	
Sunfmeal CF 160-200	
Sunfmeal CF 200-240	
Sunfmeal CF>240	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	
Potato pulp pr NL	
Potato pulp pressed	
Potato cut raw	
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	
Pot sta STA 650-775	
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	
Pot s g STA 425-550	
Pot s g STA 550-675	
Pot sta gel STA>675	
Brewers gr 22% DM	
Brewers gr 27% DM	
Brewers yeast CP<400	
Brewers y CP400-500	
Brewers yeast CP>500	
Beetp pressed f+sil	0.06
CCM CF<40	
CCM CF 40-60	
CCM CF>60	
Chicory pulp f+sil	
Distillers sol f	
Cheese whey CP<175	
Cheese w CP175-275	
Cheese whey CP>275	
Maize glutenf f+sil	
Maize solubles	
Wheat st FR STAt 300	
Wheat st STAtot 400	
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	
Beet rests sililed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	
Barley straw	
Grass fr April l y.	
Grass fr April n y.	
Grass fr April h y.	
Grass fr May l y.	
Grass fr May n y.	
Grass fr May h y.	
Grass fr June l y.	
Grass fr June n y.	
Grass fr June h y.	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	
Grass fr July n y.	
Grass fr July h y.	
Grass fr Aug l y.	
Grass fr Aug n y.	
Grass fr Aug h y.	
Grass fr Sept l y.	
Grass fr Sept n y.	
Grass fr Sept h y.	
Grass fr Oct l y.	
Grass fr Oct n y.	
Grass fr Oct h y.	
Grass average	
Grass horse gr past	
Grass horse same fld	
Grass sil May 2000	
Grass sil May 3500	
Grass sil May 5000	
Grass sil June 2000	
Grass sil June 3000	
Grass sil June 4000	
Grass sil Ju-Au 2000	
Grass sil Ju-Au 3000	
Grass sil Ju-Au 4000	
Grass sil Se-Oc 2000	
Grass sil Se-Oc 3000	
Grass sil average	
Grass sil horse fine	
Grass sil horse midd	
Grass sil horse crs	
Grass hay good qual	
Grass hay av qual	
Grass hay poor qual	
Grass hay horse fine	
Grass hay horse midd	
Grass hay horse crs	
Grass bales ad	
Grass seeds straw	
Oat straw	
Clover red fresh	
Clover red silage	
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	7
Lucerne hay	
Lucerne (alfalfa) ad	9
Maize Cob with leaves silage	31
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	
Maize fod fr DM<240	
Maize f fr DM240-280	
Maize f fr DM280-320	
Maize fod fr DM 320	
Maize sil DM < 240	
Maize sil DM240-280	
Maize sil DM280-320	
Maize sil DM 320	
Maize (Fodder) ad	
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	
Chicory rts not frcd	
Chicory rts frcd cleaned	
Chicory rts frcd dirty	
Carrots	
Sunflower silage	

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	
Calcium carbonate	
Diammonium phosphate	
Difluorinated phosphate	
Dicalcium phosphate	
Mono-dicalcium phosphate	
Monoammonium phosphate	
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of iodine in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	69.1	89.2	4	6	0.096	0.087
Piglet Starter II (complete feed)	20	70.2	77.7	5	8	0.093	0.074
Pig Grower (complete feed)	19	71.8	88.4	5	9	0.091	0.111
Pig Finisher (complete feed)	18	66.9	90.6	4	8	0.084	0.117
Sows, gestating (complete feed)	18	51.5	83.1	4	8	0.077	0.177
Sows, lactating (complete feed)	20	62.6	78.1	5	9	0.082	0.119
Starter Chicks (complete feed)	15	75.4	84.0	3	5	0.093	0.097
Chicken reared for laying (complete feed)	17	59.5	79.5	3	6	0.074	0.062
Layer Phase I (complete feed)	16	64.1	86.5	3	6	0.084	0.073
Layer Phase II (complete feed)	16	56.7	78.5	3	6	0.076	0.069
Broiler Starter (complete feed)	14	76.6	91.6	3	4	0.105	0.103
Broiler Grower (complete feed)	15	77.6	87.6	3	4	0.091	0.098
Broiler Finisher (complete feed)	15	77.2	87.3	2	3	0.075	0.092
Turkey Starter (complete feed)	14	87.8	92.8	3	4	0.104	0.289
Turkey Grower (complete feed)	13	88.2	90.2	3	4	0.091	0.135
Turkey Finisher (complete feed)	11	91.2	91.2	3	3	0.099	0.133
Turkey Breeder (complete feed)	8	80.8	82.8	2	3	0.149	0.102
Duck, grower/finisher (complete feed)	10	83.9	92.9	2	3	0.082	0.087
Geese, grower/finisher (complete feed)	8	97.0	97.0	4	4	0.133	0.134
Calf, milk replacer (complete feed)	10	10.0	0.0	1	0	0.009	0.000
Calf concentrate (complete feed)	17	8.3	80.7	4	9	0.018	0.474
Calf concentrate (complementary feed)	16	16.6	61.5	4	8	0.036	0.298
Cattle concentrate (complete feed)[4]	9	55.9	95.9	5	7	0.093	0.491
Cattle concentrate (complementary feed)	8	79.8	94.1	5	6	0.132	0.423
Dairy cows TMR (based on corn silage)[4]	15	9.9	97.7	3	9	0.010	0.304
Dairy cows TMR (based on grass silage)[4]	15	7.6	95.8	3	9	0.010	0.464
Dairy concentrate (complementary feed)	13	27.3	80.4	3	7	0.038	0.538
Dairy cows mineral feed (min. 40% crude ash)	8	0.0	0.0	0	0	0.000	0.000
Rabbit, breeder (complete feed)	8	11.0	57.0	2	3	0.011	0.061
Rabbit, grower/finisher (complete feed)	14	28.0	60.0	2	5	0.039	0.252
Salmon feed (wet)[4]	4	14.9	70.4	1	2	0.015	1.675
Salmon feed (dry)	6	27.4	79.4	2	3	0.025	1.614
Trout feed (dry)	12	57.9	66.4	2	3	0.052	0.394
Dog food (dry)	12	27.8	81.1	1	5	0.056	0.600
Cat food (dry)	16	15.2	68.1	2	7	0.024	0.534

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Iodine: Addendum to the monograph

Abstract

This addendum to the iodine monograph substantiates the data reported in Annex 5 of the iodine monograph in which iodine background levels are reported. The addendum provides the following information for each calculated background level: (1) the iodine concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no iodine concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated iodine content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.
The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.15	34.93	0.052	54.68
Maize	0.20	10.00	0.020	20.87
Soybeans heat tr		15.10		
Soybm CF<45 CP>480	0.09	7.50	0.007	7.04
Wheat	0.10	16.68	0.017	17.41
Wheat middlings		5.00		
Fat from Animals		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	0.096	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.15	15.00	0.023	24.27
Maize	0.20	15.81	0.032	34.11
Dist grains and sol		3.00		
Palm kern exp CF<180	0.10	4.00	0.004	4.32
Rapeseed exp		6.00		
Soybm CF<45 CP>480	0.09	7.86	0.007	7.63
Wheat	0.10	27.50	0.028	29.67
Wheat gluten meal		10.00		
Wheat middlings		2.00		
Fat from Animals		3.00		
Sunfmeal CF<160		2.55		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate		0.05		
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.093	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		2.00		
Barley	0.15	20.00	0.030	33.01
Maize	0.20	9.42	0.019	20.72
Dist grains and sol		5.00		
Palm kern exp CF<180	0.10	4.00	0.004	4.40
Rapeseed exp		7.00		
Soybm CF<45 CP>480	0.09	3.40	0.003	3.36
Wheat	0.10	35.00	0.035	38.51
Wheat middlings		7.27		
Fat from Animals		2.09		
Sunfmeal CF<160		2.32		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.091	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		2.50		
Barley	0.15	20.00	0.030	35.78
Maize	0.20	6.93	0.014	16.52
Dist grains and sol		6.21		
Palm kern exp CF<180	0.10	5.00	0.005	5.96
Rapeseed exp		1.35		
Wheat	0.10	35.00	0.035	41.74
Wheat gluten meal		3.04		
Wheat middlings		10.00		
Fat from Animals		2.00		
Sunfmeal CF<160		4.98		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.084	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		5.50		
Barley	0.15	20.00	0.030	39.10
Maize	0.20	15.26	0.031	39.77
Maize germ meal extr		7.50		
Sugarc mol SUG<475		0.10		
Palm kern exp CF<180	0.10	5.00	0.005	6.52
Wheat	0.10	11.22	0.011	14.62
Wheat glutenfeed		5.00		
Wheat middlings		7.50		
Wheat bran		12.50		
Fat from Animals		1.91		
Sunfmeal CF<160		6.11		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate		0.07		
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.077	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		2.41		
Barley	0.15	20.00	0.030	36.57
Maize	0.20	10.00	0.020	24.38
Palm kern exp CF<180	0.10	4.00	0.004	4.88
Rapeseed exp		6.00		
Soybean exp		1.39		
Soybm CF<45 CP>480	0.09	5.13	0.005	5.62
Wheat	0.10	23.43	0.023	28.56
Wheat glutenfeed		10.00		
Wheat middlings		7.50		
Fat from Animals		2.16		
Sunfmeal CF<160		4.22		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate		0.42		
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.082	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	20.00	0.040	42.81
Rapeseed exp		5.00		
Soybeans not heat tr		0.69		
Soybm CF<45 CP>480	0.09	19.79	0.018	19.07
Wheat	0.10	35.62	0.036	38.12
Wheat gluten meal		5.75		
Fat from Animals		2.00		
Sunfmeal CF<160		7.94		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate		0.56		
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.093	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Chicken reared for laying (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	15.00	0.030	40.43
Dist grains and sol		2.50		
Rapeseed exp		5.00		
Soybm CF<45 CP>480	0.09	2.95	0.003	3.58
Wheat	0.10	41.54	0.042	55.99
Wheat gluten meal		10.00		
Wheat bran		7.50		
Fat from Animals		2.00		
Sunfmeal CF<160		10.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.29		
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.074	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	20.00	0.040	47.89
Dist grains and sol		4.00		
Soybeans not heat tr		8.36		
Soybm CF<45 CP>480	0.09	5.93	0.005	6.39
Wheat	0.10	38.18	0.038	45.71
Wheat gluten meal		0.47		
Fat from Animals		2.87		
Sunfmeal CF<160		10.00		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.55		
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.084	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	20.00	0.040	52.58
Dist grains and sol		4.00		
Soybean exp		7.80		
Soybm CF<45 CP>480	0.09	6.34	0.006	7.50
Wheat	0.10	30.36	0.030	39.91
Wheat gluten meal		7.41		
Fat from Animals		3.40		
Sunfmeal CF<160		10.00		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate		0.43		
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.076	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	30.00	0.060	57.29
Maize gluten meal		2.50		
Soybeans not heat tr		15.00		
Soybm CF<45 CP>480	0.09	18.41	0.017	15.82
Wheat	0.10	28.16	0.028	26.89
Fat from Animals		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate		0.94		
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.105	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	15.00	0.030	33.11
Maize gluten meal		1.56		
Rapeseed exp		2.50		
Soybeans not heat tr		10.00		
Soybm CF<45 CP>480	0.09	20.22	0.018	20.08
Wheat	0.10	42.41	0.042	46.81
Fat from Animals		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate		0.78		
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.091	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize gluten meal		0.68		
Rapeseed exp		2.50		
Soybeans not heat tr		10.16		
Soybm CF<45 CP>480	0.09	19.32	0.017	23.11
Wheat	0.10	57.84	0.058	76.89
Fat from Animals		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate		0.39		
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	0.075	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	20.00	0.040	38.63
Soybm CF<45 CP>480	0.09	42.45	0.038	36.90
Wheat	0.10	25.35	0.025	24.48
Fats/oils vegetable		1.83		
Fish meal CP630-680		5.00		
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate		1.90		
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.82	0.104	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	6.94	0.014	15.25
Soybeans not heat tr		2.00		
Soybm CF<45 CP>480	0.09	41.24	0.037	40.79
Wheat	0.10	40.00	0.040	43.96
Fats/oils vegetable		5.00		
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		2.21		
Salt		0.30		
Total		100.00	0.091	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	11.74	0.023	23.71
Soybm CF<45 CP>480	0.09	39.50	0.036	35.90
Wheat	0.10	40.00	0.040	40.39
Fats/oils vegetable		4.60		
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		1.77		
Salt		0.30		
Total		100.00	0.099	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.20	69.44	0.139	93.12
Soybm CF<45 CP>480	0.09	11.40	0.010	6.88
Feather meal hydr		2.00		
Calcium carbonate		7.60		
Dicalcium Phosphate		1.00		
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.149	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Soybm CF<45 CP>480	0.09	15.00	0.014	16.38
Wheat	0.10	68.91	0.069	83.62
Wheat middlings		9.00		
Fats/oils veg h %d		3.87		
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate		0.90		
Premix		0.50		
Salt		0.37		
Total		100.02	0.082	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.15	10.00	0.015	11.30
Maize	0.20	34.00	0.068	51.24
Soybm CF<45 CP>480	0.09	33.00	0.030	22.38
Wheat	0.10	20.00	0.020	15.07
Calcium carbonate		1.20		
Dicalcium Phosphate		0.50		
Premix		1.00		
Salt		0.30		
Total		100.00	0.133	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	0.09	10.00	0.009	100.00
Wheat gluten meal		5.00		
Fat from Animals		6.25		
Whey p l lac ASH<210		15.00		
Whey powder		30.65		
Cheese whey CP>275		11.00		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	0.009	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		5.50		
Citrus pulp, dried		8.00		
Barley	0.15	0.54	0.001	4.44
Linseed	0.40	1.25	0.005	27.46
Sugarbeet molasses	0.69	1.00	0.007	37.89
Palm kern exp CF<180	0.10	5.50	0.006	30.20
Rapeseed		3.50		
Rapeseed extr CP>380		1.94		
Soybeans heat tr		5.37		
Wheat middlings		7.00		
Wheat feedfl CF<35		8.00		
Vinasse Sugb CP>250		1.50		
Grass hay good qual		50.00		
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	0.018	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		11.00		
Citrus pulp, dried		16.00		
Barley	0.15	1.08	0.002	4.44
Linseed	0.40	2.50	0.010	27.46
Sugarbeet molasses	0.69	2.00	0.014	37.89
Palm kern exp CF<180	0.10	11.00	0.011	30.20
Rapeseed		7.00		
Rapeseed extr CP>380		3.88		
Soybeans heat tr		10.74		
Wheat middlings		14.00		
Wheat feedfl CF<35		16.00		
Vinasse Sugb CP>250		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	0.036	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		10.01		
Barley	0.15	18.90	0.028	30.63
Linseed	0.40	7.51	0.030	32.46
Sugarbeet molasses	0.69	0.98	0.007	7.31
Soybm CF<45 CP>480	0.09	10.99	0.010	10.69
Wheat	0.10	17.50	0.018	18.91
Fats/oils veg h %d		1.60		
Grass sil average		30.00		
Premix		2.50		
Total		99.99	0.093	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		14.30		
Barley	0.15	27.00	0.041	30.66
Linseed	0.40	10.70	0.043	32.40
Sugarbeet molasses	0.69	1.40	0.010	7.31
Soybm CF<45 CP>480	0.09	15.70	0.014	10.70
Wheat	0.10	25.00	0.025	18.93
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	0.132	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		2.61		
Maize glfd CP200-230		0.95		
Maize feed meal		1.15		
Sugarbeet molasses	0.69	0.24	0.002	15.80
Palm kern exp CF<180	0.10	1.78	0.002	16.98
Rapeseed exp		0.59		
Rapeseed extr CP>380		6.18		
Soybm CF<45 CP>480	0.09	7.83	0.007	67.22
Wheat middlings		0.96		
Vinasse Sugb CP>250		0.36		
Grass sil average		26.89		
Maize sil DM280-320		50.23		
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.95	0.010	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		4.72		
Maize glfd CP200-230		1.72		
Maize feed meal		2.08		
Sugarbeet molasses	0.69	0.43	0.003	30.40
Palm kern exp CF<180	0.10	3.22	0.003	32.99
Rapeseed exp		1.07		
Rapeseed extr CP>380		4.39		
Soybm CF<45 CP>480	0.09	3.97	0.004	36.61
Wheat middlings		1.74		
Vinasse Sugb CP>250		0.64		
Grass sil average		49.18		
Maize sil DM280-320		26.46		
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		99.94	0.010	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		22.00		
Maize glfd CP200-230		8.00		
Maize feed meal		9.70		
Sugarbeet molasses	0.69	2.00	0.014	36.25
Palm kern exp CF<180	0.10	15.00	0.015	39.40
Rapeseed exp		5.00		
Rapeseed extr CP>380		15.00		
Soybm CF<45 CP>480	0.09	10.30	0.009	24.35
Wheat middlings		8.10		
Vinasse Sugb CP>250		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	0.038	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate		8.80		
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00		

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.15	2.00	0.003	27.03
Alf meal CP160-180		40.00		
Soybm CF<45 CP>480	0.09	9.00	0.008	72.97
Wheat germfeed		46.00		
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	0.011	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG150-200		10.00		
Barley	0.15	23.00	0.035	88.46
Alf meal CP160-180		35.00		
Soybm CF<45 CP>480	0.09	5.00	0.005	11.54
Wheat bran		12.00		
Fat from Animals		2.00		
Sunfmeal CF 200-240		10.00		
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate		1.90		
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	0.039	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat	0.10	14.90	0.015	100.00
Fish meal CP630-680		55.53		
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		99.99	0.015	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Soybm CF<45 CP>480	0.09	20.00	0.018	70.81
Wheat	0.10	7.42	0.007	29.19
Fish meal CP630-680		51.96		
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	0.025	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	0.09	55.00	0.050	94.52
Wheat	0.10	2.87	0.003	5.48
Wheat gluten meal		11.80		
Fat from Animals		16.00		
Fish meal CP630-680		8.50		
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	0.052	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Sugarb p SUG100-150		4.30		
Meat meal CFAT<100		40.62		
Maize	0.20	27.80	0.056	100.00
Maize starch		2.78		
Rice wtht hulls		7.30		
Fat from Animals		9.60		
Brewers y CP400-500		1.10		
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.056	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Brewers' yeast dried		1.80		
Meat meal Dutch		1.33		
Greaves		29.76		
Linseed	0.40	3.00	0.012	49.57
Wheat	0.10	12.21	0.012	50.43
Wheat glutenfeed		2.06		
Wheat feedfl CF<35		20.00		
Feather meal hydr		18.00		
Fat from Animals		7.97		
Fish meal CP630-680		1.00		
Meat bone m CFAT>100		1.00		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.024	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	34.93	0.031	36.02
Maize	0.09	10.00	0.009	10.31
Wheat, soft	0.06	16.68	0.010	11.47
Wheat middlings	0.09	5.00	0.005	5.16
Soybean, full fat, extruded	0.09	15.10	0.014	15.57
Soybean meal, 50	0.25	7.50	0.019	21.48
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	0.087	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	15.00	0.014	18.22
Maize	0.09	15.81	0.014	19.21
Wheat, soft	0.06	27.50	0.017	22.27
Wheat middlings	0.09	2.00	0.002	2.43
Wheat gluten feed, starch 28%		10.00		
Corn distillers	0.03	3.00	0.001	1.21
Palm kernel meal, expeller	0.13	4.00	0.005	7.02
Rapeseed cake		6.00		
Soybean meal, 50	0.25	7.86	0.020	26.54
Sunflower meal, undecorticated	0.09	2.55	0.002	3.10
Tallow		3.00		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate		0.05		
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.074	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	20.00	0.018	16.17
Maize	0.09	9.42	0.008	7.61
Wheat, soft	0.06	35.00	0.021	18.87
Wheat middlings	0.09	7.27	0.007	5.88
Corn distillers	0.03	5.00	0.002	1.35
Palm kernel meal, expeller	0.13	4.00	0.005	4.67
Rapeseed cake		7.00		
Soybean meal, 50	0.25	3.40	0.008	7.63
Sunflower meal, undecorticated	0.09	2.32	0.002	1.87
Beet pulp, dried	2.00	2.00	0.040	35.94
Tallow		2.09		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.111	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	20.00	0.018	15.37
Maize	0.09	6.93	0.006	5.32
Wheat, soft	0.06	35.00	0.021	17.94
Wheat middlings	0.09	10.00	0.009	7.69
Wheat gluten feed, starch 28%		3.04		
Corn distillers	0.03	6.21	0.002	1.59
Palm kernel meal, expeller	0.13	5.00	0.007	5.55
Rapeseed cake		1.35		
Sunflower meal, undecorticated	0.09	4.98	0.004	3.83
Beet pulp, dried	2.00	2.50	0.050	42.71
Tallow		2.00		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.117	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	20.00	0.018	10.15
Maize	0.09	15.26	0.014	7.75
Wheat, soft	0.06	11.22	0.007	3.80
Wheat bran	0.08	12.50	0.010	5.64
Wheat middlings	0.09	7.50	0.007	3.81
Wheat gluten feed, starch 28%		5.00		
Maize germ meal, expeller		7.50		
Palm kernel meal, expeller	0.13	5.00	0.007	3.67
Sunflower meal, undecorticated	0.09	6.11	0.006	3.10
Beet pulp, dried	2.00	5.50	0.110	62.08
Molasses, sugarcane		0.10		
Tallow		1.91		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate		0.07		
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.177	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	20.00	0.018	15.11
Maize	0.09	10.00	0.009	7.56
Wheat, soft	0.06	23.43	0.014	11.80
Wheat middlings	0.09	7.50	0.007	5.67
Wheat gluten feed, starch 28%		10.00		
Soybean, full fat, extruded	0.09	1.39	0.001	1.05
Palm kernel meal, expeller	0.13	4.00	0.005	4.37
Rapeseed cake		6.00		
Soybean meal, 50	0.25	5.13	0.013	10.76
Sunflower meal, undecorticated	0.09	4.22	0.004	3.19
Beet pulp, dried	2.00	2.41	0.048	40.51
Tallow		2.16		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate		0.42		
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.119	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	20.00	0.018	18.63
Wheat, soft	0.06	35.62	0.021	22.12
Wheat gluten feed, starch 28%		5.75		
Soybean, full fat, extruded	0.09	0.69	0.001	0.64
Rapeseed cake		5.00		
Soybean meal, 50	0.25	19.79	0.049	51.21
Sunflower meal, undecorticated	0.09	7.94	0.007	7.40
Tallow		2.00		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate		0.56		
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.097	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	15.00	0.014	21.93
Wheat, soft	0.06	41.54	0.025	40.49
Wheat bran	0.08	7.50	0.006	9.75
Wheat gluten feed, starch 28%		10.00		
Corn distillers	0.03	2.50	0.001	1.22
Rapeseed cake		5.00		
Soybean meal, 50	0.25	2.95	0.007	11.99
Sunflower meal, undecorticated	0.09	10.00	0.009	14.62
Tallow		2.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.29		
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.062	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	20.00	0.018	24.50
Wheat, soft	0.06	38.18	0.023	31.18
Wheat gluten feed, starch 28%		0.47		
Corn distillers	0.03	4.00	0.001	1.63
Soybean, full fat, extruded	0.09	8.36	0.008	10.24
Soybean meal, 50	0.25	5.93	0.015	20.19
Sunflower meal, undecorticated	0.09	10.00	0.009	12.25
Tallow		2.87		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.55		
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.073	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	20.00	0.018	25.98
Wheat, soft	0.06	30.36	0.018	26.29
Wheat gluten feed, starch 28%		7.41		
Corn distillers	0.03	4.00	0.001	1.73
Soybean, full fat, extruded	0.09	7.80	0.007	10.13
Soybean meal, 50	0.25	6.34	0.016	22.88
Sunflower meal, undecorticated	0.09	10.00	0.009	12.99
Tallow		3.40		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate		0.43		
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.069	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	30.00	0.027	26.10
Wheat, soft	0.06	28.16	0.017	16.34
Corn gluten meal		2.50		
Soybean, full fat, extruded	0.09	15.00	0.014	13.05
Soybean meal, 50	0.25	18.41	0.046	44.51
Tallow		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate		0.94		
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.103	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	15.00	0.014	13.71
Wheat, soft	0.06	42.41	0.025	25.84
Corn gluten meal		1.56		
Soybean, full fat, extruded	0.09	10.00	0.009	9.14
Rapeseed cake		2.50		
Soybean meal, 50	0.25	20.22	0.051	51.31
Tallow		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate		0.78		
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.098	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat, soft	0.06	57.84	0.035	37.66
Corn gluten meal		0.68		
Soybean, full fat, extruded	0.09	10.16	0.009	9.93
Rapeseed cake		2.50		
Soybean meal, 50	0.25	19.32	0.048	52.41
Tallow		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate		0.39		
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	0.092	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	20.00	0.018	6.22
Wheat, soft	0.06	25.35	0.015	5.26
Soybean meal, 50	0.25	42.45	0.106	36.68
Fish meal, protein 70%	3.00	5.00	0.150	51.84
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate		1.90		
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.97	0.289	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	6.94	0.006	4.62
Wheat, soft	0.06	40.00	0.024	17.76
Soybean, full fat, extruded	0.09	2.00	0.002	1.33
Soybean meal, 50	0.25	41.24	0.103	76.29
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		2.21		
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	0.135	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	11.74	0.011	7.93
Wheat, soft	0.06	40.00	0.024	18.00
Soybean meal, 50	0.25	39.50	0.099	74.07
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		1.77		
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	0.133	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	69.44	0.062	61.27
Soybean meal, 50	0.25	11.40	0.029	27.94
Feather meal	0.55	2.00	0.011	10.78
Calcium carbonate		7.60		
Dicalcium Phosphate		1.00		
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.102	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat, soft	0.06	68.91	0.041	47.55
Wheat middlings	0.09	9.00	0.008	9.32
Soybean meal, 50	0.25	15.00	0.038	43.13
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate		0.90		
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	0.087	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	10.00	0.009	6.71
Maize	0.09	34.00	0.031	22.82
Wheat, soft	0.06	20.00	0.012	8.95
Soybean meal, 50	0.25	33.00	0.083	61.52
Calcium carbonate		1.20		
Dicalcium Phosphate		0.50		
Premix		1.00		
Salt		0.30		
Total		100.00	0.134	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat gluten feed, starch 25%		5.00		
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic		30.65		
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00		

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	0.54	<0.001	0.10
Wheat middlings	0.09	7.00	0.006	1.33
Wheat feed flour		8.00		
Linseed, full fat	0.40	1.25	0.005	1.06
Rapeseed, full fat		3.50		
Soybean, full fat, toasted		5.37		
Palm kernel meal, expeller	0.13	5.50	0.007	1.51
Rapeseed meal	0.09	1.94	0.002	0.37
Beet pulp, dried	2.00	5.50	0.110	23.21
Citrus pulp, dried	0.09	8.00	0.007	1.52
Molasses, beet	1.10	1.00	0.011	2.32
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	0.65	50.00	0.325	68.58
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	0.474	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	1.08	0.001	0.33
Wheat middlings	0.09	14.00	0.013	4.23
Wheat feed flour		16.00		
Linseed, full fat	0.40	2.50	0.010	3.36
Rapeseed, full fat		7.00		
Soybean, full fat, toasted		10.74		
Palm kernel meal, expeller	0.13	11.00	0.014	4.80
Rapeseed meal	0.09	3.88	0.003	1.17
Beet pulp, dried	2.00	11.00	0.220	73.88
Citrus pulp, dried	0.09	16.00	0.014	4.84
Molasses, beet	1.10	2.00	0.022	7.39
Vinasse, different origins		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.47	0.298	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	18.90	0.017	3.46
Wheat, soft	0.06	17.50	0.011	2.14
Linseed, full fat	0.40	7.51	0.030	6.12
Soybean meal, 50	0.25	10.99	0.027	5.60
Beet pulp, dried	2.00	10.01	0.200	40.77
Molasses, beet	1.10	0.98	0.011	2.20
Grass silage	0.65	30.00	0.195	39.71
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	0.491	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	27.00	0.024	5.75
Wheat, soft	0.06	25.00	0.015	3.55
Linseed, full fat	0.40	10.70	0.043	10.12
Soybean meal, 50	0.25	15.70	0.039	9.28
Beet pulp, dried	2.00	14.30	0.286	67.65
Molasses, beet	1.10	1.40	0.015	3.64
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	0.423	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat middlings	0.09	0.96	0.001	0.28
Corn gluten feed	0.12	0.95	0.001	0.37
Corn gluten meal		1.15		
Palm kernel meal, expeller	0.13	1.78	0.002	0.76
Rapeseed meal	0.09	6.18	0.006	1.83
Rapeseed cake		0.59		
Soybean meal, 50	0.25	7.83	0.020	6.43
Beet pulp, dried	2.00	2.61	0.052	17.15
Molasses, beet	1.10	0.24	0.003	0.87
Vinasse, different origins		0.36		
Grass silage	0.65	26.89	0.175	57.44
Corn silage	0.09	50.23	0.045	14.86
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	0.304	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat middlings	0.09	1.74	0.002	0.34
Corn gluten feed	0.12	1.72	0.002	0.44
Corn gluten meal		2.08		
Palm kernel meal, expeller	0.13	3.22	0.004	0.90
Rapeseed meal	0.09	4.39	0.004	0.85
Rapeseed cake		1.07		
Soybean meal, 50	0.25	3.97	0.010	2.14
Beet pulp, dried	2.00	4.72	0.094	20.33
Molasses, beet	1.10	0.43	0.005	1.02
Vinasse, different origins		0.64		
Grass silage	0.65	49.18	0.320	68.85
Corn silage	0.09	26.46	0.024	5.13
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	0.464	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat middlings	0.09	8.10	0.007	1.36
Corn gluten feed	0.12	8.00	0.010	1.79
Corn gluten meal		9.70		
Palm kernel meal, expeller	0.13	15.00	0.020	3.63
Rapeseed meal	0.09	15.00	0.014	2.51
Rapeseed cake		5.00		
Soybean meal, 50	0.25	10.30	0.026	4.79
Beet pulp, dried	2.00	22.00	0.440	81.84
Molasses, beet	1.10	2.00	0.022	4.09
Vinasse, different origins		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	0.538	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate		8.80		
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00		

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	2.00	0.002	2.95
Wheat bran	0.08	46.00	0.037	60.23
Soybean meal, 50	0.25	9.00	0.023	36.82
Alfalfa, dehydrated		40.00		
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	0.061	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Barley	0.09	23.00	0.021	8.22
Wheat bran	0.08	12.00	0.010	3.81
Soybean meal, 50	0.25	5.00	0.013	4.96
Sunflower meal, undecorticated	0.09	10.00	0.009	3.57
Beet pulp, dried	2.00	10.00	0.200	79.43
Lard		2.00		
Alfalfa, dehydrated		35.00		
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate		1.90		
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	0.252	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat, soft	0.06	14.90	0.009	0.53
Fish meal, protein 70%	3.00	55.53	1.666	99.47
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	1.675	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat, soft	0.06	7.42	0.004	0.28
Soybean meal, 50	0.25	20.00	0.050	3.10
Fish meal, protein 70%	3.00	52.00	1.560	96.63
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	1.614	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat, soft	0.06	2.87	0.002	0.44
Corn gluten meal		11.80		
Soybean meal, 50	0.25	55.00	0.138	34.88
Maize starch		3.00		
Fish meal, protein 70%	3.00	8.50	0.255	64.68
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	0.394	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Maize	0.09	27.80	0.025	4.17
Rice, brown	0.02	7.30	0.001	0.24
Maize starch		2.78		
Beet pulp, dried	2.00	4.30	0.086	14.33
Brewers' yeast, dried	0.02	1.10	<0.001	0.04
Lard		9.60		
Meat and bone meal, fat <7.5%	1.20	40.62	0.487	81.22
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.600	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg I/kg feed material	% feed material	mg I/kg complete feedingstuff	I (% contribution)
Wheat, soft	0.06	12.21	0.007	1.37
Wheat feed flour		20.00		
Wheat gluten feed, starch 25%		2.06		
Linseed, full fat	0.40	3.00	0.012	2.25
Brewers' yeast, dried	0.02	1.80	<0.001	0.07
Fish meal, protein 70%	3.00	1.00	0.030	5.62
Feather meal	0.55	18.00	0.099	18.55
Meat and bone meal, fat <7.5%	1.20	29.76	0.357	66.91
Meat and bone meal, fat >7.5%	1.20	2.33	0.028	5.24
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.534	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Iron

Executive summary of the monograph for iron

Several iron compounds are presently authorized as feed and food additives in the EU. Iron is an essential trace element which has been identified as a cofactor of many enzymes and proteins among which are most of the enzymes of the Krebs cycle, cytochromes and hemoglobin. Effects of iron deficiency include impaired physical performance, anemia, adverse pregnancy outcome, impaired psychomotor development and cognitive performance, and reduced immune function. Iron deficiency is of limited importance in most livestock species. There is a high tolerance towards excess dietary iron in all species because of a powerful mucosal block to iron absorption. Hence, the primary effect of high iron intakes is gastrointestinal distress. In livestock the consumption of large amounts of iron over sustained periods may lead to a tissue overload and reactive free iron levels may cause peroxidative damage, especially in the liver. Characteristic signs of chronic iron toxicosis include reduced feed intake, growth rate, and efficiency of feed conversion. Excessive amounts of iron are preferentially deposited in the liver, spleen and bone marrow.

Acute poisoning of excessive ingestion of iron causes mucosal erosion in the stomach and intestine. Toxic shock and acute hepatic necrosis are the most common causes of death resulting from iron poisoning. Oxidant induced damage to naked DNA was shown to be enhanced by iron. This may help to explain slow organ damage caused by iron overload. Clinical symptoms of chronic iron overload include cirrhosis, diabetes and heart dysfunction. There is no clinical evidence that excess iron plays a role in the pathogenesis of cancers. IOM selected gastrointestinal effects as a toxicological endpoint for setting an upper intake level (UL). A UL value for iron for adults of 45 mg/day was established by IOM. Inhalation of iron fumes can give rise to deposition in the lungs but the deposition does not lead to fibrosis. There were no indications that the iron supplementation of feed would have an environmental impact.

Iron Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Several iron compounds are presently authorized as feed and food supplements. These are considered of importance in human and animal nutrition (Chapter 2).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Iron compounds presently authorized in the EU as additives (EC 2112/2003[1] and EC 479/2006[2]) are listed in Table 1.

Table 1 Conditions of use of iron compounds as additives in feedingstuffs according to the Commission Regulations EC 2112/2003[1] and EC 479/2006[2]

<table>
<tr><th>Additive</th><th>Chemical formula</th><th>Maximum content of the element in the complete feedingstuff</th></tr>
<tr><td>Ferrous carbonate</td><td>$FeCO_3$</td><td rowspan="11">Ovine: 500 (total) mg/kg of the complete feedingstuff
Pet animals: 1250 (total) mg/kg of the complete feedingstuff
Pigs:
- Piglets up to one week before weaning: 250 mg/day
- Other pigs: 750 (total) mg/kg of the complete feedingstuff

Other species: 750 (total) mg/kg of the complete feedingstuff</td></tr>
<tr><td>Ferrous chloride, tetrahydrate</td><td>$FeCl_2.4H_2O$</td></tr>
<tr><td>Ferric chloride, hexahydrate</td><td>$FeCl_3.6H_2O$</td></tr>
<tr><td>Ferrous citrate, hexahydrate</td><td>$Fe_3(C_6H_5O_7)_2.6H_2O$</td></tr>
<tr><td>Ferrous fumarate</td><td>$FeC_4H_2O_4$</td></tr>
<tr><td>Ferrous lactate, trihydrate</td><td>$Fe(C_3H_5O_3)_2.3H_2O$</td></tr>
<tr><td>Ferric oxide</td><td>Fe_2O_3</td></tr>
<tr><td>Ferrous sulphate, monohydrate</td><td>$FeSO_4. H_2O$</td></tr>
<tr><td>Ferrous sulphate, heptahydrate</td><td>$FeSO_4.7 H_2O$</td></tr>
<tr><td>Ferrous chelate of amino acids, hydrate</td><td>$Fe(X)_{1-3}.nH_2O$
(X: anion of any amino acid derived from hydrolysed soya protein). Molecular weight not exceeding 1500 $g.mol^{-1}$</td></tr>
<tr><td>Ferrous chelate of glycine, hydrate [2]</td><td>$Fe(X)_{1-3}.nH_2O$
(X = anion of synthetic glycine)</td></tr>
</table>

[1] OJ L 317, 2.12.2003, p.22

[2] OJ L 86, 24.3.2006, p.4

In the US, the following iron compounds are allowed in animal feeds: ferric ammonium citrate, ferric chloride, ferric choline citrate complex, ferric formate, ferric phosphate, ferric pyrophosphate, ferric sulphate, ferrous carbonate, ferrous chloride, ferrous fumarate, ferrous gluconate, ferrous glycine complex, ferrous sulphate, gypsiferrous shale, iron oxide, iron reduced, iron amino acid complex, ferric methionine complex, iron amino acid chelate, iron polysaccharide complex, iron proteinate (AAFCO Official Publication §57: Mineral Products); iron ammonium citrate (AAFCO Official Publication § 87.5; Additional Special Purpose Products, anti-caking agent in salt not to exceed 0.0025 % in the finished salt). Ferric sodium pyrophosphate and ferrous lactate are not specifically defined by AAFCO, but were adopted in its publication from the Federal Code of Regulations. They are listed as generally recognized as safe in animal feeds (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

Table 2 Range of iron guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	**Range (mg/kg)**
Chickens	80 - 750
Turkeys	60 - 750
Swine, breeding	80 - 750
Swine, weanling (up to 20 kg bw)	150 - 750
Swine, other	40 - 750
Dairy cattle, calf	100 - 750
Dairy cattle, others	50 - 750
Beef cattle	10 - 750
Sheep	30 - 250
Horses	50 - 500
Goats	50 - 500
Ducks and geese	100 - 750
Salmonid fish	50 - 500
Mink	60 - 700
Rabbits, lactating	100 - 500
Rabbits, other	50 - 500

2.2 *Human nutrition*

Iron compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[3]. The authorized iron compounds are: ferrous carbonate, ferrous citrate, ferric ammonium citrate, ferrous gluconate, ferrous fumarate, ferric sodium diphosphate, ferrous lactate, ferrous sulphate, ferric diphosphate (ferric pyrophosphate), ferric saccharate, elemental iron (carbonyl + electrolytic+ hydrogen reduced), ferrous bisglycinate, ferrous L-pidolate.

- As food supplements under Regulation EC 1170/2009[4]. The authorized iron compounds are: ferrous carbonate, ferrous citrate, ferric ammonium citrate, ferrous gluconate, ferrous fumarate, ferric sodium diphosphate, ferrous lactate, ferrous sulphate, ferric diphosphate (ferric pyrophosphate), ferric saccharate, elemental iron (carbonyl + electrolytic + hydrogen reduced), ferrous bisglycinate, ferrous L-pidolate, ferrous phosphate, iron(II) taurate.

- As substances which may be added to foods under Regulation EC 1925/2006[5] as amended by Regulation EC 1170/2009[4]. The authorized iron compounds are: ferrous bisglycinate, ferrous carbonate, ferrous citrate, ferric ammonium citrate, ferrous gluconate, ferrous fumarate, ferric sodium diphosphate, ferrous lactate, ferrous sulphate, ferric diphosphate (ferric pyrophosphate), ferric saccharate, elemental iron (carbonyl + electrolytic+ hydrogen reduced).

- Directive 2008/100/EC[6] lays down a Recommended Daily Allowance (RDA) for iron of 14 mg.

In the U.S. the Code of Federal Regulations grants a generally recognized as safe status for the use as nutrient and or dietary supplement (Part 582; Subpart F) to the following iron compounds: ferric phosphate, ferric pyrophosphate, ferric sodium pyrophosphate, ferrous gluconate, ferrous lactate, ferrous sulphate,

3 Essential functions

Iron is an essential element that serves as a cofactor for many important enzymes (McDowell, 2003; NRC, 2005). Iron is present in biological systems in one of two oxidation states, and redox interconversions of the ferrous (Fe^{2+}) and ferric (Fe^{3+}) forms are central to the biological properties of this mineral (EFSA, 2004).

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[3] OJ L 269, 14.10.2009, p. 9

[4] OJ L 314, 1.12.2009, p. 36

[5] OJ L 404, 30.12.2006, p. 26

[6] OJ L 285, 29.10.2008, p. 9

Aerobic metabolism depends on iron because of its role in the functional groups of most of the enzymes of the Krebs cycle, because it functions as an electron carrier in cytochromes, and because of its role, associated with hemoglobin, in oxygen and carbon dioxide transport (NRC, 2005). A summary of enzymes that require iron, associated physiological functions and deficiency symptoms that occur when the iron supply is inadequate, is given in Table 3.

Table 3 Summary of some important iron dependent enzymes and proteins, associated essential functions and deficiency symptoms (adapted from McDowell, 2003; Ponka *et al*., 2007; Underwood & Suttle, 1999)

Enzymes	**Physiological functions**	**Deficiency symptoms**
Hemoproteins:		
Hemoglobin	Oxygen carrier, transports oxygen from the lungs to the tissues	Reduced physical performance
Myoglobin	Oxygen carrier, binds oxygen for immediate use by muscle cells	
Heme enzymes:		
Cytochromes A, B, C	Participate in the electron transfer chain where they function as electron carriers	Reduced cellular concentrations of ATP
Peroxidases	Break down of peroxide molecules in the presence of reducing agents	
Catalases		
Nonheme proteins:		
Flavin-Fe enzymes		
Transferrin	Transport of iron from intestinal absorption, storage release and hemoglobin destruction, Fe(III) carrier in plasma	Severe anemia; iron unavailable for erythropoiesis
Ferritin	Cellular iron storage	Embryonic lethality

4 Other functions

There was no information available on other functions of iron in principal literature sources.

5 Antimicrobial properties

There was no information available on antimicrobial properties of iron in principal literature sources.

6 Typical deficiency symptoms

The most important effect of iron deficiency is impaired physical performance due to reduced levels of hemoglobin, myoglobin and lower activity of iron-dependent cytochromes, leading to reduced cellular concentrations of ATP. Other deficiency symptoms include anemia, adverse pregnancy outcome, impaired psychomotor development and cognitive performance and reduced immune function (EFSA, 2004). Iron deficiency is of limited practical significance in most livestock species, but examples of situations in which animals are vulnerable to iron deficiency are newborn pigs, calves raised for veal, copper-supplemented pigs, and animals with parasitic infestations (NRC, 2005, Underwood & Suttle, 1999).

7 Animal requirements, allowances and use levels

Iron requirements for livestock species and categories established by scientific bodies are compiled in Annex 3.1; use levels are compiled in Annex 3.2.

8 Concentration of the element in feed materials

Iron concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Iron concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

There is a high tolerance towards dietary iron in all species. The powerful mucosal block to iron absorption affords protection against toxicity (Underwood & Suttle, 1999). MTL values established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels (MTL) for iron (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Swine	3000	
Poultry, cattle, sheep	500	
Rodents, horses	500	Derived from interspecies extrapolation
Fish	-	Insufficient data to set a MTL

Additionally, to the iron MTL values NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Iron toxicosis is not a common problem in most domestic animals, probably because of the limited absorption of iron when intakes are high. When animals consume large amounts of iron over sustained periods, tissue overload occurs, iron binding capacity is exceeded, and reactive (free) iron levels become sufficient to cause peroxidative damage, especially in the liver. The extent of the injury will depend on the antioxidant status of the animal and particularly its vitamin E status (NRC, 2005; Underwood & Suttle, 1999). Characteristic signs of chronic iron toxicosis include reduced feed intake, growth rate, and efficiency of feed conversion (NRC, 2005).

12 Bioavailability

12.1 General

The two major factors affecting iron absorption are the amount of body iron stores and the rate of erythropoiesis (EVM, 2003; Ponka *et al*., 2007). The availability of nonheme iron for absorption depends on the presence of ligands and reducing agents in the diet. Ascorbic acid, citric acid and amino acids are promoters of nonheme iron absorption. Phosphates, phytates and tannins prevent absorption (Ponka *et al*., 2007). Research into the influence of the iron compound on iron bioavailability for several livestock species has been reviewed by Jongbloed *et al*. (2002) (Table 5).

Table 5 Relative bioavailability assessments (%) of iron compounds compared to ferrous sulphate in livestock (Jongbloed *et al*., 2002)

Iron compound	**Pigs**	**Broiler**
Ferrous sulphate.7 H_2O	100	100
Ferrous sulphate.H_2O	100	100
Ferrous carbonate	82	27
Ferric oxide		52
Ferric choline citrate	118	
Ferric citrate	114	
Ferric ammonium citrate		115

12.2 *Indicators of iron status*

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of iron compounds in livestock (Table 6).

Table 6 Ranking of adequacy of response criterions for assessing the relative biological value of iron compounds[1] (Jongbloed *et al*., 2002)

	Pigs		Poultry	
Supplementation level →	**Suboptimal**	**Above requirement**	**Suboptimal**	**Above requirement**
Criterion				
Iron absorption (apparent)	4	1	4	1
Iron absorption (true)	4	3	4	3
Hemoglobin regeneration (blood)	3	1	3	1
Hemoglobin content (blood)	2	1	2	1
Liver / spleen iron content	1	2	1	2
Performance	1	-	1	-

[1]: the highest values correspond to the best adequacy

13 Metabolism

The primary site of iron absorption is the duodenum. Heme, derived from hemoglobin or myoglobin is taken up intact, probably by means of specific high-affinity heme binding sites in the mucosal brush border. Inorganic iron is primarily transported by DMT1 (Ponka *et al*., 2007; Underwood & Suttle, 1999). Iron is delivered as ferric iron at the serosal surface where it becomes bound to transferrin. Transferrin is involved in transport of absorbed iron to the tissues, in redistribution of storage iron and in recycling of iron from aged erythrocytes via the reticuloendothelial system. Ferritin is the main iron storage compound of the body. Its concentration in the tissues, together with that of hemosiderin, reflects the iron status of the body (Underwood & Suttle, 1999). Iron is excreted primarily via the feces. Iron that has been absorbed in the enterocytes is partly eliminated with the sloughing of these mucosal enterocytes. Iron excretion via the kidneys is very low and renal elimination is not controlled as part of iron homeostasis (EFSA, 2004)

14 Distribution in the animal body

Approximately 70 % of body iron content is present in hemoglobin (EFSA, 2004).

15 Deposition (typical concentration) in edible tissues and products

When animals are exposed to excessive amounts of iron, it is preferentially deposited in the liver, spleen, and bone marrow. With very high doses, iron may be deposited in the heart and kidneys (NRC, 2005). The iron content of milk is highly resistant to changes in the level of dietary iron (NRC, 2005). Iron concentrations in edible tissues and products are reported in Annex 1 and iron concentrations in edible tissues and products linked with dietary intake of various iron compounds and doses are reported in Annex 2.

16 Acute toxicity

Acute poisoning of excessive ingestion of iron causes mucosal erosion in the stomach and intestine. This provokes gastrointestinal symptoms which may include abdominal pain, vomiting, diarrhea with hemathemesis, and hematochezia. More severe gastrointestinal damage may include hemorrhagic gastroenteritis (EFSA, 2004; Ponka *et al*., 2007). Toxic shock and acute hepatic necrosis are the most common causes of death resulting from iron poisoning. Cardiogenic shock may occur > 24 hours after ingestion due to the direct effect of iron on the heart and due to the profound metabolic acidosis associated with iron poisoning (Ponka *et al*., 2007).

17 Genotoxicity and Mutagenicity

Oxidant induced damage to naked DNA is greatly enhanced by iron. The products of iron-mediated DNA damage are not fully characterized but include strand breaks, oxidatively modified bases, DNA-protein cross links, covalent addition products involving lipid peroxidation products and other structurally uncharacterized bulky DNA lesions. This DNA damage may help to explain slow organ damage caused by iron overload (Ponka *et al*., 2007).

18 Subchronic toxicity

Available toxicity data in principal literature sources from human and animal studies are predominantly acute and chronic iron exposure effects.

19 Chronic toxicity, including carcinogenicity

Mammals are not equipped with mechanisms for the excretion of excess iron. In specific cases, e.g., administering of iron parenterally and chronic ingestion of excess amounts in combination with a genetic predisposition, iron overload may occur. Damage to cells and organs arising from chronic iron overload is remarkable in its ability to affect a wide range of tissues. Primarily the liver, heart and pancreatic beta cells are affected which consequently leads to conditions that include cirrhosis, diabetes and heart dysfunction (Ponka *et al*., 2007).

Clinical evidence that iron in excess plays a role in pathogenesis of cancers is lacking. Hereditary hemochromatosis (HH) is the sole iron overloading disease that can lead to one type of cancer, hepatocellular carcinoma, which occurs in 19 – 24 % of HH (Ponka *et al*., 2007). EFSA (2004) concluded that there is a possible role of luminal exposure to excessive iron in the development of colon carcinoma, but evidence is limited and not convincing.

20 Reproduction toxicity

EVM (2003) reported on a multigeneration study in rats where a supplementation of 20 mg/(kg bw.week) did not lead to any adverse effects. The numbers of offspring, growth weights and excess iron transfer across the placenta were monitored.

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake and Upper Intake Level (UL)

The IOM (2001) identified a LOAEL (Lowest Observed Adverse Effect Level) for total iron intake for adults of approximately 70 mg/day. The LOAEL was based on the results of a double blind iron supplementation study whereby gastrointestinal effects were evaluated. The identification of a NOAEL based on these data was considered impossible. Hence the LOAEL was used to derive an UL (IOM, 2001). An uncertainty factor (UF) of 1.5 was selected to account for extrapolation from a LOAEL to a NOAEL (Table 7). For children a NOAEL was identified of 40 mg/day based on the absence of gastrointestinal effects after supplementation with nonheme iron. An UF of 1 was used to derive the UL.

Table 7 Upper Intake Levels (UL) (mg/day) for iron for several life stage groups (IOM, 2001)

Live stage group	**UL**
0 - 13 years	40
14 - 18 years	45
Adults (> 19 years)	45
Pregnancy (14 - 50 years)	45
Lactation (14 - 50 years)	45

EVM (2003) established a guidance level for supplemental intakes of 17 mg/day, which would not be expected to produce adverse effects in the majority of the population. EVM (2003) decided not to establish an UL based on the fact that gastrointestinal effects are associated with the intake of iron supplements rather than iron intake through food.

EFSA (2004) considered gastrointestinal effects caused by short-term oral dosage of supplemental nonheme iron not to be a suitable basis to establish an UL for iron from all sources. Additionally, iron overload was also considered inadequate as well as the increased risk of chronic diseases as a basis to establish an UL.

BfR (2006) took into account the discussion concerning the choice of critical endpoint by the IOM (2001), namely, the reversible local gastro-intestinal disorders after ingestion of iron supplements. BfR distanced itself from setting a numeric UL. Instead BfR recommended that iron should no longer be used in food supplements for reasons of preventive health protection and it advised against exceeding recommended iron intake (BfR, 2006).

23 Toxicological risks for user/workers

Inhalation of iron fumes can give rise to deposition of iron in the lungs. The picture seen on X-ray is similar to the one in pneumoconioses like silicosis, but the deposition of iron particles in the lung does not lead to fibrosis. The pathologies provoked by inhalation exposure to iron dust have been named siderosis, iron pneumoconiosis, hematide pneumoconiosis, iron pigmentation of the lung and arc welder lung. They are considered benign conditions which do not progress to fibrosis (Ponka *et al*., 2007). The limit for occupational exposures recommended in 2006 by the American Conference of Governmental Industrial Hygienist (ACGIH) is 5 mg/m^3 for iron oxide and 1 mg/m^3 for soluble iron salts (Ponka *et al*., 2007).

24 Toxicological risks for the environment

There were no indications in principal literature sources on environmental consequences related to the use of iron as a feed supplement.

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Annex 1: Iron concentrations in edible tissues and products

Table 1.1 Iron concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Hogs	324	10.2	191.0	46.5	Coleman *et al*. (1992)
Boars / sows	281	16.5	363.0	79.0	
Pork	9	neck steak: 13 chop: 7 loin: 7			Gerber *et al*. (2009)
Pork	3	saddle: 4.9 loin: 4.2 chop: 7.0			Lombardi - Boccia *et al*. (2005)
Pigs (6 m)	62	26.5	195.00	51.6	López-Alonso *et al*. (2007)

Table 1.2 Iron concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Dairy cattle	48				0.194	Anderson (1992)
Calves (6 - 12 m)	195		43.6	58.9		Blanco-Penedo *et al.* (2006)
Calves	327	14.3	68.1	35.4		Coleman *et al*. (1992)
Heifers / Steers	289	35.1	54.5	55.8		
Bulls / Cows	95	35.4	77.0	62.4		
Lambs	165	20.5	59.6	45.6		
Mature sheep	34	25.9	100.0	77.0		
Lamb		chop: 20 loin: 26				Gerber *et al*. (2009)
Beef cattle		sirloin: 16 - 20 rib-eye: 18 - 25 steak: 17				
Veal	3	fillet: 12.0				Lombardi - Boccia *et al*. (2005)
Beef	3	sirloin: 19.3 fillet: 23.7 roast beef: 19.5				
Lamb	3	chop: 19.8				

Table 1.3 Iron concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chickens (young)	311	5.47	99.3	50.6		Coleman *et al*. (1992)
Chickens (mature)	308	9.61	129.0	59.4		
Turkeys (young)	60	9.81	137.0	59.2		
Ducks	111	24.2	163.0	50.6		
Chicken		breast: 5 - 6 leg: 12				Gerber *et al*. (2009)
Layers	82				yolk: 40.2 DM - 64.9 DM white: 1.15 DM - 2.24 DM	Kilic *et al*. (2002)
Chicken	3	breast: 4.0 leg: 6.3 - 7.0				Lombardi - Boccia *et al*. (2005)
Turkey	3	breast: 5.0 leg: 8.8 - 9.9				
Ostrich	3	fillet: 23.4 sirloin: 25.7 leg: 24.0				

Table 1.4 Iron concentrations in edible tissues (mg/kg) of fish

Species - category	**n**	**Muscle**	**Reference**
Sea bass – cultured (*Dicentrarchus labrax*)	3	51.22 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	63.1 DM	
Brushtooth lizardfish, *Saurida undosquamis*	45	4.175 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	9.682 DM	
Gilthead seabream *Sparus aurata*	45	13.166 DM	
Clarias gariepinus	38	1.485	Türkmen *et al*. (2007)
Carasobarbus luteus	23	3.682	

Table 1.5 Iron concentrations in honey (mg/kg)

Description	**n**	**Honey**	**Reference**
Origin: Argentina	19	4.0	Baroni *et al*. (2009)
Origin: Argentina	56	3.5	
Origin: Holzing (AU)	23	0.77	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.40	
Origin: Hollabrunn (AU)	19	0.61	
Origin: Siena County (It)	51	3.07	Pisani *et al*. (2008)

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Annex 2: Iron concentrations in edible tissues and products linked with the dietary intake of various iron copounds and doses

Table 1 Iron concentrations in edible tissues and products (mg/kg)

Species / category	Source of Fe supplemented	Dose of Fe supplemented (mg Fe/kg)	Fe content of complete feed [1] (mg Fe/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Nursery pigs		0	variable [2]	35 d	35				Rincker *et al*. (2004)
	Ferrous sulphate	25			38				
		50			86				
		100			123				
		150			113				
Weanling pigs		0	79	40 d	102	49.2	28.8 [3]		Feng *et al*. (2009)
	Fe glycine chelate	30			106	49.8	30.8 [3]		
	Fe glycine chelate	60			117	52.7	29.5 [3]		
	Fe glycine chelate	90			120	51.9	33.8 [3]		
	Fe glycine chelate	120			129	53.1	34.7 [3]		
	$FeSO_4$	120			117	50.8	31.7 [3]		
Laying hens			147 DM	28 d				yolk: 99 DM white: 5 DM	Huyghebaert *et al*. (2006)
	Fe sulphate	650	774 DM					yolk: 118 DM white: 15 DM	
	Bioplex Fe	650	811 DM					yolk: 90 DM white: 12 DM	
Laying hens			92.8	56 d	145.4 DM [a]			yolk: 116.5 DM [a] white: 3.15 DM [a]	Skrivan *et al*. (2005)
	$FeSO_4.7H_2O$	120	186.4		143.6 DM [a]			yolk: 123.8 DM [b] white: 3.22 DM [ab]	
Laying hens			50	42 d				yolk: 68	Revell *et al*. (2009)
	Ferrous sulphate		450 [4]					yolk: 69	
	Bioplex iron		450 [4]					yolk: 67	
	Availa iron		450 [4]					yolk: 70	

[1]: Data from feed analysis; [2]: 189 mg Fe/kg phase 1 (d 0 - 7); 223.80 mg Fe/kg phase 2(d 2 - 21); 97.80 mg Fe.kg phase 3 (d 21 - 35)
[3]: concentrations in heart muscle; [4]: Diets supplemented to reach these total concentrations
Statistics : Rincker *et al*. (2004): linear and quadratic effects of increasing iron concentrations ;
Feng *et al*. (2009): Linear effects for Fe glycine chelate supplementation on Fe heart concentration (P = 0.02), Fe liver concentration (P = 0.003); Fe kidney concentration (P = 0.005).
Skrivan *et al*. (2005): means within each column with different letters in superscript differ significantly, Anova.
Revell *et al*. (2009): no significant differences between egg yolk iron concentrations

Table 1 (continued) Iron concentrations in edible tissues and products (mg/kg)

Species / category	Source of Fe supplemented	Dose of Fe supplemented (mg Fe/kg)	Fe content of complete feed [1] (mg Fe/kg)	Duration of study	Liver	Kidney	Muscle	Reference
Lambs		0	40	76 d	162 DM	289 DM	63 DM	Rosa *et al*. (1982)
	Ferric citrate	760			1306 DM	566 DM	87 DM	
Lambs		0	154	121 d	235 DM	230 DM	57 DM	Prabowo *et al*. (1988)
	Ferrous carbonate	300			241 DM	231 DM	58 DM	
		600			283 DM	238 DM	58 DM	
		1200			306 DM	236 DM	58 DM	
Wethers			193 DM	0 d	145 DM	171 DM	96 DM	van Ravenswaay *et al*. (2001)
	$FeSO_4.7H_2O$	400		30 d	252 DM	222 DM	124 DM	
		800			523 DM	285 DM	123 DM	
		1200			801 DM	294 DM	128 DM	
Calves	$FeSO_4.7H_2O$	100 DM	([2])	42 d	121 DM [d]	171 DM [c]	33.3 DM [c]	Jenkins & Hidiroglou (1987)
		500 DM			181 DM [d]	222 DM [b]	35.8 DM [c]	
		1000 DM			273 DM [c]	243 DM [b]	35.9 DM [c]	
		2000 DM			1295 DM [b]	358 DM [a]	41.0 DM [b]	
		5000 DM			4350 DM [a]	390 DM [a]	47.3 DM [a]	

[1] : Data from feed analysis; ([2]): basal diet (milk replacer) contained 8 mg Fe.(kg dm)$^{-1}$;
Statistics : Rosa *et al*. (1982): Liver, kidney and muscle iron concentration differed significantly control vs treatment ($P < 0.01$).
Prabowo *et al*. (1988): Liver Fe conc.: control vs. others: $P < 0.01$; 300 mg Fe vs 600 mg Fe supplemented: $P< 0.05$; no other significant differences.
Jenkins & Hidiroglou (1987): Means with different superscripts within the same column differ significantly ($P < 0.05$), Anova.
van Ravenswaay *et al*. (2001): Liver Fe conc.: $P < 0.001$; Kidney Fe conc.: $P < 0,01$; Muscle Fe conc.: $P > 0.1$; Anova.

Table 1 (continued) Iron concentrations in edible tissues and products (mg/kg)

Species / category	Source of Fe	Dose of Fe	Fe content	Duration	Liver	Muscle	Reference
African catfish		0	663.5 DM	35 d	523.55	251.22	Baker *et al*. (1997)
	$FeSO_4.7H_2O$	2500	6354.4 DM		745.43	238.77	

Statistics : Baker *et al*. (1997): No significant differences between treatments, Anova.

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Annex 3.1: Iron Requirements

Pigs:

Category - Definition	Fe Req. (NRC, 1998) (mg/kg) (a)	Category - Definition	Fe Req. (GFE , 2008) (mg/kg DM)
Pigs: 3 - 5 kg	100	Piglets	80 - 120
Pigs: 5- 10 kg	100		
Pigs: 10 - 20 kg	80	Growing - fattening pigs	50 - 60
Pigs: 20 - 50 kg	60		
Pigs: 50 - 80 kg	50		
Pigs: 80 - 120 kg	40		
Sows: gestation	80	Breeding sows	80 - 90
Sows: lactation	80		
		Boars	80 - 90

Poultry:

Category - Definition	Fe Req. (NRC, 1994) (mg/kg) (a)	Category - Definition	Fe Req. (GfE, 1999) (mg/kg DM)
Broilers (0 - 8 weeks)		Broiler (Mast Broiler; Aufzucht Küken)	100
Immature leghorn- Type chickens (0-6 wk) white	80.0	Chickens reared for laying (Junghennen)	70
Immature leghorn- Type chickens (6 wk - first egg) white	60.0		
Immature leghorn- Type chickens (0-6 wk) brown	75.0		
Immature leghorn- Type chickens (6 wk - first egg) brown	56.0		
Leghorn-Type white egg layers (80 g FI.day^{-1})	56	Layers (Eiproduction Legehennen)	100
Leghorn-Type white egg layers (100 g FI.day^{-1})	45		
Leghorn-Type white egg layers (120 g FI.day^{-1})	38		
		Female birds reared for breeding (Zuchthennen)	100
Growing turkeys (0 - 4 wk)	80		
Growing turkeys (4 - 16 wk)	60		
Growing turkeys (16 - 24 wk)	50		
Turkey holding hens	50		
Turkey laying hens	60		

Bovines:

Bovines: Beef Cattle

Category - Definition	Fe Req. (NRC, 2000) (mg/kg DM)	Category - Definition	Fe Req. (GfE, 1995) (mg/kg DM)
Growing and finishing	50.00	Growing and finishing from 175 kg on	50
Cows gestation	50.00		
Cows early lactation	50.00		

Bovines: Dairy Cattle

Category - Definition	Fe Req. (NRC, 2001) (mg/kg DM)	Category - Definition	Fe Req. (CVB, 2007) (mg/kg DM)
Lactating cow: Holstein - 90 days in milk	12,3 - 18	Lactating cows (FI: 20 kg/day)	8.1
Lactating cow: Jersey	14 - 18	Lactating cows (FI: 40 kg/day)	12.8
Dry cows: Holstein (240 d pregnant)	13	Dry cows, 8 -3 weeks before calving	30.0
Dry cows: Holstein (279 d pregnant)	18	Dry cows, 3 - 0 weeks before calving	31.4

Sheep

Category - Definition	Fe Req. (NRC, 2007 (b)) (mg/day)	Category - Definition	Fe Req. (NRC, 2007 (b)) (mg/day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	32		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	156		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	8	Mature ewes; breeding. DM intake: 0.85 kg/day	11.0
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	24	Mature ewes; breeding. DM intake: 2.18 kg/day	34
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	11	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	29	Mature ewes; early lact.; DM intake: 2.14 kg/day	17
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	11	Mature ewes; early lact.; DM intake: 5.29 kg/day	32
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	29	Mature ewes; late lact.; DM intake: 2.35 kg/day	30
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	27	Mature ewes; late lact.; DM intake: 4.05 kg/day	55
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	49		

Goats

Category - Definition	Fe Req. (GfE, 2003) (mg/kg DM)
Goats	40 - 50

Category - Definition	Fe Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Fe Req. (NRC, 2007 (b)) (mg/day)
Kids; bw: 10 kg; DM intake: 0.35 kg/day	1	Mature does; breeding; DM intake: 0.60 kg/day	3
Kids; bw: 10 kg; DM intake: 0.39 kg/day	33	Mature does; breeding; DM intake: 1.86 kg/day	13
Kids; bw: 40 kg; DM intake: 1.10 kg/day	6		
Kids; bw: 40 kg; DM intake: 1.41 kg/day	100	***Milk yield: 4.65 - 6.43 kg/day***	
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	9	Dairy does; early lactation; DM intake: 2.81 kg/day	54
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	27	Dairy does; early lactation; DM intake: 4.83 kg/day	77
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	25	***Milk yield: 6.98 - 9.65 kg/day***	
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	50	Dairy does; early lactation; DM intake: 3.83 kg/day	77
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	9	Dairy does; early lactation; DM intake: 5.43 kg/day	109
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	26	***Milk yield: 1.99 - 2.76 kg/day***	
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	25	Dairy does; late lactation; DM intake: 2.48 kg/day	48
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	51	Dairy does; late lactation; DM intake: 3.64 kg/day	69
		Milk yield: 2.99 - 4.13 kg/day	
		Dairy does; late lactation; DM intake: 2.51 kg/day	68
		Dairy does; late lactation; DM intake: 4.53 kg/day	97

Horses

Category - Definition	Fe Req. (NRC, 2007) (mg/day)	Category - Definition	Fe Req. (NRC, 2007) (mg/day)
MBW 200 kg; Adult; no work	160.0	MBW 400 kg; Adult; no work	320.0
MBW 200 kg; Adult; working: light exercise	160.0	MBW 400 kg; Adult; working: light exercise	320.0
MBW 200 kg; Adult; working: moderate exercise	180.0	MBW 400 kg; Adult; working: moderate exercise	360.0
MBW 200 kg; Adult; working: (very) heavy exercise	200.0	MBW 400 kg; Adult; working: (very) heavy exercise	400.0
MBW 200 kg; Stallions nonbreeding; breeding	160.0	MBW 400 kg; Stallions nonbreeding; breeding	320.0
MBW 200 kg; Pregnant mares (till 8 m)	160.0	MBW 400 kg; Pregnant mares (till 8 m)	320.0
MBW 200 kg; Pregnant mares (from 9 m)	200.0	MBW 400 kg; Pregnant mares (from 9 m)	400.0
MBW 200 kg; Lactating mares	250.0	MBW 400 kg; Lactating mares	500.0
MBW 200 kg; Growing animals: 4 m	84.2	MBW 400 kg; Growing animals: 4 m	168.4
MBW 200 kg; Growing animals: 6 m	107.9	MBW 400 kg; Growing animals: 6 m	215.8
MBW 200 kg; Growing animals: 12 m	160.6	MBW 400 kg; Growing animals: 12 m	321.2
MBW 200 kg; Growing animals: 18 m	193.7	MBW 400 kg; Growing animals: 18 m	387.4
MBW 200 kg; Growing animals: 24 m	214.6	MBW 400 kg; Growing animals: 24 m	429.2

Horses

Category - Definition	Fe Req. (NRC, 2007) (mg/day)	Category - Definition	Fe Req. (NRC, 2007) (mg/day)
MBW 500 kg; Adult; no work	400.0	MBW 600 kg; Adult; no work	480.0
MBW 500 kg; Adult; working: light exercise	400.0	MBW 600 kg; Adult; working: light exercise	480.0
MBW 500 kg; Adult; working: moderate exercise	450.0	MBW 600 kg; Adult; working: moderate exercise	540.0
MBW 500 kg; Adult; working: (very) heavy exercise	500.0	MBW 600 kg; Adult; working: (very) heavy exercise	600.0
MBW 500 kg; Stallions nonbreeding; breeding	400.0	MBW 600 kg; Stallions nonbreeding; breeding	480.0
MBW 500 kg; Pregnant mares (till 8 m)	400.0	MBW 600 kg; Pregnant mares (till 8 m)	480.0
MBW 500 kg; Pregnant mares (from 9 m)	500.0	MBW 600 kg; Pregnant mares (from 9 m)	600.0
MBW 500 kg; Lactating mares	625.0	MBW 600 kg; Lactating mares	750.0
MBW 500 kg; Growing animals: 4 m	210.5	MBW 600 kg; Growing animals: 4 m	252.6
MBW 500 kg; Growing animals: 6 m	269.8	MBW 600 kg; Growing animals: 6 m	323.7
MBW 500 kg; Growing animals: 12 m	401.5	MBW 600 kg; Growing animals: 12 m	481.8
MBW 500 kg; Growing animals: 18 m	484.3	MBW 600 kg; Growing animals: 18 m	581.1
MBW 500 kg; Growing animals: 24 m	536.5	MBW 600 kg; Growing animals: 24 m	643.8
MBW 900 kg; Adult; no work	720.0		
MBW 900 kg; Adult; working: light exercise	720.0		
MBW 900 kg; Adult; working: moderate exercise	810.0		
MBW 900 kg; Adult; working: (very) heavy exercise	900.0		
MBW 900 kg; Stallions nonbreeding; breeding	720.0		
MBW 900 kg; Pregnant mares (till 8 m)	720.0		
MBW 900 kg; Pregnant mares (from 9 m)	900.0		
MBW 900 kg; Lactating mares	1125.0		
MBW 900 kg; Growing animals: 4 m	378.9		
MBW 900 kg; Growing animals: 6 m	485.6		
MBW 900 kg; Growing animals: 12 m	722.7		
MBW 900 kg; Growing animals: 18 m	871.7		
MBW 900 kg; Growing animals: 24 m	965.7		

Salmonids

Category - Definition	Fe Req. (NRC, 1993) (mg/kg)
Pacific salmon	not tested
Rainbow trout	60

Dogs

Category - Definition	Fe Req. (NRC, 2006) (mg/kg DM)	Fe Adequate intake (NRC, 2006) (mg/kg DM)	Fe Rec. Allowance (NRC, 2006) (mg/kg DM)
Puppies after weaning	72		88
Adult dogs at maintenance		30	30
Bitches for late gestation and peak lactation		70	70

Cats

Category - Definition	Fe Req. (NRC, 2006) (mg/kg DM)	Fe Adequate intake (NRC, 2006) (mg/kg DM)	Fe Rec. Allowance (NRC, 2006) (mg/kg DM)
Kittens after weaning	70		80
Adult cats		80	80
Queens in late gestation and peak lactation		80	80

Glossary

Req.: requirement
(a): 90 % dry matter
MBW: Mature body weight
FI: Feed Intake
lact.: lactation

Annex 3.2 Iron Use Levels

Table 1 Supplementation recommendations, calculated background level ranges (information acquired from the industry) and calculated use levels for iron

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg /kg)
Pigs (7 – 20 kg)	200	130 – 150	350	750
Pigs (20 – 30 kg)	100	140 – 210	310	750
Pigs (30 – 100 kg)	100	180 – 220	320	750
Sows	150	180 – 220	370	750
Broilers	45	140 – 170	215	750
Hens	45	240 – 290	335	750
Veal	50	210 – 250	300	750
Cattle	75	300 – 430	505	750
Sheep	50	190 - 250	300	500

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use levels for iron

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	80 - 175	150	325
Pigs (15 - 50 kg)	80 - 150	210	360
Pigs (50 - 150 kg)	65 - 112	220	332
Gestating sows	80 - 150	220	370
Lactating sows	80 - 150	220	370

Whittemore *et al.* (2002): summary of supplementation levels found in Denmark, Germany, Netherlands, United Kingdom, United States, Spain and Australia

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Annex 4. Iron concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB

COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	99
Potato prot ASH>10	141
Potato starch dried	
Potato sta heat tr	22
Potato pulp CP<95	690
Potato pulp CP>95	697
Potatoes sweet dried	
Bone meal	470
Brewers' grains dr	250
Brewers' yeast dried	116
Sugarb pulp SUG<100	510
Sugarb p SUG100-150	511
Sugarb p SUG150-200	1029
Sugarb pulp SUG>200	375
Biscuits CFAT<120	41
Biscuits CFAT>120	41
Blood meal spray dr	2429
Buckwheat	38
Beans phas heat tr	87
Bread meal	55
Casein	34
Chicory pulp dried	944
Citrus pulp dried	122
Meat meal Dutch	1116
Meat meal CFAT<100	1324
Meat meal CFAT>100	1168
Peas	84
Barley	78
Barley feed h grade	285
Barley mill byprod	860
Grass meal CP<140	921
Grass meal CP140-160	743
Grass meal CP160-200	710
Grass meal CP>200	1054
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	347
Peanut exp p with sh	
Peanut exp with sh	
Peanut extr wtht sh	0
Peanut extr with sh	0
Oats grain	92
Oats grain peeled	48
Oats husk meal	213
Oats mill fd h grade	
Hempseed	13
Carob	31

INRA

	Mean (mg/kg)	St. Dev. (mg/kg)
CEREALS		
Barley	158	136
Maize	32	11
Oats	106	54
Oats groats		
Rice, brown	16	
Rye	57	
Sorghum	58	58
Triticale	58	
Wheat, durum	70	
Wheat, soft	47	14
WHEAT BY-PRODUCTS		
Wheat bran	143	67
Wheat middlings	94	
Wheat shorts	116	
Wheat feed flour	14	
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%		
Wheat gluten feed, starch 28%		
MAIZE BY-PRODUCTS		
Corn distillers	105	
Corn gluten feed	218	191
Corn gluten meal	100	58
Maize bran		
Maize feed flour		
Maize germ meal, expeller	218	
Maize germ meal, solvent extracted	749	
Hominy feed	140	
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	278	
Brewers' dried grains	120	21
Rice bran, extracted	268	
Rice bran, full fat	109	73
Rice, broken	44	
LEGUME AND OIL SEEDS		
Chickpea	55	
Cottonseed, full fat	63	32
Faba bean, coloured flowers	59	
Faba bean, white flowers	73	
Linseed, full fat	148	
Lupin, blue	61	
Lupin, white	24	
Pea	92	29
Rapeseed, full fat	216	
Soybean, full fat, extruded	146	
Soybean, full fat, toasted	143	
Sunflower seed, full fat	134	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	95
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	148
Cottons exp p with h	150
Cottons exp with h	148
Cottons extr wtht h	143
Cotts extr p with h	143
Cottons extr with h	143
Coconut exp CFAT<100	501
Coconut exp CFAT>100	504
Coconut extr	494
Linseed	208
Linseed exp	176
Linseed extr	274
Lentils	107
Lupins CP<335	52
Lupins CP>335	
Alf meal CP<140	465
Alf meal CP140-160	406
Alf meal CP160-180	712
Alf meal CP>180	465
Poppyseed	
Macoya fruit exp	
Maize	29
Maize chem-h treated	69
Maize gluten meal	90
Maize glfeed CP<200	167
Maize glfd CP200-230	169
Maize glfeed CP>230	178
Maize germ meal extr	
Maize germ m fd exp	422
Maize germ m fd extr	244
Dist grains and sol	
Maize feedflour	39
Maize feed meal	
Maize feed meal extr	
Maize bran	
Maize starch	
Sugarbeet molasses	160
Sugarc mol SUG<475	166
Sugarc mol SUG>475	157
Milk powder skimmed	2
Milk powder whole	9
Millet	104

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	696	
Cottonseed meal, crude fibre 7-14%	159	
Cottonseed meal, crude fibre 14-20%	184	
Grapeseed oil meal, solvent extracted	167	
Groundnut meal, detoxified, crude fibre < 9%	335	
Groundnut meal, detoxified, crude fibre > 9%	516	150
Linseed meal, expeller	331	
Linseed meal, solvent extracted	291	
Palm kernel meal, expeller	534	
Rapeseed meal	172	44
Sesame meal, expeller	1780	231
Soybean meal, 46		
Soybean meal, 48	283	145
Soybean meal, 50	178	
Sunflower meal, partially decorticated	207	
Sunflower meal, undecorticated	243	
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	15	
Cassava, starch 72%	17	
Maize starch		
Potato tuber, dried	58	
Sweet potato, dried	27	
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	601	310
Beet pulp dried, molasses added	683	
Beet pulp, pressed	116	42
Brewers' yeast, dried	97	
Buckwheat hulls		
Carob pod meal	34	
Citrus pulp, dried	71	28
Cocoa hulls		
Grape marc, dried	244	
Grape seeds		
Liquid potato feed	168	
Molasses, beet	117	
Molasses, sugarcane	188	
Potato protein concentrate	455	257
Potato pulp, dried	692	
Soybean hulls	580	247
Vinasse, different origins	277	
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production	180	
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	125
Malt culms CP>200	127
Nigerseed	501
Horsebeans	74
Horsebeans white	71
Palm kernels	
Palm kern exp CF<180	770
Palm kern exp CF>180	731
Palm kernel extr	
Rapeseed	82
Rapeseed exp	578
Rapeseed extr CP<380	499
Rapeseed extr CP>380	534
Rapes meal Mervobest	150
Rice wtht hulls	13
Rice with hulls	
Rice husk meal	
Rice bran meal extr	
Rice feed m ASH<90	131
Rice feed m ASH>90	132
Rye	52
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	
Semameseed meal extr	462
Soybeans heat tr	230
Soybeans not heat tr	230
Soybean hulls CF<320	
Soyb hulls CF320-360	584
Soybean hulls CF>360	584
Soybean exp	373
Soybm CF<45 CP<480	261
Soybm CF<45 CP>480	261
Soybm CF45-70 CP<450	262
Soybm CF45-70 CP>450	262
Soyb meal CF>70	261
Soyb meal Mervobest	178
Soyb meal Rumi S	242
Sorghum	66
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	870
Tapioca STA 625-675	884
Tapioca STA 675-725	635
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	315	
Alfalfa, dehydrated, protein 17-18% dry matter	312	
Alfalfa, dehydrated, protein 18-19% dry matter	312	
Alfalfa, dehydrated, protein 22-25% dry matter	309	
Grass, dehydrated	525	
Wheat straw	171	
DAIRY PRODUCTS		
Milk powder, skimmed	7	
Milk powder, whole	7	
Whey powder, acidic	9	
Whey powder, sweet	10	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	469	412
Fish meal, protein 65%	351	132
Fish meal, protein 70%	252	73
Fish solubles, condensed, defatted	307	
Fish solubles, condensed, fat	64	
OTHER ANIMAL BY-PRODUCTS		
Blood meal	2034	475
Feather meal	575	197
Meat and bone meal, fat <7.5%	581	
Meat and bone meal, fat >7.5%	586	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	57
Wheat gluten meal	39
Wheat glutenfeed	152
Wheat middlings	158
Wheat germ	100
Wheat germfeed	
Wheat feedfl CF<35	81
Wheat feedfl CF35-55	81
Wheat feed meal	138
Wheat bran	232
Triticale	53
Feather meal hydr	481
Fat from Animals	
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	232
Vinasse Sugb CP>250	282
Fish meal CP<580	359
Fish meal CP580-630	408
Fish meal CP630-680	334
Fish meal CP>680	305
Meat bone m CFAT<100	465
Meat bone m CFAT>100	
Whey p l lac ASH<210	58
Whey p l lac ASH>210	60
Whey powder	10
Sunflowers deh	30
Sunflowers p deh	134
Sunflowers w hulls	134
Sunfls exp deh	1044
Sunfls exp p deh	1061
Sunfls exp w hulls	1052
Sunfmeal CF<160	242
Sunfmeal CF 160-200	242
Sunfmeal CF 200-240	313
Sunfmeal CF>240	242
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	
Potato pulp pr NL	30
Potato pulp pressed	44
Potato cut raw	86
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	738
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	250
Pot sta STA 500-650	1329
Pot sta STA 650-775	530
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	2431
Pot s g STA 425-550	2431
Pot s g STA 550-675	2431
Pot sta gel STA>675	2431
Brewers gr 22% DM	229
Brewers gr 27% DM	
Brewers yeast CP<400	87
Brewers y CP400-500	87
Brewers yeast CP>500	87
Beetp pressed f+sil	723
CCM CF<40	46
CCM CF 40-60	49
CCM CF>60	95
Chicory pulp f+sil	1217
Distillers sol f	
Cheese whey CP<175	49
Cheese w CP175-275	65
Cheese whey CP>275	65
Maize glutenf f+sil	102
Maize solubles	264
Wheat st FR STAt 300	58
Wheat st STAtot 400	
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	1177
Beet rests sililed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	229
Barley straw	
Grass fr April l y.	149
Grass fr April n y.	149
Grass fr April h y.	149
Grass fr May l y.	149
Grass fr May n y.	149
Grass fr May h y.	149
Grass fr June l y.	149
Grass fr June n y.	149
Grass fr June h y.	149

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	149
Grass fr July n y.	149
Grass fr July h y.	149
Grass fr Aug l y.	149
Grass fr Aug n y.	149
Grass fr Aug h y.	149
Grass fr Sept l y.	149
Grass fr Sept n y.	149
Grass fr Sept h y.	149
Grass fr Oct l y.	149
Grass fr Oct n y.	149
Grass fr Oct h y.	149
Grass average	149
Grass horse gr past	149
Grass horse same fld	149
Grass sil May 2000	443
Grass sil May 3500	443
Grass sil May 5000	443
Grass sil June 2000	443
Grass sil June 3000	443
Grass sil June 4000	443
Grass sil Ju-Au 2000	443
Grass sil Ju-Au 3000	443
Grass sil Ju-Au 4000	443
Grass sil Se-Oc 2000	443
Grass sil Se-Oc 3000	443
Grass sil average	443
Grass sil horse fine	443
Grass sil horse midd	443
Grass sil horse crs	443
Grass hay good qual	443
Grass hay av qual	443
Grass hay poor qual	443
Grass hay horse fine	443
Grass hay horse midd	443
Grass hay horse crs	443
Grass bales ad	904
Grass seeds straw	181
Oat straw	
Clover red fresh	
Clover red silage	174
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	230
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	553
Lucerne hay	212
Lucerne (alfalfa) ad	790
Maize Cob with leaves silage	49
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	372
Maize fod fr DM<240	120
Maize f fr DM240-280	120
Maize f fr DM280-320	120
Maize fod fr DM 320	120
Maize sil DM < 240	120
Maize sil DM240-280	120
Maize sil DM280-320	120
Maize sil DM 320	120
Maize (Fodder) ad	120
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	326
Chicory rts not frcd	
Chicory rts frcd cleaned	78
Chicory rts frcd dirty	
Carrots	
Sunflower silage	230

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	840
Calcium carbonate	336
Diammonium phosphate	15000
Difluorinated phosphate	9200
Dicalcium phosphate	10000
Mono-dicalcium phosphate	7000
Monoammonium phosphate	12000
Sodium tripolyphosphate	42
Phosphoric acid (75%)	5

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of iron in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	89.2	89.2	6	6	101.8	106.3
Piglet Starter II (complete feed)	20	91.2	78.2	11	10	136.1	93.2
Pig Grower (complete feed)	19	90.4	88.4	10	10	156.2	108.3
Pig Finisher (complete feed)	18	88.8	90.7	10	9	138.7	120.1
Sows, gestating (complete feed)	18	88.7	91.2	12	12	191.2	164.1
Sows, lactating (complete feed)	20	95.5	79.5	13	11	211.1	143.2
Starter Chicks (complete feed)	15	96.7	85.9	9	7	173.1	122.1
Chicken reared for laying (complete feed)	17	94.1	81.6	9	8	136.7	93.8
Layer Phase I (complete feed)	16	91.3	94.8	8	8	151.0	139.9
Layer Phase II (complete feed)	16	90.8	87.4	8	8	154.1	130.1
Broiler Starter (complete feed)	14	96.6	96.6	7	7	180.9	151.4
Broiler Grower (complete feed)	15	93.8	91.3	8	7	179.2	136.0
Broiler Finisher (complete feed)	15	92.3	89.8	7	6	153.6	108.9
Turkey Starter (complete feed)	14	96.7	96.7	6	6	287.4	246.2
Turkey Grower (complete feed)	13	93.5	93.5	6	6	295.6	255.9
Turkey Finisher (complete feed)	11	94.3	94.3	5	5	257.6	221.1
Turkey Breeder (complete feed)	8	91.4	91.4	5	5	185.0	179.5
Duck, grower/finisher (complete feed)	10	95.0	95.0	5	5	186.7	161.6
Geese, grower/finisher (complete feed)	8	98.7	98.7	6	6	169.2	148.9
Calf, milk replacer (complete feed)	10	71.7	30.7	5	1	47.0	2.8
Calf concentrate (complete feed)	17	99.6	99.6	14	14	383.9	366.6
Calf concentrate (complementary feed)	16	99.2	99.2	13	13	324.8	208.3
Cattle concentrate (complete feed)[4]	9	95.9	95.9	7	7	306.5	287.6
Cattle concentrate (complementary feed)	8	94.1	94.1	6	6	247.9	185.8
Dairy cows TMR (based on corn silage)[4]	15	98.7	99.2	12	12	281.5	212.6
Dairy cows TMR (based on grass silage)[4]	15	97.7	98.7	12	12	371.5	337.0
Dairy concentrate (complementary feed)	13	88.9	93.6	10	10	517.4	303.5
Dairy cows mineral feed (min. 40% crude ash)	8	45.7	45.7	3	3	1942.5	1942.5
Rabbit, breeder (complete feed)	8	53.1	99.1	4	5	316.9	215.6
Rabbit, grower/finisher (complete feed)	14	96.9	96.9	7	7	632.2	445.0
Salmon feed (wet)[4]	4	70.4	70.4	2	2	194.0	146.9
Salmon feed (dry)	6	79.4	79.4	3	3	230.0	170.1
Trout feed (dry)	12	78.2	78.2	4	4	178.2	132.5
Dog food (dry)	12	81.9	81.9	6	6	572.4	275.7
Cat food (dry)	16	59.4	88.1	8	8	139.4	307.3

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Iron: Addendum to the monograph

Abstract

This addendum to the iron monograph substantiates the data reported in Annex 5 of the iron monograph in which iron background levels are reported. The addendum provides the following information for each calculated background level: (1) the iron concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no iron concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated iron content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	78	34.93	27.2	26.75
Maize	29	10.00	2.9	2.85
Soybeans heat tr	230	15.10	34.7	34.09
Soybm CF<45 CP>480	261	7.50	19.6	19.22
Wheat	57	16.68	9.5	9.33
Wheat middlings	158	5.00	7.9	7.76
Fat from Animals		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	101.8	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	78	15.00	11.7	8.59
Maize	29	15.81	4.6	3.37
Dist grains and sol		3.00		
Palm kern exp CF<180	770	4.00	30.8	22.62
Rapeseed exp	578	6.00	34.7	25.47
Soybm CF<45 CP>480	261	7.86	20.5	15.07
Wheat	57	27.50	15.7	11.51
Wheat gluten meal	39	10.00	3.9	2.86
Wheat middlings	158	2.00	3.2	2.32
Fat from Animals		3.00		
Sunfmeal CF<160	242	2.55	6.2	4.53
Phytase		1.50		
Calcium carbonate	336	0.45	1.5	1.12
L-Lysine HCl		0.49		
Monocalciumphosphate	7000	0.05	3.4	2.52
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	136.1	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	2.00	20.6	13.18
Barley	78	20.00	15.6	9.99
Maize	29	9.42	2.7	1.75
Dist grains and sol		5.00		
Palm kern exp CF<180	770	4.00	30.8	19.72
Rapeseed exp	578	7.00	40.5	25.91
Soybm CF<45 CP>480	261	3.40	8.9	5.68
Wheat	57	35.00	20.0	12.78
Wheat middlings	158	7.27	11.5	7.36
Fat from Animals		2.09		
Sunfmeal CF<160	242	2.32	5.6	3.59
Calcium carbonate	336	0.02	0.1	0.05
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	156.2	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	2.50	25.7	18.54
Barley	78	20.00	15.6	11.24
Maize	29	6.93	2.0	1.45
Dist grains and sol		6.21		
Palm kern exp CF<180	770	5.00	38.5	27.75
Rapeseed exp	578	1.35	7.8	5.62
Wheat	57	35.00	20.0	14.38
Wheat gluten meal	39	3.04	1.2	0.85
Wheat middlings	158	10.00	15.8	11.39
Fat from Animals		2.00		
Sunfmeal CF<160	242	4.98	12.1	8.69
Calcium carbonate	336	0.04	0.1	0.09
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	138.7	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	5.50	56.6	29.62
Barley	78	20.00	15.6	8.16
Maize	29	15.26	4.4	2.31
Maize germ meal extr		7.50		
Sugarc mol SUG<475	166	0.10	0.2	0.08
Palm kern exp CF<180	770	5.00	38.5	20.14
Wheat	57	11.22	6.4	3.35
Wheat glutenfeed	152	5.00	7.6	3.98
Wheat middlings	158	7.50	11.9	6.20
Wheat bran	232	12.50	29.0	15.17
Fat from Animals		1.91		
Sunfmeal CF<160	242	6.11	14.8	7.74
Phytase		1.50		
Calcium carbonate	336	0.48	1.6	0.85
L-Lysine HCl		0.24		
Monocalciumphosphate	7000	0.07	4.6	2.42
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	191.2	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	2.41	24.8	11.76
Barley	78	20.00	15.6	7.39
Maize	29	10.00	2.9	1.37
Palm kern exp CF<180	770	4.00	30.8	14.59
Rapeseed exp	578	6.00	34.7	16.43
Soybean exp	373	1.39	5.2	2.46
Soybm CF<45 CP>480	261	5.13	13.4	6.34
Wheat	57	23.43	13.4	6.33
Wheat glutenfeed	152	10.00	15.2	7.20
Wheat middlings	158	7.50	11.9	5.61
Fat from Animals		2.16		
Sunfmeal CF<160	242	4.22	10.2	4.83
Phytase		1.50		
Calcium carbonate	336	1.02	3.4	1.63
L-Lysine HCl		0.34		
Monocalciumphosphate	7000	0.42	29.7	14.06
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	211.1	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	20.00	5.8	3.35
Rapeseed exp	578	5.00	28.9	16.69
Soybeans not heat tr	230	0.69	1.6	0.92
Soybm CF<45 CP>480	261	19.79	51.7	29.84
Wheat	57	35.62	20.3	11.73
Wheat gluten meal	39	5.75	2.2	1.29
Fat from Animals		2.00		
Sunfmeal CF<160	242	7.94	19.2	11.10
Calcium carbonate	336	1.34	4.5	2.60
L-Lysine HCl		0.07		
Monocalciumphosphate	7000	0.56	38.9	22.48
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	173.1	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Chicken reared for laying (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	15.00	4.4	3.18
Dist grains and sol		2.50		
Rapeseed exp	578	5.00	28.9	21.14
Soybm CF<45 CP>480	261	2.95	7.7	5.64
Wheat	57	41.54	23.7	17.32
Wheat gluten meal	39	10.00	3.9	2.85
Wheat bran	232	7.50	17.4	12.73
Fat from Animals		2.00		
Sunfmeal CF<160	242	10.00	24.2	17.70
Calcium carbonate	336	1.79	6.0	4.39
L-Lysine HCl		0.23		
Monocalciumphosphate	7000	0.29	20.6	15.05
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	136.7	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	20.00	5.8	3.84
Dist grains and sol		4.00		
Soybeans not heat tr	230	8.36	19.2	12.74
Soybm CF<45 CP>480	261	5.93	15.5	10.26
Wheat	57	38.18	21.8	14.42
Wheat gluten meal	39	0.47	0.2	0.12
Fat from Animals		2.87		
Sunfmeal CF<160	242	10.00	24.2	16.03
Calcium carbonate	336	7.78	26.2	17.32
L-Lysine HCl		0.23		
Monocalciumphosphate	7000	0.55	38.2	25.27
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	151.0	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	20.00	5.8	3.76
Dist grains and sol		4.00		
Soybean exp	373	7.80	29.1	18.89
Soybm CF<45 CP>480	261	6.34	16.6	10.74
Wheat	57	30.36	17.3	11.23
Wheat gluten meal	39	7.41	2.9	1.88
Fat from Animals		3.40		
Sunfmeal CF<160	242	10.00	24.2	15.70
Calcium carbonate	336	8.48	28.5	18.49
L-Lysine HCl		0.20		
Monocalciumphosphate	7000	0.43	29.8	19.31
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	154.1	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	30.00	8.7	4.81
Maize gluten meal	90	2.50	2.3	1.24
Soybeans not heat tr	230	15.00	34.5	19.07
Soybm CF<45 CP>480	261	18.41	48.1	26.56
Wheat	57	28.16	16.1	8.87
Fat from Animals		1.50		
Calcium carbonate	336	1.62	5.4	3.01
L-Lysine HCl		0.44		
Monocalciumphosphate	7000	0.94	65.9	36.44
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	180.9	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	15.00	4.4	2.43
Maize gluten meal	90	1.56	1.4	0.78
Rapeseed exp	578	2.50	14.5	8.06
Soybeans not heat tr	230	10.00	23.0	12.83
Soybm CF<45 CP>480	261	20.22	52.8	29.44
Wheat	57	42.41	24.2	13.49
Fat from Animals		4.44		
Calcium carbonate	336	1.38	4.6	2.59
L-Lysine HCl		0.33		
Monocalciumphosphate	7000	0.78	54.5	30.38
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	179.2	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize gluten meal	90	0.68	0.6	0.40
Rapeseed exp	578	2.50	14.5	9.41
Soybeans not heat tr	230	10.16	23.4	15.21
Soybm CF<45 CP>480	261	19.32	50.4	32.82
Wheat	57	57.84	33.0	21.46
Fat from Animals		6.00		
Calcium carbonate	336	1.38	4.6	3.02
L-Lysine HCl		0.28		
Monocalciumphosphate	7000	0.39	27.2	17.68
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	153.6	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	20.00	5.8	2.02
Soybm CF<45 CP>480	261	42.45	110.8	38.55
Wheat	57	25.35	14.4	5.03
Fats/oils vegetable		1.83		
Fish meal CP630-680	334	5.00	16.7	5.81
Calcium carbonate	336	1.99	6.7	2.33
L-Lysine HCl		0.34		
Monocalciumphosphate	7000	1.90	133.0	46.27
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.97	287.4	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	6.94	2.0	0.68
Soybeans not heat tr	230	2.00	4.6	1.56
Soybm CF<45 CP>480	261	41.24	107.6	36.41
Wheat	57	40.00	22.8	7.71
Fats/oils vegetable		5.00		
Calcium carbonate	336	1.15	3.9	1.31
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	7000	2.21	154.7	52.33
Salt		0.30		
Total		100.00	295.6	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	11.74	3.4	1.32
Soybm CF<45 CP>480	261	39.50	103.1	40.03
Wheat	57	40.00	22.8	8.85
Fats/oils vegetable		4.60		
Calcium carbonate	336	1.30	4.4	1.70
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	7000	1.77	123.9	48.10
Salt		0.30		
Total		100.00	257.6	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	29	69.44	20.1	10.88
Soybm CF<45 CP>480	261	11.40	29.8	16.08
Feather meal hydr	481	2.00	9.6	5.20
Calcium carbonate	336	7.60	25.5	13.80
Dicalcium Phosphate	10000	1.00	100.0	54.04
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	185.0	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Soybm CF<45 CP>480	261	15.00	39.2	20.97
Wheat	57	68.91	39.3	21.04
Wheat middlings	158	9.00	14.2	7.62
Fats/oils veg h %d		3.87		
Calcium carbonate	336	1.20	4.0	2.16
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	10000	0.90	90.0	48.21
Premix		0.50		
Salt		0.37		
Total		100.02	186.7	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	78	10.00	7.8	4.61
Maize	29	34.00	9.9	5.83
Soybm CF<45 CP>480	261	33.00	86.1	50.90
Wheat	57	20.00	11.4	6.74
Calcium carbonate	336	1.20	4.0	2.38
Dicalcium Phosphate	10000	0.50	50.0	29.55
Premix		1.00		
Salt		0.30		
Total		100.00	169.2	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	261	10.00	26.1	55.57
Wheat gluten meal	39	5.00	2.0	4.15
Fat from Animals		6.25		
Whey p l lac ASH<210	58	15.00	8.7	18.52
Whey powder	10	30.65	3.1	6.53
Cheese whey CP>275	65	11.00	7.2	15.22
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	47.0	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	5.50	56.6	14.74
Citrus pulp, dried	122	8.00	9.8	2.54
Barley	78	0.54	0.4	0.11
Linseed	208	1.25	2.6	0.68
Sugarbeet molasses	160	1.00	1.6	0.42
Palm kern exp CF<180	770	5.50	42.4	11.03
Rapeseed	82	3.50	2.9	0.75
Rapeseed extr CP>380	534	1.94	10.4	2.70
Soybeans heat tr	230	5.37	12.4	3.22
Wheat middlings	158	7.00	11.1	2.88
Wheat feedfl CF<35	81	8.00	6.5	1.69
Vinasse Sugb CP>250	282	1.50	4.2	1.10
Grass hay good qual	443	50.00	221.5	57.70
Calcium carbonate	336	0.51	1.7	0.45
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	383.9	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	11.00	113.2	34.85
Citrus pulp, dried	122	16.00	19.5	6.01
Barley	78	1.08	0.8	0.26
Linseed	208	2.50	5.2	1.60
Sugarbeet molasses	160	2.00	3.2	0.99
Palm kern exp CF<180	770	11.00	84.7	26.08
Rapeseed	82	7.00	5.7	1.77
Rapeseed extr CP>380	534	3.88	20.7	6.38
Soybeans heat tr	230	10.74	24.7	7.61
Wheat middlings	158	14.00	22.1	6.81
Wheat feedfl CF<35	81	16.00	13.0	3.99
Vinasse Sugb CP>250	282	3.00	8.5	2.60
Calcium carbonate	336	1.02	3.4	1.06
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.47	324.8	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	10.01	103.0	33.61
Barley	78	18.90	14.7	4.81
Linseed	208	7.51	15.6	5.10
Sugarbeet molasses	160	0.98	1.6	0.51
Soybm CF<45 CP>480	261	10.99	28.7	9.36
Wheat	57	17.50	10.0	3.25
Fats/oils veg h %d		1.60		
Grass sil average	443	30.00	132.9	43.36
Premix		2.50		
Total		99.99	306.5	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	14.30	147.1	59.35
Barley	78	27.00	21.1	8.49
Linseed	208	10.70	22.3	8.98
Sugarbeet molasses	160	1.40	2.2	0.90
Soybm CF<45 CP>480	261	15.70	41.0	16.53
Wheat	57	25.00	14.3	5.75
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	247.9	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	2.61	26.9	9.54
Maize glfd CP200-230	169	0.95	1.6	0.57
Maize feed meal		1.15		
Sugarbeet molasses	160	0.24	0.4	0.14
Palm kern exp CF<180	770	1.78	13.7	4.87
Rapeseed exp	578	0.59	3.4	1.21
Rapeseed extr CP>380	534	6.18	33.0	11.72
Soybm CF<45 CP>480	261	7.83	20.4	7.26
Wheat middlings	158	0.96	1.5	0.54
Vinasse Sugb CP>250	282	0.36	1.0	0.36
Grass sil average	443	26.89	119.1	42.31
Maize sil DM280-320	120	50.23	60.3	21.41
Calcium carbonate	336	0.06	0.2	0.07
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	281.5	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	4.72	48.6	13.07
Maize glfd CP200-230	169	1.72	2.9	0.78
Maize feed meal		2.08		
Sugarbeet molasses	160	0.43	0.7	0.19
Palm kern exp CF<180	770	3.22	24.8	6.67
Rapeseed exp	578	1.07	6.2	1.66
Rapeseed extr CP>380	534	4.39	23.4	6.31
Soybm CF<45 CP>480	261	3.97	10.4	2.79
Wheat middlings	158	1.74	2.7	0.74
Vinasse Sugb CP>250	282	0.64	1.8	0.49
Grass sil average	443	49.18	217.9	58.65
Maize sil DM280-320	120	26.46	31.8	8.55
Calcium carbonate	336	0.11	0.4	0.10
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	371.5	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	22.00	226.4	43.75
Maize glfd CP200-230	169	8.00	13.5	2.61
Maize feed meal		9.70		
Sugarbeet molasses	160	2.00	3.2	0.62
Palm kern exp CF<180	770	15.00	115.5	22.32
Rapeseed exp	578	5.00	28.9	5.59
Rapeseed extr CP>380	534	15.00	80.1	15.48
Soybm CF<45 CP>480	261	10.30	26.9	5.20
Wheat middlings	158	8.10	12.8	2.47
Vinasse Sugb CP>250	282	3.00	8.5	1.64
Calcium carbonate	336	0.50	1.7	0.32
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	517.4	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize starch		0.17		
Calcium carbonate	336	30.50	102.5	5.28
Dicalcium Phosphate	10000	8.80	880.0	45.30
Salt		22.60		
Diammonium phosphate	15000	6.40	960.0	49.42
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	1942.5	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	78	2.00	1.6	0.49
Alf meal CP160-180	712	40.00	284.8	89.87
Soybm CF<45 CP>480	261	9.00	23.5	7.41
Wheat germfeed		46.00		
Calcium carbonate	336	2.10	7.1	2.23
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	316.9	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG150-200	1029	10.00	102.9	16.28
Barley	78	23.00	17.9	2.84
Alf meal CP160-180	712	35.00	249.2	39.42
Soybm CF<45 CP>480	261	5.00	13.1	2.06
Wheat bran	232	12.00	27.8	4.40
Fat from Animals		2.00		
Sunfmeal CF 200-240	313	10.00	31.3	4.95
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	10000	1.90	190.0	30.05
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	632.2	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat	57	14.90	8.5	4.38
Fish meal CP630-680	334	55.53	185.5	95.62
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		99.99	194.0	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Soybm CF<45 CP>480	261	20.00	52.2	22.70
Wheat	57	7.42	4.2	1.84
Fish meal CP630-680	334	51.96	173.5	75.46
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	230.0	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	261	55.00	143.6	80.57
Wheat	57	2.87	1.6	0.92
Wheat gluten meal	39	11.80	4.6	2.58
Fat from Animals		16.00		
Fish meal CP630-680	334	8.50	28.4	15.93
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	178.2	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Sugarb p SUG100-150	511	4.30	22.0	3.84
Meat meal CFAT<100	1324	40.62	537.8	93.95
Maize	29	27.80	8.1	1.41
Maize starch		2.78		
Rice wtht hulls	13	7.30	0.9	0.17
Fat from Animals		9.60		
Brewers y CP400-500	87	1.10	1.0	0.17
Calcium carbonate	336	0.80	2.7	0.47
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	572.4	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Brewers' yeast dried	116	1.80	2.1	1.50
Meat meal Dutch	1116	1.33	14.8	10.65
Greaves		29.76		
Linseed	208	3.00	6.2	4.48
Wheat	57	12.21	7.0	4.99
Wheat glutenfeed	152	2.06	3.1	2.25
Wheat feedfl CF<35	81	20.00	16.2	11.62
Feather meal hydr	481	18.00	86.6	62.12
Fat from Animals		7.97		
Fish meal CP630-680	334	1.00	3.3	2.40
Meat bone m CFAT>100		1.00		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	139.4	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	34.93	55.2	51.91
Maize	32	10.00	3.2	3.01
Wheat, soft	47	16.68	7.8	7.37
Wheat middlings	94	5.00	4.7	4.42
Soybean, full fat, extruded	146	15.10	22.0	20.73
Soybean meal, 50	178	7.50	13.4	12.56
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	106.3	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	15.00	23.7	25.43
Maize	32	15.81	5.1	5.43
Wheat, soft	47	27.50	12.9	13.87
Wheat middlings	94	2.00	1.9	2.02
Wheat gluten feed, starch 28%		10.00		
Corn distillers	105	3.00	3.2	3.38
Palm kernel meal, expeller	534	4.00	21.4	22.92
Rapeseed cake		6.00		
Soybean meal, 50	178	7.86	14.0	15.02
Sunflower meal, undecorticated	243	2.55	6.2	6.64
Tallow		3.00		
Phytase		1.50		
Calcium carbonate	336	0.45	1.5	1.63
L-Lysine HCl		0.49		
Monocalciumphosphate	7000	0.05	3.4	3.68
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	93.2	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	20.00	31.6	29.18
Maize	32	9.42	3.0	2.78
Wheat, soft	47	35.00	16.5	15.19
Wheat middlings	94	7.27	6.8	6.31
Corn distillers	105	5.00	5.3	4.85
Palm kernel meal, expeller	534	4.00	21.4	19.73
Rapeseed cake		7.00		
Soybean meal, 50	178	3.40	6.0	5.59
Sunflower meal, undecorticated	243	2.32	5.6	5.20
Beet pulp, dried	601	2.00	12.0	11.10
Tallow		2.09		
Calcium carbonate	336	0.02	0.1	0.07
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	108.3	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	20.00	31.6	26.30
Maize	32	6.93	2.2	1.84
Wheat, soft	47	35.00	16.5	13.69
Wheat middlings	94	10.00	9.4	7.82
Wheat gluten feed, starch 28%		3.04		
Corn distillers	105	6.21	6.5	5.43
Palm kernel meal, expeller	534	5.00	26.7	22.22
Rapeseed cake		1.35		
Sunflower meal, undecorticated	243	4.98	12.1	10.07
Beet pulp, dried	601	2.50	15.0	12.51
Tallow		2.00		
Calcium carbonate	336	0.04	0.1	0.10
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	120.1	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	20.00	31.6	19.26
Maize	32	15.26	4.9	2.98
Wheat, soft	47	11.22	5.3	3.21
Wheat bran	143	12.50	17.9	10.89
Wheat middlings	94	7.50	7.1	4.30
Wheat gluten feed, starch 28%		5.00		
Maize germ meal, expeller	218	7.50	16.4	9.96
Palm kernel meal, expeller	534	5.00	26.7	16.27
Sunflower meal, undecorticated	243	6.11	14.9	9.05
Beet pulp, dried	601	5.50	33.1	20.16
Molasses, sugarcane	188	0.10	0.2	0.11
Tallow		1.91		
Phytase		1.50		
Calcium carbonate	336	0.48	1.6	0.99
L-Lysine HCl		0.24		
Monocalciumphosphate	7000	0.07	4.6	2.82
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	164.1	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	20.00	31.6	22.06
Maize	32	10.00	3.2	2.23
Wheat, soft	47	23.43	11.0	7.69
Wheat middlings	94	7.50	7.1	4.92
Wheat gluten feed, starch 28%		10.00		
Soybean, full fat, extruded	146	1.39	2.0	1.42
Palm kernel meal, expeller	534	4.00	21.4	14.91
Rapeseed cake		6.00		
Soybean meal, 50	178	5.13	9.1	6.37
Sunflower meal, undecorticated	243	4.22	10.2	7.15
Beet pulp, dried	601	2.41	14.5	10.12
Tallow		2.16		
Phytase		1.50		
Calcium carbonate	336	1.02	3.4	2.40
L-Lysine HCl		0.34		
Monocalciumphosphate	7000	0.42	29.7	20.72
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	143.2	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	20.00	6.4	5.24
Wheat, soft	47	35.62	16.7	13.71
Wheat gluten feed, starch 28%		5.75		
Soybean, full fat, extruded	146	0.69	1.0	0.83
Rapeseed cake		5.00		
Soybean meal, 50	178	19.79	35.2	28.86
Sunflower meal, undecorticated	243	7.94	19.3	15.81
Tallow		2.00		
Calcium carbonate	336	1.34	4.5	3.68
L-Lysine HCl		0.07		
Monocalciumphosphate	7000	0.56	38.9	31.87
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	122.1	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	15.00	4.8	5.12
Wheat, soft	47	41.54	19.5	20.81
Wheat bran	143	7.50	10.7	11.43
Wheat gluten feed, starch 28%		10.00		
Corn distillers	105	2.50	2.6	2.80
Rapeseed cake		5.00		
Soybean meal, 50	178	2.95	5.3	5.60
Sunflower meal, undecorticated	243	10.00	24.3	25.90
Tallow		2.00		
Calcium carbonate	336	1.79	6.0	6.39
L-Lysine HCl		0.23		
Monocalciumphosphate	7000	0.29	20.6	21.94
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	93.8	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	20.00	6.4	4.57
Wheat, soft	47	38.18	17.9	12.83
Wheat gluten feed, starch 28%		0.47		
Corn distillers	105	4.00	4.2	3.00
Soybean, full fat, extruded	146	8.36	12.2	8.73
Soybean meal, 50	178	5.93	10.6	7.55
Sunflower meal, undecorticated	243	10.00	24.3	17.37
Tallow		2.87		
Calcium carbonate	336	7.78	26.2	18.69
L-Lysine HCl		0.23		
Monocalciumphosphate	7000	0.55	38.2	27.27
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	139.9	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	20.00	6.4	4.92
Wheat, soft	47	30.36	14.3	10.97
Wheat gluten feed, starch 28%		7.41		
Corn distillers	105	4.00	4.2	3.23
Soybean, full fat, extruded	146	7.80	11.4	8.76
Soybean meal, 50	178	6.34	11.3	8.68
Sunflower meal, undecorticated	243	10.00	24.3	18.68
Tallow		3.40		
Calcium carbonate	336	8.48	28.5	21.90
L-Lysine HCl		0.20		
Monocalciumphosphate	7000	0.43	29.8	22.87
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	130.1	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	30.00	9.6	6.34
Wheat, soft	47	28.16	13.2	8.74
Corn gluten meal	100	2.50	2.5	1.65
Soybean, full fat, extruded	146	15.00	21.9	14.47
Soybean meal, 50	178	18.41	32.8	21.65
Tallow		1.50		
Calcium carbonate	336	1.62	5.4	3.60
L-Lysine HCl		0.44		
Monocalciumphosphate	7000	0.94	65.9	43.55
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	151.4	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	15.00	4.8	3.53
Wheat, soft	47	42.41	19.9	14.66
Corn gluten meal	100	1.56	1.6	1.14
Soybean, full fat, extruded	146	10.00	14.6	10.74
Rapeseed cake		2.50		
Soybean meal, 50	178	20.22	36.0	26.46
Tallow		4.44		
Calcium carbonate	336	1.38	4.6	3.42
L-Lysine HCl		0.33		
Monocalciumphosphate	7000	0.78	54.5	40.05
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	136.0	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat, soft	47	57.84	27.2	24.96
Corn gluten meal	100	0.68	0.7	0.63
Soybean, full fat, extruded	146	10.16	14.8	13.62
Rapeseed cake		2.50		
Soybean meal, 50	178	19.32	34.4	31.58
Tallow		6.00		
Calcium carbonate	336	1.38	4.6	4.27
L-Lysine HCl		0.28		
Monocalciumphosphate	7000	0.39	27.2	24.94
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	108.9	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	20.00	6.4	2.60
Wheat, soft	47	25.35	11.9	4.84
Soybean meal, 50	178	42.45	75.6	30.70
Fish meal, protein 70%	252	5.00	12.6	5.12
Calcium carbonate	336	1.99	6.7	2.72
L-Lysine HCl		0.34		
Monocalciumphosphate	7000	1.90	133.0	54.03
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.97	246.2	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	6.94	2.2	0.87
Wheat, soft	47	40.00	18.8	7.35
Soybean, full fat, extruded	146	2.00	2.9	1.14
Soybean meal, 50	178	41.24	73.4	28.68
Calcium carbonate	336	1.15	3.9	1.51
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	7000	2.21	154.7	60.45
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	255.9	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	11.74	3.8	1.70
Wheat, soft	47	40.00	18.8	8.50
Soybean meal, 50	178	39.50	70.3	31.80
Calcium carbonate	336	1.30	4.4	1.98
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	7000	1.77	123.9	56.03
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	221.1	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	69.44	22.2	12.38
Soybean meal, 50	178	11.40	20.3	11.30
Feather meal	575	2.00	11.5	6.40
Calcium carbonate	336	7.60	25.5	14.22
Dicalcium Phosphate	10000	1.00	100.0	55.70
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	179.5	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat, soft	47	68.91	32.4	20.04
Wheat middlings	94	9.00	8.5	5.24
Soybean meal, 50	178	15.00	26.7	16.52
Calcium carbonate	336	1.20	4.0	2.50
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	10000	0.90	90.0	55.70
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	161.6	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	10.00	15.8	10.61
Maize	32	34.00	10.9	7.31
Wheat, soft	47	20.00	9.4	6.31
Soybean meal, 50	178	33.00	58.7	39.46
Calcium carbonate	336	1.20	4.0	2.71
Dicalcium Phosphate	10000	0.50	50.0	33.59
Premix		1.00		
Salt		0.30		
Total		100.00	148.9	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat gluten feed, starch 25%		5.00		
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	9	30.65	2.8	100.00
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	2.8	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	0.54	0.9	0.23
Wheat middlings	94	7.00	6.6	1.79
Wheat feed flour	14	8.00	1.1	0.31
Linseed, full fat	148	1.25	1.9	0.50
Rapeseed, full fat	216	3.50	7.6	2.06
Soybean, full fat, toasted	143	5.37	7.7	2.10
Palm kernel meal, expeller	534	5.50	29.4	8.01
Rapeseed meal	172	1.94	3.3	0.91
Beet pulp, dried	601	5.50	33.1	9.02
Citrus pulp, dried	71	8.00	5.7	1.55
Molasses, beet	117	1.00	1.2	0.32
Vinasse, different origins	277	1.50	4.2	1.13
Grassland, rich in grass, dehydrated	525	50.00	262.5	71.60
Calcium carbonate	336	0.51	1.7	0.47
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	366.6	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	1.08	1.7	0.82
Wheat middlings	94	14.00	13.2	6.32
Wheat feed flour	14	16.00	2.2	1.08
Linseed, full fat	148	2.50	3.7	1.78
Rapeseed, full fat	216	7.00	15.1	7.26
Soybean, full fat, toasted	143	10.74	15.4	7.38
Palm kernel meal, expeller	534	11.00	58.7	28.20
Rapeseed meal	172	3.88	6.7	3.21
Beet pulp, dried	601	11.00	66.1	31.74
Citrus pulp, dried	71	16.00	11.4	5.45
Molasses, beet	117	2.00	2.3	1.12
Vinasse, different origins	277	3.00	8.3	3.99
Calcium carbonate	336	1.02	3.4	1.65
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.47	208.3	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	18.90	29.9	10.38
Wheat, soft	47	17.50	8.2	2.86
Linseed, full fat	148	7.51	11.1	3.87
Soybean meal, 50	178	10.99	19.6	6.80
Beet pulp, dried	601	10.01	60.2	20.92
Molasses, beet	117	0.98	1.1	0.40
Grass silage	525	30.00	157.5	54.77
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	287.6	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	27.00	42.7	22.96
Wheat, soft	47	25.00	11.8	6.32
Linseed, full fat	148	10.70	15.8	8.52
Soybean meal, 50	178	15.70	27.9	15.04
Beet pulp, dried	601	14.30	85.9	46.26
Molasses, beet	117	1.40	1.6	0.88
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	185.8	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat middlings	94	0.96	0.9	0.42
Corn gluten feed	218	0.95	2.1	0.97
Corn gluten meal	100	1.15	1.2	0.54
Palm kernel meal, expeller	534	1.78	9.5	4.47
Rapeseed meal	172	6.18	10.6	5.00
Rapeseed cake		0.59		
Soybean meal, 50	178	7.83	13.9	6.56
Beet pulp, dried	601	2.61	15.7	7.38
Molasses, beet	117	0.24	0.3	0.13
Vinasse, different origins	277	0.36	1.0	0.47
Grass silage	525	26.89	141.2	66.40
Corn silage	32	50.23	16.1	7.56
Calcium carbonate	336	0.06	0.2	0.09
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	212.6	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat middlings	94	1.74	1.6	0.49
Corn gluten feed	218	1.72	3.7	1.11
Corn gluten meal	100	2.08	2.1	0.62
Palm kernel meal, expeller	534	3.22	17.2	5.10
Rapeseed meal	172	4.39	7.6	2.24
Rapeseed cake		1.07		
Soybean meal, 50	178	3.97	7.1	2.10
Beet pulp, dried	601	4.72	28.4	8.42
Molasses, beet	117	0.43	0.5	0.15
Vinasse, different origins	277	0.64	1.8	0.53
Grass silage	525	49.18	258.2	76.63
Corn silage	32	26.46	8.5	2.51
Calcium carbonate	336	0.11	0.4	0.11
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	337.0	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat middlings	94	8.10	7.6	2.51
Corn gluten feed	218	8.00	17.4	5.75
Corn gluten meal	100	9.70	9.7	3.20
Palm kernel meal, expeller	534	15.00	80.1	26.39
Rapeseed meal	172	15.00	25.8	8.50
Rapeseed cake		5.00		
Soybean meal, 50	178	10.30	18.3	6.04
Beet pulp, dried	601	22.00	132.2	43.56
Molasses, beet	117	2.00	2.3	0.77
Vinasse, different origins	277	3.00	8.3	2.74
Calcium carbonate	336	0.50	1.7	0.55
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	303.5	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize starch		0.17		
Calcium carbonate	336	30.50	102.5	5.28
Dicalcium Phosphate	10000	8.80	880.0	45.30
Salt		22.60		
Diammonium phosphate	15000	6.40	960.0	49.42
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	1942.5	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	2.00	3.2	1.47
Wheat bran	143	46.00	65.8	30.51
Soybean meal, 50	178	9.00	16.0	7.43
Alfalfa, dehydrated	309	40.00	123.6	57.32
Calcium carbonate	336	2.10	7.1	3.27
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	215.6	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Barley	158	23.00	36.3	8.17
Wheat bran	143	12.00	17.2	3.86
Soybean meal, 50	178	5.00	8.9	2.00
Sunflower meal, undecorticated	243	10.00	24.3	5.46
Beet pulp, dried	601	10.00	60.1	13.51
Lard		2.00		
Alfalfa, dehydrated	309	35.00	108.2	24.31
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	10000	1.90	190.0	42.70
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	445.0	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat, soft	47	14.90	7.0	4.77
Fish meal, protein 70%	252	55.53	139.9	95.23
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	146.9	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat, soft	47	7.42	3.5	2.05
Soybean meal, 50	178	20.00	35.6	20.93
Fish meal, protein 70%	252	52.00	131.0	77.02
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	170.1	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat, soft	47	2.87	1.3	1.02
Corn gluten meal	100	11.80	11.8	8.91
Soybean meal, 50	178	55.00	97.9	73.90
Maize starch		3.00		
Fish meal, protein 70%	252	8.50	21.4	16.17
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	132.5	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Maize	32	27.80	8.9	3.23
Rice, brown	16	7.30	1.2	0.42
Maize starch		2.78		
Beet pulp, dried	601	4.30	25.8	9.37
Brewers' yeast, dried	97	1.10	1.1	0.39
Lard		9.60		
Meat and bone meal, fat <7.5%	581	40.62	236.0	85.61
Calcium carbonate	336	0.80	2.7	0.98
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	275.7	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Fe/kg feed material	% feed material	mg Fe/kg complete feedingstuff	Fe (% contribution)
Wheat, soft	47	12.21	5.7	1.87
Wheat feed flour	14	20.00	2.8	0.91
Wheat gluten feed, starch 25%		2.06		
Linseed, full fat	148	3.00	4.4	1.44
Brewers' yeast, dried	97	1.80	1.7	0.57
Fish meal, protein 70%	252	1.00	2.5	0.82
Feather meal	575	18.00	103.5	33.68
Meat and bone meal, fat <7.5%	581	29.76	172.9	56.27
Meat and bone meal, fat >7.5%	586	2.33	13.7	4.44
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	307.3	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Lanthanum

Executive summary of the monograph for lanthanum

Lanthanum is a rare earth element and more specifically a lanthanoid. In the EU, lanthanum carbonate octahydrate is presently authorised as a feed additive for cats. NRC did not classify lanthanum as an essential nutrient and no essential function has yet been demonstrated. Rare earth elements have been widely used in China as growth promoters. Increases in body weight gain and improvements of feed conversion were observed in studies evaluating rare earth element supplementation in pigs and broilers. It was suggested that rare earth elements promote animal growth by inhibiting undesirable bacterial strains in the gastrointestinal tract. Results from experiments with cats indicate that feed supplementation with lanthanum carbonate octahydrate decreases the apparent phosphorus digestibility. It is suggested that this might prevent or reduce chronic renal malfunction in ageing animals. Rare earth elements are generally considered to be nontoxic to animals. In cats and dogs, vomiting was observed after feeding high dietary lanthanum carbonate octahydrate concentrations. NRC did not establish maximum tolerable levels but stated that dietary concentrations of 100 mg/kg DM should be considered safe. Lanthanides are generally excepted to be poorly absorbable. Lanthanides are primarily deposited in the liver and the skeleton. In edible tissues and products the lanthanum concentrations are in the µg/kg range. The acute toxicity of rare earth elements is low. Genotoxic effects, carcinogenic and teratogenic effects have not been reported for rare earths and are considered unlikely. Inhalation exposure to rare earths was shown to contribute to the development of progressive pulmonary fibrosis and they possess a mild toxic potential compared to other fibrogenic dusts. There were no indications that the presence of lanthanum in animal diets would have environmental consequences.

Lanthanum Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

The transfer of rare earth elements from the soil into plants is low. Only little accumulation of rare earth elements is reported in animal tissues and edible products (Redling, 2006).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

In the EU, lanthanum carbonate octahydrate is presently authorised as a feed additive for cats under Commission Regulation EC 163/2008[1].

3 Essential functions

NRC (2005) did not classify lanthanum as an essential nutrient.

4 Other functions

In China, rare earth elements have been used as feed additives for their growth promoting effects. In studies on pigs, increases in body weight gain and improvements of feed conversion rate have been observed. Organically bound rare earth elements, e.g., rare earth ascorbates and citrates, were shown to further enhance performance in pigs and poultry (Redling, 2006). Results from experiments with cats indicate that feed supplementation with lanthanum carbonate octahydrate ranging from dietary concentrations of 1500 mg/kg to 7500 mg/kg decreases the apparent phosphorus digestibility. It is suggested that this might prevent or reduce chronic renal malfunction in ageing animals (EFSA, 2007).

5 Antimicrobial properties

It has been suggested that rare earth elements promote animal growth by selectively influencing bacterial species within the gastrointestinal tract and inhibiting the development of undesirable strains (Redling, 2006).

6 Typical deficiency symptoms

No lanthanum deficiency signs have been reported in principal literature sources.

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[1] OJ L 50, 23.2.2008, p. 3

7 Animal requirements, allowances and use levels

No scientific bodies have published lanthanum requirements for livestock species.

8 Concentration of the element in feed materials

The concentrations of rare earth elements in plants are generally reported to be low. Though they vary considerably depending on the plant species and growing conditions. The following values have been reported: rice: 0.5 – 1 mg/kg; wheat: 1 – 2 mg/kg (Redling, 2006).

9 Concentration of the element in complete feedingstuffs

In pig feed lanthanum concentrations were reported in the range of 170 – 200 µg/kg (Redling, 2006).

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

The rare earth elements are relatively nontoxic to animals. NRC did not establish MTL values for lanthanum. It was stated that, taken the limited available information into account, rare earth dietary concentrations of 100 mg/kg DM should be considered safe (NRC, 2005).

11 Typical symptoms of toxicosis

NRC (2005) reported on an experiment where rats were given oral doses of $LaCl_3.7H_2O$ ranging from 0 – 1000 mg $LaCl_3.7H_2O$/(kg bw.day) for 28 days. The highest administered dose irritated the stomach mucosa and changed some liver enzymes suggestive of a hepatotoxic effect. In cats, repeated vomiting was observed after oral administration of 2 g lanthanum carbonate octahydrate/kg bw (Schmidt *et al*. 2009). In dogs, a dietary concentration of 100 g lanthanum carbonate octahydrate/kg complete feed was shown to induce vomiting on the second day of administration (Schmidt *et al*., 2009 b).

12 Bioavailability

In general, ingested lanthanides are only poorly absorbed (Redling, 2006).

13 Metabolism

It is generally agreed that rare earths are predominantly excreted with feces through both bile as well as through the wall of the gastrointestinal tract (Redling, 2006)

14 Distribution in the animal body

The liver and the skeleton were shown to be the organs with the highest deposition of lanthanides. High concentrations have also been reported in oocytes, ovaries, testes, the intestine and cecum (Redling, 2006). In humans, values of the lanthanum concentrations in plasma, serum, lung, bone, brain, and heart were reported of respectively, < 0.006 mg/L, < 0.006 mg/L, 0.01 µg/kg, 0.2 µg/kg, 0.001 – 0.036 µg/kg, 0.0012 µg/kg (Redling, 2006).

15 Deposition (typical concentration) in edible tissues and products

Lanthanum concentrations in edible tissues and products are given in Table 1 (Redling, 2006).

Table 1 Lanthanum concentrations in edible tissues (µg/kg) derived from various feed trials as compiled by Redling (2006)

	La concentration		
Species	Muscle	Liver	Kidney
Broiler	Breast: 5	7.5	
Broiler	Breast: 15	19	9.6
	Thigh: 15		
Pigs	3.0 DM	2.8 DM	< 3 DM
Piglets	11.6	25.3	

16 Acute toxicity

Rare earths are generally considered to be of low toxicity. Oral LD_{50} values are reported in Table 2 (Redling, 2006).

Table 2 Oral LD_{50} values for lanthanum (Redling, 2006)

Lanthanum compound	**Species**	**LD_{50} (mg/kg bw)**
La^{3+}- acetate	Rats	10000
La^{3+}- ammonium nitrate	Rats	3400
$LaCl_3$	Rats	4200
$LaCl_3$	Mice, male	2354
$La(NO_3)_3$	Rats	4500
$La(SO_4)_3$	Rats	> 5000
La_2O_3	Rats	> 10000

17 Genotoxicity and Mutagenicity

No information on genotoxic effects of lanthanum was reported in principal literature sources. Redling (2006) stated that genotoxic effects of ingested rare earth elements are not to be expected.

18 Subchronic toxicity

Except for the data reported in Chapter 11, no information on the subchronic toxicity of lanthanum was reported in principal literature sources.

19 Chronic toxicity, including carcinogenicity

Rare earths are mainly deposited in the liver and hepatotoxic effects have been observed. The induction of the fatty liver phenomenon, i.e. the massive hepatic accumulation of neutral fat esters, has been shown following intravenous injection of rare earths but not following oral exposure (Redling, 2006).

Lanthanides were shown to associate to both the organic and inorganic matrix of bone. Although the skeleton is the second major deposition site or rare earth elements, no toxic effects on bone structure have been found (Redling, 2006).

20 Reproduction and developmental toxicity

No information on reproductive and developmental effects of lanthanum was reported in principal literature sources. Redling (2006) stated that teratogenic effects of ingested rare earth elements are not to be expected.

21 Non Observed Adverse Effect Level (NOAEL)

Upper intake levels have not been established by scientific bodies, hence, no NOAEL level was identified to serve as the basis to establish an upper intake level.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

No scientific body has yet established an UL for lanthanum. An acceptable daily intake was suggested by some authors for rare earth nitrates and rare earth oxides of respectively, 12 – 120 mg/day and 6 – 60 mg/day (Redling, 2006).

23 Toxicological risks for user/workers

Inhalation exposure of stable rare earths was shown to contribute to the development of progressive pulmonary fibrosis. The accumulation of fine granular dust particles containing rare earth elements, mainly cerium, may cause interstitial disorders and emphysema. Compared to other fibrogenic dusts, e.g., quarts and silica, the toxic potential of rare earth dusts is mild (Redling, 2006). For lanthanum carbonate octahydrate, EFSA (2007) did not identify any risks for the user/owner, when this lanthanum compound is used as a feed additive for cats.

24 Toxicological risks for the environment

There were no indications in principal literature sources that the presence of rare earth elements in animal diets would have environmental consequences. EFSA (2007) concluded that the use of lanthanum carbonate octahydrate as a feed additive for cats is not considered to pose any risk to the environment.

25 References

EFSA. 2007. Safety and efficacy of Lantharenol® (Lanthanum carbonate octahydrate) as a feed additive for cats according to Regulation (EC) No 1831/2003. Opinion of the Scientific Panel on Additives and Products or Substances used in Animal Feed. Summary of opinion.

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Lead

Executive summary of the monograph for lead

EU legislation governs the maximum content for lead in products intended for animal feed and in foodstuffs. Lead is not considered an essential nutrient and a defined biochemical function has not yet been identified. Lead concentration in pastures and soils rarely exceed 5 mg/kg DM. Grazing animals ingest lead through the consumption of soil. Lead impurities are often present in mineral feed material. Lead is a chronic and cumulative poison. Low levels of lead exposure cause subtle cardiovascular, haematological, and neurodevelopmental changes. Higher levels of exposure cause renal, gastrointestinal, hepatic and immunological disturbances. Lead absorbability varies considerably depending on the animal species, dose, compounds, the presence of dietary constituents, age and physiological state. Lead in feed is not efficiently absorbed, but lead ingested after a fast is much more available. Measurement of the blood lead concentration is the most widely used biomarker of lead exposure. The lead concentration in bone is considered a biomarker of cumulative exposure to lead because lead accumulates in bone over a lifetime. Absorbed lead is transported bound to haemoglobin and is consecutively taken up by peripheral tissues. Over time lead redistributes to bone where it forms stable complexes with phosphate, replacing calcium in hydroxyapatite. Lead is excreted in urine and feces. Lead accumulates predominantly in bone, kidney, liver and brain. Muscle lead concentrations are low except at very high ingestion levels.

Acute lead poisoning induces neurological symptoms including dullness, irritability, fatigue, delirium. In humans, overt signs of neurotoxicity occur when blood lead levels reach 40 – 60 µg/dL. Results of genotoxicity tests suggest that lead is a clastogenic agent, as judged by the induction of chromosomal aberrations micronuclei, and sister chromatid exchanges in peripheral blood cells. There is only limited evidence of direct genotoxic or DNA damaging effects. Lead exposure may increase the susceptibility to genotoxic agents. Lead could potentially affect any organ system . The developing nervous system, the haematological and cardiovascular systems and the kidney are considered most sensitive. Lead impairs cognitive function in children and adults. Population studies suggest that there is a significant association between bone lead levels and elevated blood pressure. Glomerular filtration is affected at the lowest blood lead levels. IARC classified inorganic lead compounds as probably carcinogenic to humans (Group 2 A) and organic lead compounds as not classifiable as to their carcinogenicity to humans (Group 3). WHO identified reduced cognitive development and intellectual performance in children to be the most critical effect of lead at low exposure concentrations and established a provisional tolerable weekly intake for lead of 25 µg/kg bw for all age groups. Inhaled and deposited lead is absorbed to high extents. Clinical lead poisoning is mainly reported from occupational settings. The implementation of the actual EU legislation, fixing maximum lead levels in feedingstuffs, limits the contribution of lead originating from animal excreta to the environment.

Lead Monograph

1 Forms/Sources of the element of importance in human and animal nutrition

In the diet, fruits, vegetables, cereals, bakery wares, and beverages are major sources of lead. Lead is present in vegetables mainly as a result of deposition from air. Wines may contain considerable lead concentrations, partly because of use of lead arsenate as a fungicide in vineyards and contamination from containers such as decanters (Skerfving & Bergdahl, 2007).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Presently, in the EU the Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2] on undesirable substances in animal feed governs the maximum tolerable levels of cadmium in feedingstuffs (Table 1).

Table 1 Maximum allowed lead content (*) in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2]

Products intended for animal feed	Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12%
Feed materials with the exception of	10
– green fodder (**)	30
– phosphates and calcareous marine algae	15
– calcium carbonate	20
– yeasts	5
Additives belonging to the functional group of compounds of trace elements except	100
– zinc oxide	400
– manganous oxide, iron carbonate, copper carbonate	200

[1] OJ L 140, 30.5.2002, p. 10

[2] OJ L 318, 6.12.2005, p. 19

Table 1 (continued) Maximum allowed cadmium content in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2005/87/EC[2]

Products intended for animal feed	**Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12%**
Additives belonging to the functional groups of binders and anti-caking agents except:	30
– clinoptilolite of volcanic origin	60
Premixtures	200
Complementary feedingstuffs with the exception of	10
– mineral feedingstuffs	15
Complete feedingstuffs	5

(*) Maximum levels refer to an analytical determination of lead, whereby extraction is performed in nitric acid (5% w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency.
(**) Green fodder includes products intended for animal feed such as hay, silage, fresh grass, etc.

2.2 Human nutrition

In the EU, Regulation EC 1881/2006[3] ammended by Regulation EC 629/2008[4] sets maximum levels (ML) for lead in certain foodstuffs, as summarized in Table 2.

Table 2 Maximum Levels (ML) for lead (mg/kg) in foodstuffs in the EU set by Regulations EC 1881/2006[3] and EC 629/2008[4]

Foodstuffs	**ML**
Raw milk, heat treated milk and milk for the manufacture of milk based products	0.020
Infant formulae and follow-on formulae	0.020
Meat (excluding offal) of bovine animals, sheep, pig and poultry	0.10
Offal of bovine animals, sheep, pig and poultry	0.50
Muscle meat of fish	0.30

[3] OJ L 364, 20.12.2006, p. 19

[4] OJ L 173, 3.7.2008, p. 6

Table 2 (continued) Maximum Levels (ML) for lead (mg/kg) in foodstuffs in the EU set by Regulations EC 1881/2006[3] and EC 629/2008[4]

Foodstuffs	ML
Crustaceans, excluding brown meat of crab and excluding head and thorax meat of lobster and similar large crustaceans (*Nephropidae* and *Palinuridae*)	0.50
Bivalve molluscs	1.5
Cephalopods (without viscera)	1.0
Cereals, legumes and pulses	0.20
Vegetables, excluding brassica vegetables, leaf vegetables, fresh herbs and fungi. For potatoes the maximum level applies to peeled potatoes	0.10
Brassica vegetables, leaf vegetables and the following fungi: *Agaricus bisporus* (common mushroom), *Pleurotus ostreatus* (Oyster mushroom), *Lentinula edodes* (Shiitake mushroom)	0.30
Fruits excluding berries and small fruit	0.10
Berries and small fruit	0.20
Fats and oils, including milk fat	0.10
Fruit juices, concentrated fruit juices as reconstituted and fruit nectars	0.050
Wine (including sparkling wine, excluding liqueur wine), cider, perry and fruit wine	0.20
Aromatized wine, aromatized wine-based drinks and aromatized wine-product cocktails	0.20
Food supplements	3.0

3 Essential functions

Lead is not considered an essential nutrient for animals and does not participate in any known beneficial biochemical function (NRC, 2005).

4 Other functions

In several studies, the addition of lead to the diet of rats and pigs improved growth rates and lipid metabolism and in chickens, improved egg production has been observed (NRC, 2005).

5 Antimicrobial properties

There was no information found on antimicrobial properties of lead relevant for animal husbandry in principal literature sources.

6 Typical deficiency symptoms

Lead is not an essential trace element and no deficiency symptoms haven been described (NRC, 2005).

7 Animal requirements, allowances and use levels

No lead requirements have been established by scientific bodies.

8 Concentration of the element in feed materials

The lead content of soils varies widely. Lead levels in soil of 20 – 40 mg/kg DM may be considered normal, though, significantly higher concentrations have been reported, mainly as a result of mining or industrial activity, or the application of sewage sludge. Lead uptake by plants is limited, and concentrations in pasture and crops rarely exceed 5 mg/kg DM. Consequently, exposure to lead is principally a result of consuming soil while grazing or foraging on contaminated land, or consuming contaminated feed. Lead impurities are often present in mineral feed material, like phosphates, and can contribute significantly to the diet contamination, even within the fixed limits (EFSA, 2004; SCAN, 2003). Mean lead concentrations in feed materials and forages are compiled in Table 3.

Table 3 Mean lead concentrations (mg/kg DM) in feed materials and forages

Feed material	**n**	**Pb concentration (EFSA, 2004)**	**Feed material**	**n**	**Pb concentration (Li *et al*., 2005)**
Barley grain	11	0.97			
Citrus pulp meal	14	0.76			
Fish meal	77	0.52			
Maize and maize products	31	0.56	Maize grain	16	0.134
Meat meal and meat and bone meal	23	0.81			
Rapeseed meal	18	0.6			
Soya beans and soybean meal	21	0.93			
Sugar beet pulp	14	1.47			
Sunflower seeds and by-products	36	0.37			
Wheat and wheat products	12	0.26			

Table 3 (continued) Mean lead concentrations (mg/kg DM) in feed materials and forages

Feed material	n	Pb concentration (EFSA, 2004)	Feed material	n	Pb concentration (Li *et al*., 2005)
Grass / herbage	1077	4.93			
Hay	809	3.89	Alfalfa hay	43	0.198
Grass silage	225	2.02			
Maize silage	336	2.19	Maize silage	20	0.260
All forages (including forages not included in above categories)	2460	2.52			
Premixes	100	19.05	Mineral mix[1]	21	2.857
Mineral supplements	198	3.38			
Magnesium oxide	2	30			

[1]: included phosphorus containing mineral nutrients, trace mineral mixes, buffers, and limestone

9 Concentration of the element in complete feedingstuffs

Lead concentrations in complete feedingstuffs are compiled in Table 4.

Table 4 Mean lead concentrations (mg/kg DM) in commercial complete feedingstuffs

Complete feedingstuff	n	Pb conc. (EFSA, 2004)	Complete feedingstuff	n	Pb conc. (Nicholson *et al*., 1999)
Poultry layers	12	0.87	Layer	4	< 1.00
Poultry broilers	8	0.52	Broiler	11	< 1.00
Poultry unspecified	20	1.16	Turkey	13	< 1.00
Pigs < 17 weeks	13	0.77	Rearer - creep	4	< 1.00
Pigs > 16 weeks	9	0.38	Rearer - weaner	4	< 1.00
Pigs unspecified	39	1.03	Rearer - grower	5	< 1.00
			Rearer - finisher	7	< 1.00
Pigs sows	5	0.70	Sow - dry	3	< 1.00
			Sow - lactating	3	2.10
Ruminants unspecified	311	0.34			
Ruminants dairy	7	1.03			
Ruminants beef cattle	15	1.14			
Ruminants calves	9	0.82			
Ruminants sheep	12	0.64			
Fish	352	0.07			

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

MTL values established by NRC (2005) are compiled in Table 5.

Table 5 Maximum Tolerable Levels (MTL) for lead (mg/kg DM) (NRC, 2005)

Species	**MTL**
Rodents, poultry, swine, horses, fish	10
Cattle, sheep	100

Additionally to the lead MTL values, NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Lead is a chronic and cumulative poison. It provokes anemia, renal toxicity, cancer, has a cardiovascular and neurological/behavioural impact and negative consequences on the reproductive system. In cattle, clinical signs of lead intoxication comprise neurotoxicity including blindness, muscle twitching, hyperirritability, depression, convulsions, grinding teeth, ataxia, circling and head pressing. Additional signs include excessive salivation, anorexia, tucked abdomen, and rumen stasis, and diarrhea alternating with constipation. In sheep and goats, chronic excessive lead exposure was observed to affect the foetus. Muscle weakness, roaring due to laryngeal paralysis, respiratory distress, stiffness of joints, progressive arching of the back and anorexia followed by loss of weight, and cachexia, have been observed in horses. After chronic exposure, degeneration of the liver and the kidney may be seen (EFSA, 2004; SCAN, 2003).

12 Bioavailability

12.1 General

Lead absorption after oral ingestion ranges from 1 – 80 %, and varies considerably depending on the animal species, dose, compound, the presence of dietary constituents, age and physiological state (EFSA, 2004; NRC, 2005). In adult humans, the proportion of a dose of highly soluble lead may vary from less than 10 % when ingested with a meal to 60 – 80 % when ingested after a fast. Estimates derived from dietary balance studies conducted in infants and children indicate that approximately 40 – 50 % of ingested lead is absorbed. Calcium and phosphate are particularly effective in reducing lead absorption (ATSDR, 2007; EFSA, 2004; NRC, 2005).

12.2 *Lead status indicators / biomarkers of lead exposure*

The ideal biomarker of lead exposure would be a measurement of the total body burden. Measurement of the blood lead concentration is the most widely used biomarker of lead exposure. The elimination half-time of lead in blood is approximately 30 days, therefore, the lead concentration in blood relatively reflects the exposure history of the previous few months. Hence, it does not necessarily reflect the larger burden and much slower elimination kinetics of lead in bone. The lead concentration in bone, measurable with noninvasive XRF techniques, is considered a biomarker of cumulative exposure to lead because lead accumulates in bone over a lifetime and most of the lead body burden resides in bone (ATSDR, 2007).

13 Metabolism

The gastrointestinal absorption of lead occurs primarily in the duodenum. It is likely that the lead absorption occurs by inadvertent uptake through pathways of essential nutrients such as the divalent metal transporter 1, which transports non-heme iron. The rate limiting processes in lead absorption are associated with transfer of lead from erythrocytes to the blood rather than transport across the apical membrane of the erythrocytes. Once absorbed lead enters the blood where > 90% is taken up by red blood cells. Most of the lead in red blood cells is bound to hemoglobin within the cell rather than the erythrocyte membrane. After entering peripheral tissues, lead is predominantly bound to protein. Over time lead redistributes from soft tissues to bone where it forms stable complexes with phosphate, replacing calcium in hydroxyapatite. As a result, lead is incorporated into bone during bone growth and remodeling and is also released to the blood during the process of bone resorption. The metabolism of inorganic lead consists primarily of reversible ligand reactions, including the formation of complexes and thiols with free amino acids and proteins. Organolead compounds are actively metabolized in the liver by oxidative dealkylation catalysed by cytochrome P-450. Tetraethyl and tetramethyl lead are oxidized to triethyl and trimethyl metabolites, respectively, and to inorganic lead. Further biotransformation of these intermediate metabolites is highly species specific. The half-life for lead in blood and other soft tissues of adult humans is about 1 month, but is much longer in the various bone compartments. Lead is excreted in urine following glomerular filtration and in the feces, either by transmucosal losses or through biliary clearance in the form of organolead conjugates (NRC, 2005).

14 Distribution in the animal body

During long term exposure, lead accumulates in bones by co-precipitation with calcium. It is deposited predominantly in physiologically inactive cortical bones where it may persist for decades without substantially influencing the concentrations of lead in blood and other tissues. The skeleton is reported to contain > 90 % of the body burden of lead. This fraction may be even higher in lead workers. In bone accumulated lead may be released when bone recomposition occurs (EFSA, 2004; Skerfving & Bergdahl, 2007). Among the soft tissues the liver and the kidneys attain the highest concentrations. Lead does, to some extent pass the blood brain barrier. The peripheral nervous system accumulates more lead then the central nervous system (EFSA, 2004; NRC, 2005; Skerfving & Bergdahl, 2007).

15 Deposition (typical concentration) in edible tissues and products

In muscle lead residues are reported to be low compared to liver and kidney lead concentrations. Following high exposure doses lead may be excreted with milk (EFSA, 2004; Oskarsson *et al*., 1992). Lead concentrations in edible tissues and products are reported in Annex 1 and lead concentrations in edible tissues and products linked with the dietary intake of several lead compounds and doses are reported in Annex 2.

16 Acute toxicity

In humans, early neurological symptoms of acute lead poisoning include dullness, irritability, fatigue, decreased libido, dizziness, and confusion. The condition may worsen to delirium, convulsions, paralysis, coma or death. Overt signs of neurotoxicity occur when blood levels reach 40 – 60 µg/dL (NRC, 2005).

17 Genotoxicity and Mutagenicity

The potential genotoxic effects of lead have been studied in lead workers, in members of the general public, in animal studies, as well as in *in vitro* cultures of mammalian cells and microorganisms. Although not always consistent, the results suggest that lead is a clastogenic agent, as judged by the induction of chromosomal aberrations, micronuclei, and sister chromatid exchanges in peripheral blood cells (ATSDR, 2007). There is only limited evidence of direct genotoxic or DNA damaging effects. Rather, lead-induced nongenotoxic, epigenetic mechanisms seem to affect DNA. Thus, lead exposure may increase the susceptibility to genotoxic agents (Skerfving & Bergdahl, 2007). Results exposure studies in humans and animal trials indicate that generally DNA damage in the lungs, liver and kidneys correlates with the length of exposure and lead concentration in the tissue (ATSDR, 2007). ATSDR (2007) and IARC (2006) extensively reported on genotoxicity and mutagenicity studies with lead compounds.

18 Subchronic toxicity

The ATSDR Toxicological profile for lead includes information on the subchronic toxicity of several lead compounds on several organ systems and by several exposure routes (ATSDR, 2007).

19 Chronic toxicity, including carcinogenicity

The most sensitive targets for lead toxicity are the developing nervous system, the hematological and cardiovascular systems, and the kidney. However, lead could potentially affect any system or organ in the body. Lead can impair cognitive function in children and adults, but children are more vulnerable than adults. Population studies suggest that there is a significant association between bone-lead levels and elevated blood pressure. Glomerular filtration rate appears to be the function affected at the lowest blood lead levels (PbB). Lead alters the hematological system by inhibiting the activities of several enzymes involved in heme biosynthesis, e.g., δ-aminolevulinic acid dehydratase. Lead induced anemia results of the inhibition of heme synthesis and shortening of erythrocyte lifespan. Changes in circulating levels of thyroid hormones, particularly serum thyroxine (T_4) and thyroid stimulating hormone (TSH) have occurred in exposed individuals having mean PbB ≥ 40 - 60 µg/dL. Altered immune parameters have been described at PbB values in the range of 30 – 70 µg/dL (ATSDR, 2007).

Animal experiments have shown a tumorigenic effect of lead. Soluble lead salts have produced kidney and brain tumors in rodents after oral or parenteral administration. Synergistic effects were demonstrated for the development of cancer between lead acetate and lead oxide, on the one hand and some organic carcinogens, such as benzopyrene and nitrosamines, on the other (Skerfving & Bergdahl, 2007). IARC concluded in its evaluation of inorganic and organic lead compounds that inorganic lead compounds are probably carcinogenic to humans (Group 2 A) and organic lead compounds are not classifiable as to their carcinogenicity to humans (Group 3) (IARC, 2006).

20 Reproduction toxicity

The developing nervous system is known to be one of the most sensitive targets for lead toxicity. Altered serum levels of reproductive hormones have been observed at PbB ≥ 30 - 40 µg/dL (ATSDR, 2007)

21 Non observed adverse effect level (NOAEL)

No information was available on the identification of a NOAEL to serve as the basis to establish an upper intake level for lead.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

WHO (2000) identified reduced cognitive development and intellectual performance in children to be the most critical effect of lead at low exposure concentrations. A provisional tolerable weekly intake for lead of 25 µg/kg bw was established for all age groups (WHO, 2000).

ATSDR (2007) did not derive minimal risk levels because clear thresholds for some of the more sensitive effects in humans have not been identified.

23 Toxicological risks for user/workers

Clinical lead poisoning is reported mainly from occupational exposures. High risk occupations include primary and secondary lead smelting, production of lead paint, spray painting with lead paint. The organolead compounds tetraethyl and tetramethyl lead, which have been used in high quantities in leaded petrol may cause acute encephalopathia as a result of inhalation or dermal exposure (Skerfving & Bergdahl, 2007). Inorganic lead in ambient air consists of aerosols of particulates that can be deposited in the respiratory tract when the aerosols are inhaled. The absorption of deposited lead is influenced by particle size and solubility of the lead compound as well as the pattern of deposition within the respiratory tract. Approximately 95 % of deposited inorganic lead that is inhaled as submicron particles is absorbed. Inhaled and deposited organic tetraalkyl lead is also reported to be absorbed to a high extent (ATSDR, 2007).

24 Toxicological risks for the environment

The implementation of the actual EU legislation, fixing maximum lead levels in feedingstuffs, limits the contribution of lead originating from animal excreta to the environment.

Lead concentrations in manure from multiple monitoring studies are compiled in Table 6.

Table 6 Lead content of manure from various species

Species, category	**Pb content (mg/kg DM)**	**Reference**
Dairy cattle FYM	3.61	Nicholson *et al*. (1999)
Dairy cattle slurry	5.87	
Beef cattle FYM	1.95	
Beef cattle slurry	7.07	
Pig FYM	2.94	
Pig slurry	2.48	
Broiler / turkey	3.62	
Layer	8.37	
Broiler	0.55	van Ryssen (2008)
Layer	1.17	

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Glossary

PbB: Blood lead level

Annex 1: Lead concentrations in edible tissues and products

Table 1.1 Lead concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pork	5	0.00662			Bordajandi *et al*. (2004)
Hogs	326	1.20	0.81	0.97	Coleman *et al*. (1992)
Boars / sows	280		0.7	0.62	
Pork	31	0.018			Gerber *et al*. (2009)
Pigs	20	0.0794	0.075	0.07	Gyori *et al*. (2005)
Pigs	426	0.001	0.019	0.11	Jorhem & Sundström (1993)
Pork		< 0.015	< 0.016	< 0.016	Larsen *et al*. (2002)
Pigs (6 m)	62	0.003	0.004	0.008	López-Alonso *et al*. (2007)

Table 1.2 Lead concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Male calves	230	0.00642	0.0348	0.0388		Alonso *et al*. (2000)
Female calves	200	0.00630	0.0311	0.0392		
Cows	56	0.0125	0.0475	0.0583		
Veal	438	0.00874	0.0526			Alonso *et al*. (2002)
Beef	56	0.0170				
Dairy cattle	4				0.09 - 0.11	Ayar *et al*. (2009)
Calves (6 - 12 m)	195		0.156	0.0632		Blanco-Penedo *et al.* (2006) [b]
Cattle	118	< 0.03 - 0.0189				Blanco-Penedo *et al.* (2010)
Calves	327	0.62	0.84	0.87		Coleman *et al*. (1992)
Heifers / Steers	287	0.52	1.00	0.58		
Bulls / Cows	95	0.58		0.70		
Lambs	165	0.77	0.71	0.64		
Mature sheep	34		0.61	0.60		
Lamb		0.019				Gerber *et al*. (2009)
Beef		0.018 - 0.02				
Cattle	34	0.001	0.070	0.35		Jorhem & Sundström (1993)
Beef		< 0.016	0.043	0.089		Larsen *et al*. (2002)[a]
Calf		< 0.014	0.017	0.053		
Lamb		< 0.014				
Dairy cattle	16				0.003	Leblanc *et al*. (2005)[a]
Dairy cattle	40				0.00132	Licata *et al*. (2004)
Calves	312	0.0111	0.0345	0.0346		Miranda *et al*. (2003)
Calves, industrialized area	78	0.00814	0.0381	0.0383		Miranda *et al*. (2005)
Calves, rural area	92	0.00805	0.0207	0.0159		
Cattle	100		0.052	0.126		Nriagu *et al*. (2009)
Dairy cattle	3				0.046 - 0.397	Santos *et al*. (2004)[a]
Cattle	97	0.003	0.082	0.212		Waegeneers *et al*. (2009)
Dairy cattle					0.001	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: calves grazing on pastures fertilized with pig slurry; [c]: n= 187

Table 1.3 Lead concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken and eggs		0.0248 - 0.0557	0.020		0.00182 - 0.0242	Bordajandi *et al*. (2004)
Chickens (young)	311			0.93		Coleman *et al*. (1992)
Chickens (mature)	308		0.54	0.63		
Ducks	111		0.62	0.66		
Chicken		0.018 - 0.02				Gerber *et al*. (2009)
Chicken		< 0.014	< 0.016			Larsen *et al*. (2002)[a]
Turkey						
Poultry		0.015 [b]			0.011 [c]	Leblanc *et al*. (2005)[a]
Hens, private owners	22				0.06856	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.00891	
Hens, eggs collected in autumn	40				0.116	Waegeneers *et al*. (2008)
Hens, eggs collected in spring	58				0.0738	
Poultry and eggs		0.005			0.003	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Lead concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	1.03 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	0.84 DM	
Atlantic herring	3	< 0.005	Engman & Jorhem (1998)
Baltic herring	3	0.007	
Burbot	2	< 0.004	
Cod	4	0.009	
Eel	3	0.002	
Mackerel	3	< 0.006	
Perch	3	< 0.005	
Picked dogfish	2	0.007	
Pike	5	< 0.005	
Plaice	4	< 0.006	
Pollack	2	< 0.004	
Salmon	3	< 0.005	
Turbot	3	0.005	
Whitefish	3	0.008	
Chub mackerel	60	0.14 - 0.30	Ersoy & Celik (2009)
Mediterranean horse mackerel	60	0.14 - 0.35	
Golden grey mullet	60	0.14 - 0.26	
Round herring	60	0.14 - 0.36	
Fish	62	0.023	Leblanc *et al*. (2005) [a]
Shellfish	18	0.098	
Fish	3	0.024 - 0.049	Santos *et al*. (2004) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	3.025 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	4.078 DM	
Gilthead seabream *Sparus aurata*	45	4.873 DM	
Clarias gariepinus	38	0.014	Türkmen *et al*. (2007)
Carasobarbus luteus	23	0.008	

[a]: Total diet study

Table 1.5 Lead concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Holzing (AU)	23	0.0066	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.0064	
Origin: Hollabrunn (AU)	19	< 0.002	
Origin: Siena County (It)	51	0.076	Pisani *et al*. (2008)
Origin: Turkey	75	0.0084 - 0.106	Tuzen *et al*. (2007)

Annex 1: References

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Annex 2: Lead concentrations in edible tissues and products linked with the dietary intake of several lead compounds and doses

Table 1 Lead concentrations in edible tissues and products of pigs and poultry (mg/kg)

Species / category	Source of Pb supplemented	Dose of Pb supplemented (mg Pb/kg)	Pb content of complete feed [1] (mg Pb/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Pigs				6 m	0.0163	0.0178	heart: 0.0232		Phillips *et al*. (2003)[2]
	Lead acetate $Pb(CH_3COOH)_2.3H_2O$	10			0.0534	0.0355	heart: 0.0433		
Broilers				7 d	1.39 DM [a]	2.13 DM [a]			Bakalli *et al.* (1995)
	Lead sulphate	50			3.56 DM [c]	4.90 DM [c]			

[1]: Data from feed analysis; [2]: experimental diet was also supplemented with 1 mg Cd/kg

Statistics:

Phillips *et al*. (2003): Liver and kidney Pb concentrations differ significantly between control and experimental diet at P< 0.01; Pb concentrations in heart differ significantly at P < 0.05

Bakalli *et al.* (1995): means within each column with different superscripts differ significantly at P< 0.05, Anova

Table 1 (continued) Lead concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Pb supplemented	Dose of Pb supplemented (mg Pb/kg)	Pb content of complete feed [1] (mg Pb/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Sheep			3.4 DM	84 d	1.3 DM [b]	1.0 DM [e]	0.2 DM [e]		Fick *et al*. (1976)
	Lead acetate	10			1.8 DM [b]	2.0 DM [e]	0.2 DM [e]		
	Lead acetate	100			5.3 DM [b]	9.4 DM [e]	0.2 DM [e]		
	Lead acetate	500			11.6 DM [c]	25.1 DM [e]	0.2 DM [e]		
	Lead acetate	1000			14.4 DM [c]	230.6 DM [f]	0.7 DM [f]		
Lactating Cows			3.67	12 w	0.15	0.63	0.02	< 0.02	Sharma *et al.* (1982) [2]
	Lead acetate		9.23		0.43	1.24 [*]	0.06	< 0.02	
	Lead acetate		31.45		0.72	4.04 [*]	0.03	0.1	

1: Data from feed analysis;[2]: supplemented doses of lead acetate are expressed as 100 mg Pb/(animal .day) and 500 mg Pb/(animal.day)

Statistics:

Fick *et al*. (1976): [b,c]: means in the same column with different superscripts differ significantly at P < 0.01; [e,f]: means in the same column with different superscripts differ significantly at P < 0.05

Sharma *et al.* (1982) : [*] value significantly different from control at P < 0.05.

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Lithium

Executive summary of the monograph for lithium

NRC classified lithium as a non-essential nutrient for animals. Lithium deprivation in goats and rats under experimental conditions caused several symptoms including reduced fertility, birth weight, litter size and lifespan. Lithium was shown to be an effective agent in the recovery of animals with bovine spastic paresis. The aversion to lithium salts has been exploited by training livestock to associate their aversion to lithium with the concurrent intake of toxic plants. Forage and grains are generally rich lithium sources. Excessive ingestion of lithium was shown to reduce feed intake in pigs, chickens, cattle and sheep. In chickens, lithium toxicity signs include reduced egg production and egg weight. In pigs, a thirst response has been observed. Ingested lithium in the form of soluble salts is essentially fully absorbed in the small intestine. Absorbed lithium is not protein bound and distributes throughout the body with only small differences between extracellular and intracellular concentrations. About 90 % of lithium excretion occurs via urine, most of the rest is excreted via the feces.

Lithium is widely used as acute and maintenance treatment of bipolar mood disorders. Acute lithium neurotoxicity syndrome may include tremor, rigidity, hyperreflexia, mycoclonus, disorientation, fluctuations in consciousness, drowsiness, hallucinations and delusions. Lithium compounds were shown not to be significantly clastogenic and, based on studies with microorganisms, the mutagenic activity is considered doubtful. Long term excessive lithium ingestion adversely affects renal tubular function, causing polyuria secondary to a deficit in urine concentrating ability. Lithium at doses resulting in serum levels typical of the therapeutic range, might cause developmental toxicity and increase the risk of major malformations, particularly cardiac. In addition, lithium induced cell death in the neuroepithelium may lead to neural tube defects. No relevant information was available in principal literature sources on environmental consequences related to the presence of lithium in livestock diets.

Lithium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Lithium is taken up by all plants dependent upon the available lithium in the soil. Some plants accumulate lithium in very high concentrations, e.g., lithium contents up to 1000 mg Li/kg can occur in nightshade species. Drinking water can also be a significant source of lithium as some ground water may reach 0.5 mg/L and lithium concentrations up to 100 mg/L were found in some mineral waters. Hence, the major dietary lithium sources are vegetables and in some areas drinking water (NRC, 2005; Schrauzer, 2002).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorisation of use of lithium and lithium compounds in human and animal nutrition.

3 Essential functions

NRC (2005) classified lithium as a non-essential nutrient for animals. However, several authors suggested essential functions to be on the basis of experimentally induced deficiency symptoms in rats and goats (Table 1) (NRC, 2005; Nielsen, 1996).

Table 1 Experimentally induced lithium deficiency in rats and goats (Nielsen, 1996; Schrauzer; 2002)

Species	Reported deficiency signs
Goats	Depressed fertility, birth weight, lifespan, liver monoamine oxidase activity and serum isocitrate dehydrogenase, malate dehydrogenase, aldolase and glutamate dehydrogenase activities and increased serum creatine kinase activity
Rats	Depressed fertility, birth weight, litter size and weaning weight and behavioural abnormalities

4 Other functions or effects

Lithium was shown to be an effective agent in the recovery of animals with bovine spastic paresis, a disease of the central nervous system including cerebral structures regulating specific muscle motricity (McDowell, 2003). Aversion to lithium salts has been exploited by training livestock to associate their aversion to lithium with concurrent intake of toxic plants (e.g., tall larkspur), which they subsequently avoid when given a choice (Underwood & Suttle, 1999).

5 Antimicrobial properties

No information was available on antimicrobial properties of lithium in principal literature sources.

6 Typical deficiency symptoms

Lithium deficiency has been experimentally induced in goats and rats (Chapter 3). In humans, lithium deficiency is unlikely ever to reach the degree of severity observed in experimentally lithium depleted animals. If it would occur, it is expected to be mild and manifest itself primarily by behavioural rather than physiological abnormalities. Results of epidemiologic studies suggest that low lithium intakes cause behavioural defects. Inverse associations were observed of tap water lithium contents in areas of Texas with the rates of mental hospital admissions, suicides, homicides and certain other crimes (Schrauzer, 2002).

7 Animal requirements, allowances and use levels

No scientific bodies have established lithium requirements.

8 Concentration of the element in feed materials

Forage and grains are generally rich lithium sources but the lithium contents vary with soil on which they are grown. The following concentrations (mg/kg DM) have been reported for feedstuffs grown on lithium-rich and lithium-poor soils, respectively: red clover, 3.0 and 1.4; rye, 4.1 and 1.0; wheat, 2.9 and 0.7; barley, 1.1 and 0.7; and oats, 1 and 0.5 (NRC, 2005). Lithium concentrations in staple foods reported by Spiegel *et al*. (2009) are given in Table 2.

Table 2 Lithium concentrations (mg/kg DM) in staple foods (Spiegel *et al*., 2009)

Staple food	n	Li concentration
Spring durum	30	0.021
Winter durum	15	0.034
Winter rye	49	0.003
Spring barley	30	0.015
Potatoes	40	0.071

9 Concentration of the element in complete feedingstuffs

There was no information available in principal literature sources on lithium concentrations in complete feedingstuffs.

10 Tolerance of animal species and Maximum Tolerable levels (MTL)

MTL values for lithium established by NRC (2005) are compiled in Table 3.

Table 3 Maximum Tolerable Levels (MTL) (mg/kg DM) for lithium (NRC, 2005)

Species	MTL	Additional remarks
Poultry, swine, cattle, sheep	25	
Rodents, horses	25	Value derived from interspecies extrapolation
Fish	-	Available data were considered insufficient to establish a MTL value

11 Typical symptoms of toxicosis

The effects of high lithium intake have been systematically investigated in pigs, chickens, cattle, sheep and rats. It was demonstrated that lithium supplements of > 100 mg/kg DM reduced feed consumption in all experiments. Excessive lithium consumption by pigs reduced feed intake drastically and induced a thirst response that led to an enormous water consumption. In chickens, lithium toxicity signs included reduced egg production and egg weight (McDowell, 2003; NRC, 2005). Reports of poisoning following exposure to industrial products showed that symptoms of acute oral lithium toxicity may include depression, diarrhoea, ataxia, and death in mature beef cattle (Underwood & Suttle, 1999).

12 Bioavailability

Ingested lithium in the form of soluble salts is essentially completely absorbed by the small intestine. Several studies indicated that lithium transfer in the gastrointestinal tract occurs by paracellular transport via the tight junctions and pericellular spaces and not by passage through the cell (NRC, 2005).

13 Metabolism

Absorbed lithium is not protein bound and distributes throughout the body with only small differences between extracellular and intracellular concentrations. Lithium distribution and excretion is similar to that of sodium. About 90 percent of lithium excretion occurs via urine, most of the rest is excreted via the feces with about 20 % arising from the bile and the remainder through the intestinal wall (NRC, 2005).

14 Distribution in the animal body

The lithium concentration in animal and human tissues is very dependent upon lithium intake. The following mean lithium concentrations (µg/kg DM) were found in tissues of rats fed 2 and 500 µg Li/kg as lithium carbonate, respectively: liver, 1.6 and 12; heart, 2.3 and 25; skeletal muscle,4.6 and 34; kidney, 2.9 and 40; bone, < 7 and 304. Tissue lithium concentrations in domestic animals fed normal diets are probably similar to those of the rats fed the diet containing 500 µg Li/kg (NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

Lithium concentrations in edible tissues are given in Table 4.

Table 4 Lithium concentrations in edible tissues and products

Edible tissue / product	Li concentration (mg/kg)	Reference
Milk, n = 48	0.024	Anderson (1992)
Milk, n = 16	0.006	Leblanc *et al*. (2005)
Dairy products	0.50	Schrauzer (2002)
Poultry and game	0.006	Leblanc *et al*. (2005)
Eggs and egg products	0.014	
Meat	0.012	Schrauzer (2002)

16 Acute toxicity

Lithium is widely used as acute and maintenance treatment of bipolar mood disorders. Acute lithium toxicity is well described as it can occur at any time during lithium therapy. Acute lithium neurotoxicity syndrome may include tremor, rigidity, hyperreflexia, mycoclonus, disorientation, fluctuations in consciousness, drowsiness, hallucinations and delusions (Kores & Lader, 1997).

17 Genotoxicity and Mutagenicity

Lithium compounds were shown not to be significantly clastogenic and, based on studies with microorganisms the mutagenic activity is considered doubtful. A concise summary is given in Table 5 (Aral & Vecchio-Sadus, 2008).

Table 5 Summary of *in vitro* genotoxicity and mutagenicity test with several lithium compounds (Aral & Vecchio-Sadus, 2008)

Test system	Li compound	Result
Bacillus aluminium	Lithium chloride and trilithium citrate	-
Salmonella typhimurium, Ames test		-
V79 Chinese hamster cells, Human EUE fibroblasts	Lithium carbonate	Slightly inhibited DNA synthesis

18 Subchronic toxicity

No information on subchronic toxicity of lithium or lithium compounds was available in principal literature sources.

19 Chronic toxicity, including carcinogenicity

Lithium as a medication is often used on a maintenance basis for a lifelong disorder. Hence, the potential of lithium to cause long term organ toxicity has been well documented. The foremost concern are the renal effects. Lithium adversely affects renal tubular function, causing polyuria secondary to a defecit in urine concentrating ability. Additionally, toxic symptoms in the neuromuscular, cardiovascular and gastrointestinal system were observed as a result of non-supervised or indiscriminate therapeutic use of lithium. It is therefore advised that the lithium blood level should not exceed 11.1 mg/L (Gitlin, 1999; Aral & Vecchio-Sadus, 2008).

20 Reproduction toxicity

Human data indicate that lithium at doses resulting in serum levels typical of the therapeutic range, might cause developmental toxicity and an increased risk of major malformations, particularly cardiac. Experiments in animals suggest that the developing cardiovascular system may be a target for lithium. In addition lithium-induced cell death in the neuroepithelium may lead to neural tube defects. In animals, nephrotoxicity and behavioural alterations in offspring were also observed. These effects were not confirmed in children of lithium treated women (Apostoli *et al*., 2007; Aral & Vecchio-Sadus, 2008).

21 Non observed adverse effect level (NOAEL)

There were no NOAEL values identified for lithium by scientific bodies to establish upper intake levels.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

No Upper Intake Levels for lithium were established by scientific bodies.

23 Toxicological risks for user/workers

The American Conference of Governmental Industrial Hygienists recommended an exposure limit for lithium hydride of 25 µg/m^3 for respirable dust or fumes for TLV – TWA (time weighted average concentrations for a normal 8 h working day and a 40 h working week to which all workers may be repeatedly exposed without adverse effects) (Aral & Vecchio-Sadus, 2008).

24 Toxicological risks for the environment

There were no indications in principal literature sources that the presence of lithium in livestock diets would have an impact on the environment.

25 References

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Manganese

Executive summary of the monograph for manganese

Several manganese compounds are presently authorized as feed additives in the EU. Manganese is an essential element that is a constituent of multiple enzymes, e.g., glycosyl transferases, pyruvate carboxylase, manganese superoxide dismutase. Primary manifestations of manganese deficiency in livestock are impaired growth, skeletal abnormalities, depressed reproductive function, ataxia of the newborn and defects in lipid and carbohydrate metabolism. Manganese deficiency as a practical problem is largely confined to avian species. In poultry perosis is the most commonly observed manganese deficiency disorder. Manganese is considered to be one of the least toxic of the essential trace elements. Depressed iron status and haematological changes are the most common signs of manganese toxicosis. Manganese is absorbed in the small intestine via a carrier mediated mechanism. The dietary iron intake is a key determinant of manganese absorption, with low iron levels leading to increased manganese absorption. Manganese is reported to accumulate in the liver, kidneys, pancreas and brain. Manganese is primarily excreted via the feces. Absorbed manganese is cleared by the liver and bile is the major excretory route. The acute toxicity of manganese is relatively low. Information on the genotoxicity and mutagenicity of manganese compounds is scarce and there is no evidence that manganese is a human carcinogen. Results from animal studies indicate that reproductive effects of excessive manganese intake may occur. SCF, EVM and BfR considered the available data from toxicity studies insufficient to establish an upper intake level for manganese. IOM derived an upper intake level for manganese of 11mg/day for adults. Manganese toxicity in humans is a well recognized occupational hazard for people who inhale manganese dust and neurological effects as a hallmark of excessive exposure to manganese, are primarily associated with manganese inhalation in occupational settings. The minimal exposure level producing neurological effects is probably in the range of 0.1 – 1 mg/m^3. There are no indications of any significant environmental impact of the use of manganese as a feed additive.

Manganese Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Several manganese compounds are presently authorized as feed and food supplements. These are considered of importance in human and animal nutrition (Chapter 2).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Manganese compounds presently authorized in the EU as additives (EC 1334/2003[1] and EC 479/2006[2]) are listed in Table 1.

Table 1 Conditions of use of manganese compounds as additives in feedingstuffs according to the Commission Regulations EC 1334/2003[1] and EC 479/2006[2]

Additive	Chemical formula	Maximum content of the element in the complete feedingstuff (mg/kg)
Manganous carbonate	$MnCO_3$	Fish: 100 (total) Other species: 150 (total)
Manganous chloride, tetrahydrate	$MnCl_2.4H_2O$	
Manganous hydrogen phosphate, trihydrate	$MnHPO_4.3H_2O$	
Manganous oxide	MnO	
Manganic oxide	Mn_2O_3	
Manganous sulphate , tetrahydrate	$MnSO_4.4H_2O$	
Manganous sulphate, monohydrate	$MnSO_4.H_2O$	
Manganese chelate of amino acids hydrate	$Mn(x)_{1-3}.nH_2O$ (x = anion of any amino acid derived from hydrolysed soya protein), Molecular weight not exceeding 1500 g/mol)	
Manganomanganic oxide	MnO Mn_2O_3	
Manganese chelate of glycine hydrate [2]	$Mn(x)_{1-3}.nH_2O$ (x = anion of synthetic glycine)	

[1] OJ L 187, 26.7.2003, p.11

[2] OJ L 86, 24.3.2006, p.4

In the US, the following manganese compounds are allowed in animal feeds: manganese acetate, manganese carbonate, manganese chloride, manganese citrate (soluble), manganese gluconate, manganese orthophosphate, manganese phosphate (dibasic), manganese sulphate, manganous oxide, manganese amino acid complex, manganese methionine complex, manganese amino acid chelate, manganese proteinate (AAFCO Official Publication §57: Mineral Products). Manganese glycerophosphate and manganese hypophosphite are not specifically defined by AAFCO, but were adopted in its publication from the Federal Code of Regulations. It is listed as generally recognized as safe in animal feeds (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

Table 2 Range of manganese guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	**Range (mg/kg)**
Chickens	55 - 500
Turkeys	55 - 500
Swine	10 - 200
Dairy cattle	40 -300
Beef cattle	20 - 200
Sheep	20 - 200
Horses	40 - 400
Goats	40 - 200
Ducks and geese	40 - 500
Salmonid fish	20 - 150
Mink	44 (breeding); 40 (others) - NS
Rabbits	10 - 200

NS: Not specified

2.2 Human nutrition

Manganese compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[3]. The authorized manganese compounds are: manganese carbonate,

[3] OJ L 269, 14.10.2009, p. 9

manganese chloride, manganese citrate, manganese gluconate, manganese glycerophosphate, manganese sulphate.

- As food supplements under Regulation EC 1170/2009[4]. The authorized manganese compounds are: manganese ascorbate, manganese L-aspartate, manganese bisglycinate, manganese carbonate, manganese chloride, manganese citrate, manganese gluconate, manganese glycerophosphate, manganese pidolate, manganese sulphate.

- As substances which may be added to foods under Regulation EC 1925/2006[5] as amended by Regulation 1170/2009[4]. The authorized manganese compounds are: manganese carbonate, manganese chloride, manganese citrate, manganese gluconate, manganese glycerophosphate, manganese sulphate.

- Directive 2008/100/EC[6] lays down a Recommended Daily Allowance (RDA) for manganese of 2 mg.

In the U.S. the Code of Federal Regulations grants a generally recognized as safe status for the use as nutrient and or dietary supplement (Part 582; Subpart F) to the following manganese compounds: manganese chloride, manganese citrate, manganese gluconate, manganese glycerophosphate, manganese hypophosphite, manganese sulphate, manganous oxide.

3 Essential functions

Manganese is an essential element that functions as an enzyme activator and is a constituent of multiple enzymes (NRC, 2005; Underwood & Suttle, 1999). A summary of enzymes that require manganese, associated physiological functions as well as deficiency symptoms that occur when the manganese supply is inadequate, is given in Table 3.

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[4] OJ L 314, 1.12.2009, p. 36

[5] OJ L 404, 30.12.2006, p. 26

[6] OJ L 285, 29.10.2008, p. 9

Table 3 Manganese dependent enzymes and associated essential functions and deficiency symptoms (adapted from McDowell, 2003; Underwood & Suttle, 1999)

Enzymes	Physiological functions	Deficiency symptoms
Glycosyltransferases	Development of the organic matrix of the bone; cartilage development	Reduced synthesis of mucopolysaccharides
	Maintenance of bone mineralization	Lowered bone calcium concentrations
	Reproduction	Irreversible congenital defects; Hens: decreased rate of egg production, poor shell quality, reduced hatchability, chondrodystrophy; Rat, mice, rabbits: testicular degeneration
Pyruvate carboxylase	Lipid and glucose metabolism	Fat accumulation; fatty liver
	Membrane integrity	
	Biosynthesis of glycoproteins e.g., prothrombin	E.g., reduction vitamin K- induced clotting response
Manganese superoxide dismutase	Protection of cells from damage by free oxygen radicals	Structural changes in liver mitochondria and cell membranes

4 Other functions

There was no information available on other functions of manganese in principal literature sources.

5 Antimicrobial properties

There was no information available on antimicrobial properties of manganese in principal literature sources.

6 Typical deficiency symptoms

The primary manifestations of manganese deficiency in livestock are impaired growth, skeletal abnormalities, disrupted or depressed reproductive function, ataxia of the newborn, and defects in lipid and carbohydrate metabolism. Reproductive processes are particularly sensitive to manganese deficiency. Birds are considered more susceptible to manganese deficiency than mammals and manganese deprivation as a practical problem is largely confined to avian species (McDowell, 2003; Underwood & Suttle, 1999).

In poultry perosis is the most commonly observed manganese deficiency disorder. The disease includes malformation of bones characterized by enlarged and malformed tibiometatarsal joints, twisting and bending of the tibia, and the tarso metatarsus, thickening and shortening of the long bones, and slippage of the Achilles tendon from the condyles. Manganese deficiency in the diet of breeding hens causes nutritional chondrodystrophy in embryonic chicks. In young chicks defective or absent otoliths of the inner ear cause ataxia. Manganese deficiency in laying and breeding hens reduces egg production and hatchability and increases the incidence of thin shelled and shell-less eggs (McDowell, 2003; Underwood & Suttle, 1999).

In pigs manganese deficiency causes decreased growth, feed efficiency, and impaired reproduction. In ruminants an insufficient manganese supply may cause suboptimal soft tissue and skeletal growth, decreased breaking strength of bones, abnormal bone shape, ataxia, muscular weakness, excess accumulation of body fat, reduced milk production, delayed or absent estrus, resorption of fetus, fetal deformities and small birth weights (McDowell, 2003; Underwood & Suttle, 1999).

In humans evidence for manganese deficiency is poor and a clinical deficiency has not yet been clearly associated with poor dietary intakes of healthy individuals (SCF, 2000; IOM, 2001).

7 Animal requirements, allowances and use levels

Manganese requirements established by scientific bodies are listed in Annex 3.1, manganese use levels are listed in Annex 3.2.

8 Concentration of the element in feed materials

Manganese concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Manganese concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Manganese is considered to be one of the least toxic of the essential elements (NRC, 2005). MTL values established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels for manganese (MTL) (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Rodents, poultry, cattle, sheep	2000	
Swine	1000	
Horses	400	Value derived from interspecies extrapolation
Fish	-	Data are insufficient to set a MTL

11 Typical symptoms of toxicosis

Generally, depressed iron status and hematological changes were the most common signs of manganese toxicosis, even in animals fed typically adequate levels of iron (NRC, 2005).

Swine are more sensitive to excess manganese than other livestock. Some of the differences in sensitivity of animals to the hematological effects of excess manganese reflect the iron content of the diets. Many studies have demonstrated an increased sensitivity to excess manganese when the dietary iron levels were low. Occasionally depressed liver zinc, elevated liver copper concentrations and depressed copper absorption were observed caused by excess dietary manganese (NRC, 2005).

12 Bioavailability

12.1 General

In humans absorption is reported to average between approximately 3 – 5 % (Saric & Lucchini, 2007) and 3 – 8 % SCF (2000). Studies evaluating absorption of orally ingested manganese in animals yielded results that are generally similar to those in humans (Saric & Lucchini, 2007). Jongbloed *et al*. (2002) summarized relative bioavailability assessment studies for various manganese compounds (see Table 5). EFSA (2008) assessed the relative bioavailability of a manganese chelate of hydroxy analogue of methionine compared to manganese sulphate and manganese oxide and concluded that the manganese from the chelate was at least as available to broiler chicks as manganese from the inorganic sources. Dietary factors influencing manganese bioavailability are compiled in Table 6.

Table 5 Relative bioavailability assessments (%) of manganese compounds compared to manganese sulphate monohydrate in livestock (Jongbloed *et al*., 2002)

	Pigs [1]	**Poultry** [2]	**Ruminants** [3]
Manganese sulphate monohydrate	100	100	100
Manganese carbonate	95	66	69
Manganese oxide	96	85	91 - 80
Manganese methionine		101	113

[1]: Criterion: absorption of Mn; [2]: Criterion: tibia ash Mn concentration; [3]: Criterion: liver, kidney and bone Mn concentration

Table 6 Dietary factors influencing bioavailability of manganese (adapted from ATSDR 2008, Barceloux 1999, EFSA 2009, Jongbloed *et al*., 2002, NRC 2005)

Chelating agents	Inhibitors	Phytate, fibre
	Promotors	Cysteine, histidine, lactose
Metal ion interactions	Inhibitors	Non- heme iron, calcium, magnesium

12.2 *Indicators of manganese status*

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of manganese compounds in livestock (Table 7).

Table 7 Ranking of adequacy of response criterions for assessing the relative biological value of manganese compounds [1] (Jongbloed *et al*., 2002)

	Pigs		**Poultry**		**Ruminants**	
Supplementation level →	Suboptimal	Above requirement	Suboptimal	Above requirement	Suboptimal	Above requirement
Criterion						
Mn absorption	4	3	4	3	4	2
Bone Mn	2	2	2	2	3	1
Performance	2	-	2	-	-	-
Liver / kidney Mn	1	-	1	-	2	1
Perosis severity index	-	-	3	-	-	-

[1]: the highest values correspond to the best adequacy

For the assessment of the relative bioavailability of manganomanganic oxide and a manganese chelate of hydroxy analogue of methionine compared to manganese sulphate and manganese oxide, respectively, SCAN and EFSA considered feeding trials with chickens in which the manganese concentration in tibia was used as a parameter to calculate the relative biological value (EFSA, 2008; SCAN, 2002).

13 Metabolism

Manganese is absorbed rapidly in the small intestine via a carrier mediated mechanism (ATSDR, 2008; EFSA, 2009). One of the key determinants of absorption appears to be dietary iron intake, with low iron levels leading to increased manganese absorption (ATSDR, 2008). Manganese absorbed in the gut is transported by α2-macroglobulins and albumin to the liver. Manganese leaving the liver is bound to transferrin (IOM, 2001; NRC, 2005). Manganese is reported to accumulate in the liver, kidney, pancreas and the brain (EFSA, 2009). Manganese is excreted primarily via the feces (EFSA, 2009). Absorbed and injected manganese is efficiently cleared by the liver and bile is the major excretory route. Urinary excretion of manganese does not appear to be sensitive to dietary intake and is a minor route of excretion (IOM, 2001; NRC, 2005).

14 Distribution in the animal body

The highest manganese tissue concentrations are found in the liver, kidney, pancreas and adrenals (SCF, 2000).

15 Deposition (typical concentration) in edible tissues and products

Generally, livestock do not accumulate extremely high levels of manganese in their tissues when excess manganese is fed (NRC, 2005). Manganese concentrations in edible tissues and products are reported in Annex 1 and concentrations linked with the dietary manganese intake are reported in Annex 2.

16 Acute toxicity

The acute toxicity of manganese is relatively low. The oral LD_{50} of manganese chloride is ranges between 275 – 450 mg/kg bw, 250 – 275 mg/kg bw and 400 – 810 mg/kg bw in mice, rats, and guinea pigs, respectively (SCF, 2000).

17 Genotoxicity and Mutagenicity

Information on the genotoxicity and mutagenicity of manganese compounds is scarce. Manganese chloride provoked an enhanced viral transformation of hamster embryo cells and a decreased fidelity of DNA synthesis *in vitro* (Ke *et al*., 2007).

18 Subchronic toxicity

The ATSDR Toxicological profile of manganese includes information on the subchronic toxicity of several manganese compounds on several organ systems and by several exposure routes (ATSDR, 2008).

19 Chronic toxicity, including carcinogenicity

ATSDR (2008) and Ke *et al*. (2007) did not locate any clinical report implicating manganese as a human carcinogen nor any epidemiological studies that have attempted to relate manganese exposure to cancer.

20 Reproduction toxicity

The ingestion of manganese may delay reproductive maturation in male animals, reduce testosterone levels and delay growth of the testes. Parenteral manganese administration was reported to have provoked degenerative changes in the seminiferous tubulus, resulting in infertility (SCF, 2000). Reproductive effects of manganese are concisely summarized in Table 8.

Table 8 Reproductive effects of oral manganese exposure

Species	**Manganese compound**	**Dose**	**Effect**	**Reference**
Rats	Mn_3O_4	< 1100 mg Mn/kg diet 3500 mg Mn/kg diet	No effect Decreased testicular weight and sperm count	Apostoli *et al*. (2007)[a]
Mice	Mn acetate	15 – 30 mg Mn/(kg bw.day)	Decreased sperm count and motility	
Rats	Mn chloride	33 mg Mn/(kg bw.day)	Increased post implantation loss	ATSDR (2008)[a]
Mice	Mn chloride	227 mg Mn/(kg bw.day)	Decreased number of implantations and viable fetuses	

[a]: References herein

21 Non observed adverse effect level (NOEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

Orally ingested manganese, despite its poor absorption in the gastrointestinal tract, has been shown to cause neurotoxic effects. In 2000 SCF concluded that because of limited human data and the nonavailability of NOAELs for critical endpoints from animal studies, an UL could not be set (SCF, 2000). Additionally, the SCF (2000) stated that oral exposure to manganese beyond the amounts normally present in food and beverages could represent a risk of adverse health effects without evidence of any health benefit.
IOM (2001) identified a NOEAL of 11 mg/day based on estimated maximum manganese intakes for people eating Western-type and vegetarian diets and for which no adverse effects have been observed. An uncertainty factor of 1 was selected based on the absence of evidence of human toxicity from doses less than 11 mg/day. The UL values derived by IOM (2001) are listed in Table 9.

Table 9 Upper Intake Levels (UL) (mg/day) for several life stage groups (IOM, 2001)

	UL
1 - 3 years	2
4 - 8 years	3
9 - 13 years	6
14 – 18 years	9
Adults	11
Pregnancy 14 – 18 years	9
Pregnancy 19 – 50 years	11
Lactation 14 – 18 years	9
Lactation 19 – 50 years	11

The EVM (2003) concluded that there are insufficient data available to establish a Safe Upper Level for manganese. For guidance purposes, it was considered reasonable to assume that in the general population, a supplemental manganese intake of 4 mg/day in addition to the diet would be unlikely to produce adverse effects. In older people it could be assumed that a manganese intake of 0.5 mg/day in addition to the diet would not result in adverse effects (EVM, 2003).
BfR (2006) also considered the available data inadequate to derive a numerical UL. Furthermore, BfR recommended that, on the grounds of preventive health protection, manganese should not be added to food

supplements or fortified foods. Manganese was assigned to the highest risk category because of the small margin between estimated intake and the levels at which adverse effects have already been observed (BfR, 2006). Based on the IOM (2001) UL, ATSDR (2008) issued an interim guidance value for oral exposure to inorganic manganese of 0.16 mg/(kg bw.day).

23 Toxicological risks for user/workers

Manganese toxicity in humans is a well-recognized occupational hazard for people who inhale manganese dust. The most prominent effect is the central nervous system pathology, especially in the extra-pyramidal motor system (IOM, 2001).

The central nervous system is the primary target of manganese toxicity. Studies of the neuropathological bases for manganese neurotoxicity have pointed to the involvement of the corpus stratium and the extra-pyramidal motor system. Neurological effects as a hallmark of excessive exposure to manganese, are primarily associated with inhalation in occupational settings (Saric & Luccini, 2007).

In workers chronically exposed to manganese dusts and fumes, neurological effects of inhaled manganese have been well documented. The syndrome known as manganism is characterized by weakness, anorexia, muscle pain, apathy slow speech without inflection, emotionless " mask-like facial expression, and slow clumsy movement of the limbs. In general, these effects are irreversible (SCF, 2000). The minimal exposure level producing neurological effects is not certain but is probably in the range of 0.1 – 1 mg/m^3 (SCF, 2000). For manganomanganic oxide around 90 % of the product particles have a diameter ≤ 5 µm suggesting that inhalation exposure is likely if a dust is being formed. A dust made up of such small particles is respirable and may be inhaled deep into the lungs (SCAN, 2002).

There are indications that laboratory animals, especially rodents, might not be as sensitive as humans, to the neurological effects of inhalation exposure to manganese (SCAN, 2002).

24 Toxicological risks for the environment

In the opinion on the use of manganomanganic oxide in feedingstuffs, SCAN (2002) considered the environmental impact of manganese as a generic issue. The lead content of the manganomanganic oxide is possibly a matter of concern for the environment (SCAN, 2002).

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Annex 1: Manganese concentrations in edible tissues and products

Table 1.1 Manganese concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Hogs	324	0.13	4.2	1.40	Coleman *et al*. (1992)
Boars / sows	280	0.14	2.37	1.22	
		Neck steak: 0.128 Chop: 0.062 Loin: 0.063			Gerber *et al*. (2009)
Pigs	45	0.12	3.0	1.5	Jorhem & Sundström (1993)
Pigs (6 m)	62	1.01	3.32	1.56	López-Alonso *et al*. (2007)

Table 1.2 Manganese concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Calves (6 - 12 m)	195		3.45	1.19		Blanco-Penedo *et al.* (2006)
Calves	327	0.19	1.93	0.66		Coleman *et al*. (1992)
Heifers / Steers	287	0.29	2.89	1.13		
Bulls / Cows	95	0.18	2.86	0.99		
Lambs	165	0.2	3.66	1.13		
Mature sheep	34	0.21	2.68	0.93		
Lamb		Chop: 0.167 Loin: 0.160				Gerber *et al*. (2009)
Beef cattle		Sirloin: 0.056 - 0.108 Braising steak: 0.031 Rib-eye: 0.069 - 0.098				
Cattle	5	0.093	3.2	1.1		Jorhem & Sundström (1993)
Dairy cattle	16				0.09	Leblanc *et al*. (2005)[a]
Dairy cattle	3				0.05 - 0.07	Santos *et al*. (2004)[a]

[a]: Total diet study

Table 1.3 Manganese concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chickens (young)	311	0.13	4.15	2.03		Coleman *et al*. (1992)
Chickens (mature)	308	0.19	3.43	2.29		
Turkeys (young)	60	0.21	3.24	2.37		
Ducks	111	0.30	10.4	2.54		
Chicken		Breast + skin: 0.043 Leg + skin: 0.166				Gerber *et al*. (2009)
Poultry		0.13 [b]			0.28 [c]	Leblanc *et al*. (2005)[a]
Hens, private owners	22				0.314	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.280	

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Manganese concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	7.25 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	6.53 DM	
Atlantic herring	3	0.35	Engman & Jorhem (1998)
Baltic herring	3	0.33	
Burbot	2	0.21	
Cod	4	0.15	
Eel	3	0.17	
Mackerel	4	0.12	
Perch	3	0.19	
Picked dogfish	2	0.10	
Pike	5	0.14	
Plaice	4	0.053	
Pollack	2	0.073	
Salmon	3	0.068	
Turbot	3	0.13	
Whitefish	3	0.12	
Fish	62	0.3	Leblanc *et al*. (2005) [a]
Fish	3	0.2 - 0.4	Santos *et al*. (2004) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	1.361 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	2.151 DM	
Gilthead seabream *Sparus aurata*	45	1.266 DM	
Clarias gariepinus	38	0.068	Türkmen *et al*. (2007)
Carasobarbus luteus	23	0.45	

[a]: Total diet study;

Table 1.5 Manganese concentrations in honey (mg/kg)

Description	n	Honey	Reference
Eucalyptus	3	9.471	Fernandez - Torres *et al*. (2005)
Orange-blossom	3	0.133	
Origin: Holzing (AU)	23	0.68	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.29	
Origin: Hollabrunn (AU)	19	0.15	
Origin: Siena County (It)	51	1.54	Pisani *et al*. (2008)

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Annex 2: Manganese concentrations in edible tissues and products linked with the dietary intake of various manganese sources and doses

Table 1 Manganese concentrations in edible tissues and products of poultry and pigs (mg/kg)

Species / category	Source of Mn supplemented	Dose of Mn supplemented (mg Mn/kg)	Mn content of complete feed [1] (mg Mn/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Plasma (µg/L)	Reference
Broilers			116 DM	26 d	11.6 DM [a]		0.79 DM [a]		37.4 [a]	Black *et al*. (1984)
	$MnSO_4.H_2O$	1000			20.9 DM [bcd]		1.10 DM [ab]		63.4 [ab]	
	$MnSO_4.H_2O$	2000			24.2 DM [de]		1.71 DM [bc]		84.1 [bc]	
	$MnSO_4.H_2O$	4000			31 DM [f]		2.25 DM [c]		135.7 [e]	
	$MnCO_3$	1000			16.1 DM [ab]		1.02 DM [ab]		64.5 [ab]	
	$MnCO_3$	2000			18.9 DM [bc]		1.72 DM [bc]		75.7 [bc]	
	$MnCO_3$	4000			20.3 DM [bcd]		2.31 DM [c]		91 [bcd]	
	MnO	1000			17.8 DM [bc]		1.21 DM [ab]		62.5 [ab]	
	MnO	2000			22.4 DM [cd]		1.40 DM [ab]		108.7 [cde]	
	MnO	4000			27.4 DM [ef]		1.52 DM [abc]		120.4 [de]	
Laying hens		0	40 DM	28 d				yolk: < 2 DM white: < 2 DM		Huyghebaert *et al.* (2006)
	Manganese oxide	80	87 DM					yolk: < 2 DM white: < 2 DM		
	Bioplex Mn	80	121 DM					yolk: < 2 DM white: < 2 DM		
Pigs		0	0.4	42 d	2.51 DM	2.20 DM	0.32 DM			Leibholz *et al*. (1962) [2]
	Mn sulphate	40			8.31 DM	4.82 DM	0.40 DM			
		0	11.8	42 d	8.08 DM	6.10 DM	0.40 DM			Leibholz *et al*. (1962) [3]
	Mn sulphate	40			9.21 DM	4.92 DM	0.50 DM			

Mn content of complete feed [1]: data from feed analysis

Leibholz *et al*. (1962) [2] : casein based ration;

Leibholz *et al*. (1962) [3]: soybean meal based ration

Statistics: Black *et al*.(1984): means within columns with different superscripts differ significantly ($P < 0.01$), ANOVA

Table 2 Manganese concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Mn supplemented	Dose of Mn supplemented (mg Mn/kg)	Mn content of complete feed [1] (mg Mn/kg)	Duration of study	Liver	Kidney	Muscle	Serum (µg/L)	Reference
Sheep		0	31 DM	84 d	9.0 DM ^{x}	4.2 DM ^{d}	0.40 DM ^{d}	44.3 ^{d}	Black *et al*. (1985)
	MnO	500			19.5 DM ^{x}	6.4 DM ^{d}	0.70 DM ^{de}	57.7 ^{de}	
	MnO	1000			37.4 DM ^{x}	19.5 DM ^{def}	0.69 DM ^{de}	83 ^{def}	
	MnO	2000			45.8 DM ^{x}	16.4 DM ^{def}	0.96 DM ^{e}	76 ^{def}	
	MnO	4000			232.2 DM ^{y}	34.8 DM ^{f}	1.04 DM ^{e}	161 ^{f}	
	$MnCO_3$	2000			19.3 DM ^{x}	12.8 DM ^{de}	0.96 DM ^{e}	43.3 ^{d}	
	$MnCO_3$	4000			39.1 DM ^{x}	20.7 DM ^{def}	0.89 DM ^{e}	70.7 ^{de}	
	$MnCO_3$	8000			630.4 DM ^{y}	31.0 DM ^{ef}	1.06 DM ^{e}	144 ^{ef}	
Lambs		0	34.40 DM	21 d	10.9 DM	4.0 DM			Henry *et al*. (1992)
	$MnSO_4.H_2O$	900			35.5 DM	14.6 DM			
	$MnSO_4.H_2O$	1800			38.7 DM	22.7 DM			
	$MnSO_4.H_2O$	2700			77.0 DM	20.9 DM			
	Mn methionine	900			35.7 DM	16.9 DM			
	Mn methionine	1800			77.1 DM	18.1 DM			
	Mn methionine	2700			41.8 DM	22.5 DM			
Lambs		0	31.50 DM	21 d	9.8 DM	4.7 DM			Henry *et al*. (1992)
	$MnSO_4.H_2O$	900			28.4 DM	21.8 DM			
	$MnSO_4.H_2O$	1800			28.8 DM	20.3 DM			
	$MnSO_4.H_2O$	2700			76.3 DM	33.3 DM			
	Mn methionine	1800			43.8 DM	28.9 DM			
	MnO (supplier A)	1800			32.7 DM	20.2 DM			
	MnO (supplier B)	1800			32.0 DM	17.5 DM			

Mn content of complete feed [1]: data from feed analysis

Statistics: Black *et al*.(1985): ^{d,e,f,g} means within columns that do not have a common superscript differ ($P < 0.01$), ANOVA;

^{x,y} Means within columns that do not have a common superscript differ ($P< 0.05$), ANOVA

Table 2 (continued) Manganese concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Mn supplemented	Dose of Mn supplemented (mg Mn /kg)	Mn content of complete feed [1] (mg Mn/kg)	Duration of study	Liver	Kidney	Muscle	Plasma (mg/L)	Reference
Lambs		0	37.6 DM	21 d	9.6 DM [g]	4.0 DM [f]			Wong-Valle *et al*. (1989)
	$MnSO_4$	1500			35.3 DM [d]	19.8 DM [cd]			
	$MnSO_4$	3000			43.7 DM [c]	26.2 DM [c]			
	$MnSO_4$	4500			43.8 DM [c]	26.7 DM [c]			
	MnO	3000			33.3 DM [de]	17.8 DM [de]			
	MnO_2	3000			24.3 DM [f]	11.2 DM [ef]			
	$MnCO_3$	3000			26.3 DM [ef]	10.2 DM [f]			
Heifers		0	15.8 DM	196 d	8.2 DM				Hansen *et al*. (2006)
	$MnSO_4$	10 DM			8.6 DM *				
	$MnSO_4$	30 DM			8.7 DM *				
	$MnSO_4$	50 DM			9.4 DM *				
Calves			55 DM	18 d	9.49 DM	4.92 DM	3.75 DM		Ho *et al.* (1984)
	Mn carbonate	1000			13.25 DM	5.20 DM	2.01 DM		
Calves (Holstein)	$MnSO_4.H_2O$		40 DM	35 d	7.2 DM [c]	4.0 DM	2.6 DM	0.004 [b]	Jenkins & Hidiroglou (1991)
	$MnSO_4.H_2O$		200 DM		10.3 DM [c]	3.2 DM	2.5 DM	0.004 [b]	
	$MnSO_4.H_2O$		500 DM		15.6 DM [b]	2.9 DM	1.9 DM	0.005 [b]	
	$MnSO_4.H_2O$		1000 DM		26.7 DM [a]	3.3 DM	1.8 DM	0.010 [a]	
	$MnSO_4.H_2O$		5000 DM						
Steers		0	8.1 DM	104 - 132 d	12.1 DM		0.30 DM		Legleiter *et al*. (2005)
	$MnSO_4.H_2O$	10 DM			12.1 DM		0.34 DM		
	$MnSO_4.H_2O$	20 DM			12.6 DM		0.32 DM		
	$MnSO_4.H_2O$	30 DM			13.9 DM		0.38 DM		
	$MnSO_4.H_2O$	120 DM			14.9 DM		0.40 DM		
	$MnSO_4.H_2O$	240 DM			15.1 DM		0.46 DM		

Mn content of complete feed [1]: data from feed analysis

Statistics: Wong-Valle *et al*. (1989): [c,d,e,f,g] Means in the same column with different letters in their superscripts differ ($P < 0.05$)

Hansen *et al*. (2006): control vs. supplemental and control vs. 30 and 50 mg of supplemental Mn/kg DM: $P < 0.05$

Jenkins & Hidiroglou (1991): [a, b, c] Means with different letters in the same column differ ($P < 0.05$), Anova

Legleiter *et al*. (2005): Liver Mn concentrations: Linear, $P = 0.02$; R^2: 0.515; Control vs. 120 and 240 mg Mn/kg DM , $P = 0.03$.

Muscle Mn concentrations: Linear, $P = 0.002$; Control vs. 120 and 240 mg Mn/kg DM , $P = 0.006$.

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Annex 3. 1 Manganese Requirements

Pigs:

Category - Definition	Mn Req. (NRC, 1998) (mg/kg) (a)	Category - Definition	Mn Req. (GFE , 2008) (mg /kg DM)
Pigs: 3 - 5 kg	4.00	Piglets	15 - 20
Pigs: 5- 10 kg	4.00		
Pigs: 10 - 20 kg	3.00	Growing - fattening pigs	20
Pigs: 20 - 50 kg	2.00		
Pigs: 50 - 80 kg	2.00		
Pigs: 80 - 120 kg	2.00		
Sows: gestation	20	Breeding sows	20 - 25
Sows: lactation	20		
		Boars	20 - 25

Poultry:

Category - Definition	Mn Req. (NRC, 1994) (mg/kg) (a)	Category - Definition	Mn Req. (GfE, 1999) (mg/kg DM)
Broilers (0 - 8 weeks)	60	Broiler (Mast Broiler; Aufzucht Küken)	60
Immature leghorn- Type chickens (0-6 wk) white	60.0	Chickens reared for laying (Junghennen)	50
Immature leghorn- Type chickens (6 wk - first egg) white	30.0		
Immature leghorn- Type chickens (0-6 wk) brown	56.0		
Immature leghorn- Type chickens (6 wk - first egg) brown	28.0		
Leghorn-Type white egg layers (80 g FI/day)	25	Layers (Eiproduction Legehennen)	50
Leghorn-Type white egg layers (100 g FI/day)	20		
Leghorn-Type white egg layers (120 g FI/day)	17		
		Female birds reared for breeding (Zuchthennen)	50
Growing turkeys (0 - 24 wk)	60		
Turkey holding hens	60		
Turkey laying hens	60		
White pekin ducks (0 - 2 wk)	50		

Bovines:

Category - Definition	Mn Req. (Meschy, 2007) (mg/kg DM)
Bovines	45

Bovines: Beef Cattle

Category - Definition	Mn Req. (NRC, 2000) (mg/kg DM)	Category - Definition	Mn Req. (GfE, 1995) (mg/kg DM)
Growing and finishing	20.00	Growing and finishing from 175 kg on	40
Cows gestation	40.00		
Cows early lactation	40.00		

Bovines: Dairy Cattle

Category - Definition	Mn Req. (NRC, 2001) (mg/kg DM)	Category - Definition	Mn Req. (CVB, 2007) (mg/kg DM)
Lactating cow: Holstein - 90 days in milk	13 - 14	Lactating cows (FI: 20 kg/day)	40
Lactating cow: Jersey	12 - 13	Lactating cows (FI: 40 kg/day)	40
Dry cows: Holstein (240 d pregnant)	16	Dry cows, 8 -3 weeks before calving	40
Dry cows: Holstein (279 d pregnant)	24	Dry cows, 3 - 0 weeks before calving	40

Sheep

Category - Definition	Mn Req. (Meschy, 2007) (mg/kg DM)
Sheep	45

Category - Definition	Mn Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Mn Req. (NRC, 2007 (b)) (mg /day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	12		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	53		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	15	Mature ewes; breeding. DM intake: 0.85 kg/day	12
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	45	Mature ewes; breeding. DM intake: 2.18 kg/day	40
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	20	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	55	Mature ewes; early lact.; DM intake: 2.14 kg/day	32
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	13	Mature ewes; early lact.; DM intake: 5.29 kg/day	61
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	42	Mature ewes; late lact.; DM intake: 2.35 kg/day	25
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	23	Mature ewes; late lact.; DM intake: 4.05 kg/day	52
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	49		

Goats

Category - Definition	Mn Req. (GfE, 2003) (mg/kg DM)	Category - Definition	Mn Req. (Meschy, 2007) (mg /kg DM)
Goats	60 - 80	Goats	45

Category - Definition	Mn Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Mn Req. (NRC, 2007 (b)) (mg /day)
Kids; bw: 10 kg; DM intake: 0.35 kg/day	3	Mature does; breeding; DM intake: 0.60 kg/day	5
Kids; bw: 10 kg; DM intake: 0.39 kg/day	9	Mature does; breeding; DM intake: 1.86 kg/day	24
Kids; bw: 40 kg; DM intake: 1.10 kg/day	11		
Kids; bw: 40 kg; DM intake: 1.41 kg/day	29	***Milk yield: 4.65 - 6.43 kg/day***	
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	10	Dairy does; early lactation; DM intake: 2.81 kg/day	42
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	34	Dairy does; early lactation; DM intake: 4.83 kg/day	64
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	22	***Milk yield: 6.98 - 9.65 kg/day***	
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	49	Dairy does; early lactation; DM intake: 3.83 kg/day	65
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	8	Dairy does; early lactation; DM intake: 5.43 kg/day	95
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	30	***Milk yield: 1.99 - 2.76 kg/day***	
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	17	Dairy does; late lactation; DM intake: 2.48 kg/day	32
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	40	Dairy does; late lactation; DM intake: 3.64 kg/day	50
		Milk yield: 2.99 - 4.13 kg/day	
		Dairy does; late lactation; DM intake: 2.51 kg/day	42
		Dairy does; late lactation; DM intake: 4.53 kg/day	63

Horses

Category - Definition	Mn Req. (NRC, 2007) (mg/day)	Category - Definition	Mn Req. (NRC, 2007) (mg/day)
MBW 200 kg; Adult; no work	160.0	MBW 400 kg; Adult; no work	320.0
MBW 200 kg; Adult; working: light exercise	160.0	MBW 400 kg; Adult; working: light exercise	320.0
MBW 200 kg; Adult; working: moderate exercise	180.0	MBW 400 kg; Adult; working: moderate exercise	360.0
MBW 200 kg; Adult; working: (very) heavy exercise	200.0	MBW 400 kg; Adult; working: (very) heavy exercise	400.0
MBW 200 kg; Stallions nonbreeding; breeding	160.0	MBW 400 kg; Stallions nonbreeding; breeding	320.0
MBW 200 kg; Pregnant mares	160.0	MBW 400 kg; Pregnant mares	320.0
MBW 200 kg; Lactating mares	200.0	MBW 400 kg; Lactating mares	400.0
MBW 200 kg; Growing animals: 4 m	67.4	MBW 400 kg; Growing animals: 4 m	134.8
MBW 200 kg; Growing animals: 6 m	86.4	MBW 400 kg; Growing animals: 6 m	172.8
MBW 200 kg; Growing animals: 12 m	128.5	MBW 400 kg; Growing animals: 12 m	257.0
MBW 200 kg; Growing animals: 18 m	155.0	MBW 400 kg; Growing animals: 18 m	310.0
MBW 200 kg; Growing animals: 24 m	171.7	MBW 400 kg; Growing animals: 24 m	343.4

Horses

Category - Definition	Mn Req. (NRC, 2007) (mg/day)	Category - Definition	Mn Req. (NRC, 2007) (mg/day)
MBW 500 kg; Adult; no work	400.0	MBW 600 kg; Adult; no work	480.0
MBW 500 kg; Adult; working: light exercise	400.0	MBW 600 kg; Adult; working: light exercise	480.0
MBW 500 kg; Adult; working: moderate exercise	450.0	MBW 600 kg; Adult; working: moderate exercise	540.0
MBW 500 kg; Adult; working: (very) heavy exercise	500.0	MBW 600 kg; Adult; working: (very) heavy exercise	600.0
MBW 500 kg; Stallions nonbreeding; breeding	400.0	MBW 600 kg; Stallions nonbreeding; breeding	480.0
MBW 500 kg; Pregnant mares	400.0	MBW 600 kg; Pregnant mares	480.0
MBW 500 kg; Lactating mares	500.0	MBW 600 kg; Lactating mares	600.0
MBW 500 kg; Growing animals: 4 m	168.5	MBW 600 kg; Growing animals: 4 m	202.2
MBW 500 kg; Growing animals: 6 m	216.0	MBW 600 kg; Growing animals: 6 m	259.2
MBW 500 kg; Growing animals: 12 m	321.3	MBW 600 kg; Growing animals: 12 m	385.5
MBW 500 kg; Growing animals: 18 m	387.5	MBW 600 kg; Growing animals: 18 m	465.0
MBW 500 kg; Growing animals: 24 m	429.3	MBW 600 kg; Growing animals: 24 m	515.1
MBW 900 kg; Adult; no work	720.0		
MBW 900 kg; Adult; working: light exercise	720.0		
MBW 900 kg; Adult; working: moderate exercise	810.0		
MBW 900 kg; Adult; working: (very) heavy exercise	900.0		
MBW 900 kg; Stallions nonbreeding; breeding	720.0		
MBW 900 kg; Pregnant mares	720.0		
MBW 900 kg; Lactating mares	900.0		
MBW 900 kg; Growing animals: 4 m	303.3		
MBW 900 kg; Growing animals: 6 m	388.8		
MBW 900 kg; Growing animals: 12 m	578.3		
MBW 900 kg; Growing animals: 18 m	697.5		
MBW 900 kg; Growing animals: 24 m	772.7		

Salmonids

Category - Definition	Mn Req. (NRC, 1993) (mg/kg)
Pacific salmon	required but quantity not determined
Rainbow trout	13

Dogs

Category - Definition	Mn Req. (NRC, 2006) (mg/kg DM)	Mn Adequate intake (NRC, 2006) (mg /kg DM)	Mn Rec. Allowance (NRC, 2006) (mg /kg DM)
Puppies after weaning		5.6	5.6
Adult dogs at maintenance		4.8	4.8
Bitches for late gestation and peak lactation		7.2	7.2

Cats

Category - Definition	Mn Req. (NRC, 2006) (mg/kg DM)	Mn Adequate intake (NRC, 2006) (mg /kg DM)	Mn Rec. Allowance (NRC, 2006) (mg /kg DM)
Kittens after weaning		4.8	4.8
Adult cats		4.8	4.8
Queens in late gestation and peak lactation		7.2	7.2

Glossary:

Req.: requirement
(a): 90 % dry matter
MBW: Mature body weight
FI: Feed Intake
lact.: lactation

Annex 3.2: Manganese Use Levels

Table 1 Supplementation recommendations, calculated background level ranges and use levels for manganese (information acquired from the industry)

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg /kg)
Pigs (7 – 20 kg)	60	30 – 35	95	150
Pigs (20 – 30 kg)	50	35 – 45	95	150
Pigs (30 – 100 kg)	40	40 – 50	90	150
Sows	50	55 – 65	115	150
Broilers	60	25 – 35	95	150
Hens	75	30 – 40	115	150
Veal	50	50 – 65	115	150
Cattle	50	50 – 90	140	150
Sheep	40	60 - 75	115	150

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use levels for manganese

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	40 - 50	35	85
Pigs (15 - 50 kg)	30 - 50	45	95
Pigs (50 - 150 kg)	25 - 45	50	95
Gestating sows	40 - 60	65	125
Lactating sows	40 - 60	65	125

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Annex 4. Manganese concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	4
Potato prot ASH>10	4
Potato starch dried	
Potato sta heat tr	
Potato pulp CP<95	37
Potato pulp CP>95	37
Potatoes sweet dried	
Bone meal	17
Brewers' grains dr	38
Brewers' yeast dried	6
Sugarb pulp SUG<100	56
Sugarb p SUG100-150	80
Sugarb p SUG150-200	66
Sugarb pulp SUG>200	61
Biscuits CFAT<120	6
Biscuits CFAT>120	6
Blood meal spray dr	3
Buckwheat	34
Beans phas heat tr	29
Bread meal	
Casein	6
Chicory pulp dried	34
Citrus pulp dried	10
Meat meal Dutch	34
Meat meal CFAT<100	54
Meat meal CFAT>100	37
Peas	13
Barley	16
Barley feed h grade	46
Barley mill byprod	57
Grass meal CP<140	132
Grass meal CP140-160	111
Grass meal CP160-200	94
Grass meal CP>200	108
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	36
Peanut exp p with sh	
Peanut exp with sh	
Peanut extr wtht sh	52
Peanut extr with sh	
Oats grain	43
Oats grain peeled	42
Oats husk meal	55
Oats mill fd h grade	
Hempseed	
Carob	8

INRA	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	16	4
Maize	8	7
Oats	40	13
Oats groats	32	
Rice, brown	25	
Rye	46	
Sorghum	9	6
Triticale	20	15
Wheat, durum	50	
Wheat, soft	34	13
WHEAT BY-PRODUCTS		
Wheat bran	112	
Wheat middlings	100	
Wheat shorts	97	
Wheat feed flour	50	
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%	83	
Wheat gluten feed, starch 28%	81	
MAIZE BY-PRODUCTS		
Corn distillers	19	
Corn gluten feed	18	7
Corn gluten meal	8	4
Maize bran	19	
Maize feed flour		
Maize germ meal, expeller	12	
Maize germ meal, solvent extracted	17	
Hominy feed	21	
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	55	
Brewers' dried grains	43	11
Rice bran, extracted	267	
Rice bran, full fat	211	59
Rice, broken	14	
LEGUME AND OIL SEEDS		
Chickpea	19	
Cottonseed, full fat	14	1
Faba bean, coloured flowers	7	2
Faba bean, white flowers	7	
Linseed, full fat	29	
Lupin, blue	38	
Lupin, white	1707	
Pea	9	3
Rapeseed, full fat	34	
Soybean, full fat, extruded	23	
Soybean, full fat, toasted	28	
Sunflower seed, full fat	33	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	49
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	22
Cottons exp p with h	23
Cottons exp with h	22
Cottons extr wtht h	21
Cotts extr p with h	21
Cottons extr with h	22
Coconut exp CFAT<100	71
Coconut exp CFAT>100	71
Coconut extr	59
Linseed	20
Linseed exp	43
Linseed extr	42
Lentils	16
Lupins CP<335	34
Lupins CP>335	62
Alf meal CP<140	54
Alf meal CP140-160	33
Alf meal CP160-180	38
Alf meal CP>180	38
Poppyseed	
Macoya fruit exp	
Maize	5
Maize chem-h treated	6
Maize gluten meal	4
Maize glfeed CP<200	19
Maize glfd CP200-230	21
Maize glfeed CP>230	20
Maize germ meal extr	9
Maize germ m fd exp	14
Maize germ m fd extr	18
Dist grains and sol	
Maize feedflour	7
Maize feed meal	
Maize feed meal extr	18
Maize bran	
Maize starch	
Sugarbeet molasses	24
Sugarc mol SUG<475	24
Sugarc mol SUG>475	18
Milk powder skimmed	3
Milk powder whole	2
Millet	11

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	94	
Cottonseed meal, crude fibre 7-14%	25	
Cottonseed meal, crude fibre 14-20%	15	
Grapeseed oil meal, solvent extracted	21	
Groundnut meal, detoxified, crude fibre < 9%	35	10
Groundnut meal, detoxified, crude fibre > 9%	33	6
Linseed meal, expeller	39	
Linseed meal, solvent extracted	43	
Palm kernel meal, expeller	131	73
Rapeseed meal	52	6
Sesame meal, expeller	64	
Soybean meal, 46	35	
Soybean meal, 48	38	11
Soybean meal, 50	34	
Sunflower meal, partially decorticated	48	
Sunflower meal, undecorticated	27	10
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	26	
Cassava, starch 72%	16	
Maize starch		
Potato tuber, dried	19	
Sweet potato, dried	11	
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	70	17
Beet pulp dried, molasses added	73	
Beet pulp, pressed	17	3
Brewers' yeast, dried	40	
Buckwheat hulls		
Carob pod meal	10	
Citrus pulp, dried	7	3
Cocoa hulls		
Grape marc, dried	11	
Grape seeds		
Liquid potato feed	5	
Molasses, beet	29	
Molasses, sugarcane	59	21
Potato protein concentrate	5	
Potato pulp, dried	43	
Soybean hulls	22	8
Vinasse, different origins		
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production	23	
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	32
Malt culms CP>200	32
Nigerseed	33
Horsebeans	12
Horsebeans white	12
Palm kernels	129
Palm kern exp CF<180	294
Palm kern exp CF>180	279
Palm kernel extr	
Rapeseed	35
Rapeseed exp	47
Rapeseed extr CP<380	69
Rapeseed extr CP>380	68
Rapes meal Mervobest	48
Rice wtht hulls	8
Rice with hulls	
Rice husk meal	
Rice bran meal extr	
Rice feed m ASH<90	142
Rice feed m ASH>90	142
Rye	35
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	64
Semameseed meal extr	57
Soybeans heat tr	34
Soybeans not heat tr	34
Soybean hulls CF<320	
Soyb hulls CF320-360	21
Soybean hulls CF>360	21
Soybean exp	50
Soybm CF<45 CP<480	38
Soybm CF<45 CP>480	38
Soybm CF45-70 CP<450	39
Soybm CF45-70 CP>450	38
Soyb meal CF>70	38
Soyb meal Mervobest	26
Soyb meal Rumi S	34
Sorghum	15
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	54
Tapioca STA 625-675	33
Tapioca STA 675-725	26
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	40	
Alfalfa, dehydrated, protein 17-18% dry matter	49	
Alfalfa, dehydrated, protein 18-19% dry matter	56	
Alfalfa, dehydrated, protein 22-25% dry matter	37	
Grass, dehydrated	49	17
Wheat straw	42	
DAIRY PRODUCTS		
Milk powder, skimmed	2	
Milk powder, whole	1.1	
Whey powder, acidic	3	
Whey powder, sweet	3	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	23	14
Fish meal, protein 65%	13	7
Fish meal, protein 70%	6	
Fish solubles, condensed, defatted	51	
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	5	
Feather meal	15	6
Meat and bone meal, fat <7.5%	25	
Meat and bone meal, fat >7.5%	25	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	25
Wheat gluten meal	
Wheat glutenfeed	79
Wheat middlings	115
Wheat germ	179
Wheat germfeed	103
Wheat feedfl CF<35	65
Wheat feedfl CF35-55	65
Wheat feed meal	97
Wheat bran	135
Triticale	29
Feather meal hydr	18
Fat from Animals	
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	50
Vinasse Sugb CP>250	66
Fish meal CP<580	18
Fish meal CP580-630	18
Fish meal CP630-680	17
Fish meal CP>680	14
Meat bone m CFAT<100	12
Meat bone m CFAT>100	
Whey p l lac ASH<210	4
Whey p l lac ASH>210	12
Whey powder	1
Sunflowers deh	21
Sunflowers p deh	15
Sunflowers w hulls	15
Sunfls exp deh	56
Sunfls exp p deh	57
Sunfls exp w hulls	56
Sunfmeal CF<160	44
Sunfmeal CF 160-200	44
Sunfmeal CF 200-240	47
Sunfmeal CF>240	42
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	37
Potato pulp pr NL	7
Potato pulp pressed	12
Potato cut raw	16
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	25
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	12
Pot sta STA 650-775	12
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	28
Pot s g STA 425-550	28
Pot s g STA 550-675	28
Pot sta gel STA>675	28
Brewers gr 22% DM	55
Brewers gr 27% DM	
Brewers yeast CP<400	8
Brewers y CP400-500	8
Brewers yeast CP>500	8
Beetp pressed f+sil	71
CCM CF<40	6
CCM CF 40-60	6
CCM CF>60	8
Chicory pulp f+sil	45
Distillers sol f	
Cheese whey CP<175	13
Cheese w CP175-275	14
Cheese whey CP>275	20
Maize glutenf f+sil	15
Maize solubles	74
Wheat st FR STAt 300	49
Wheat st STAtot 400	27
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	183
Beet rests sililed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	61
Barley straw	
Grass fr April l y.	95
Grass fr April n y.	95
Grass fr April h y.	95
Grass fr May l y.	95
Grass fr May n y.	95
Grass fr May h y.	95
Grass fr June l y.	95
Grass fr June n y.	95
Grass fr June h y.	95

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	95
Grass fr July n y.	95
Grass fr July h y.	95
Grass fr Aug l y.	95
Grass fr Aug n y.	95
Grass fr Aug h y.	95
Grass fr Sept l y.	95
Grass fr Sept n y.	95
Grass fr Sept h y.	95
Grass fr Oct l y.	95
Grass fr Oct n y.	95
Grass fr Oct h y.	95
Grass average	95
Grass horse gr past	95
Grass horse same fld	95
Grass sil May 2000	98
Grass sil May 3500	98
Grass sil May 5000	98
Grass sil June 2000	98
Grass sil June 3000	98
Grass sil June 4000	98
Grass sil Ju-Au 2000	98
Grass sil Ju-Au 3000	98
Grass sil Ju-Au 4000	98
Grass sil Se-Oc 2000	98
Grass sil Se-Oc 3000	98
Grass sil average	98
Grass sil horse fine	98
Grass sil horse midd	98
Grass sil horse crs	98
Grass hay good qual	98
Grass hay av qual	98
Grass hay poor qual	98
Grass hay horse fine	98
Grass hay horse midd	98
Grass hay horse crs	98
Grass bales ad	119
Grass seeds straw	24
Oat straw	
Clover red fresh	
Clover red silage	17
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	106
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	46
Lucerne hay	24
Lucerne (alfalfa) ad	27
Maize Cob with leaves silage	8
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	73
Maize fod fr DM<240	28
Maize f fr DM240-280	28
Maize f fr DM280-320	28
Maize fod fr DM 320	28
Maize sil DM < 240	28
Maize sil DM240-280	28
Maize sil DM280-320	28
Maize sil DM 320	28
Maize (Fodder) ad	28
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	49
Chicory rts not frcd	
Chicory rts frcd cleaned	4
Chicory rts frcd dirty	
Carrots	
Sunflower silage	30

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	30.4
Calcium carbonate	279
Diammonium phosphate	500
Difluorinated phosphate	220
Dicalcium phosphate	300
Mono-dicalcium phosphate	220
Monoammonium phosphate	500
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of manganese in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	89.2	89.2	6	6	23.99	23.08
Piglet Starter II (complete feed)	20	81.2	88.2	10	11	32.42	33.65
Pig Grower (complete feed)	19	90.4	88.4	10	10	39.53	32.56
Pig Finisher (complete feed)	18	85.8	93.7	9	10	43.07	39.04
Sows, gestating (complete feed)	18	96.2	96.2	13	13	59.43	48.28
Sows, lactating (complete feed)	20	95.5	89.5	13	12	50.53	41.48
Starter Chicks (complete feed)	15	90.9	91.7	8	8	28.47	32.36
Chicken reared for laying (complete feed)	17	84.1	91.6	8	9	34.76	41.63
Layer Phase I (complete feed)	16	90.8	95.3	7	9	42.96	45.28
Layer Phase II (complete feed)	16	83.4	94.8	7	9	43.90	49.93
Broiler Starter (complete feed)	14	96.6	96.6	7	7	27.33	28.48
Broiler Grower (complete feed)	15	93.8	91.3	8	7	29.24	30.49
Broiler Finisher (complete feed)	15	92.3	89.8	7	6	31.17	33.34
Turkey Starter (complete feed)	14	96.7	96.7	6	6	34.06	34.69
Turkey Grower (complete feed)	13	93.5	93.5	6	6	34.77	36.71
Turkey Finisher (complete feed)	11	94.3	94.3	5	5	33.12	35.49
Turkey Breeder (complete feed)	8	91.4	91.4	5	5	32.37	33.94
Duck, grower/finisher (complete feed)	10	95.0	95.0	5	5	39.33	43.58
Geese, grower/finisher (complete feed)	8	98.7	98.7	6	6	25.69	27.19
Calf, milk replacer (complete feed)	10	66.7	35.7	4	2	6.91	5.07
Calf concentrate (complete feed)	17	99.6	98.1	14	13	90.22	52.99
Calf concentrate (complementary feed)	16	99.2	96.2	13	12	82.43	56.97
Cattle concentrate (complete feed)[4]	9	95.9	95.9	7	7	49.32	36.88
Cattle concentrate (complementary feed)	8	94.1	94.1	6	6	28.45	31.68
Dairy cows TMR (based on corn silage)[4]	15	98.7	98.9	12	11	56.59	28.69
Dairy cows TMR (based on grass silage)[4]	15	97.7	98.0	12	11	76.38	40.02
Dairy concentrate (complementary feed)	13	88.9	90.6	10	9	89.93	58.64
Dairy cows mineral feed (min. 40% crude ash)	8	45.7	45.7	3	3	143.50	143.50
Rabbit, breeder (complete feed)	8	99.1	99.1	5	5	72.18	75.56
Rabbit, grower/finisher (complete feed)	14	96.9	96.9	7	7	52.08	47.17
Salmon feed (wet)[4]	4	70.4	70.4	2	2	13.17	8.40
Salmon feed (dry)	6	79.4	79.4	3	3	18.29	12.44
Trout feed (dry)	12	66.4	78.2	3	4	23.06	21.13
Dog food (dry)	12	81.9	81.9	6	6	29.67	19.89
Cat food (dry)	16	59.4	90.2	8	9	22.25	28.23

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Manganese: Addendum to the monograph

Abstract

This addendum to the manganese monograph substantiates the data reported in Annex 5 of the manganese monograph in which manganese background levels are reported. The addendum provides the following information for each calculated background level: (1) the manganese concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no manganese concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated manganese content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	34.93	5.59	23.29
Maize	5	10.00	0.50	2.08
Soybeans heat tr	34	15.10	5.13	21.40
Soybm CF<45 CP>480	38	7.50	2.85	11.88
Wheat	25	16.68	4.17	17.38
Wheat middlings	115	5.00	5.75	23.97
Fat from Animals		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	23.99	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	15.00	2.40	7.40
Maize	5	15.81	0.79	2.44
Dist grains and sol		3.00		
Palm kern exp CF<180	294	4.00	11.76	36.27
Rapeseed exp	47	6.00	2.82	8.70
Soybm CF<45 CP>480	38	7.86	2.99	9.22
Wheat	25	27.50	6.88	21.20
Wheat gluten meal		10.00		
Wheat middlings	115	2.00	2.30	7.09
Fat from Animals		3.00		
Sunfmeal CF<160	44	2.55	1.12	3.46
Phytase		1.50		
Calcium carbonate	279	0.45	1.26	3.89
L-Lysine HCl		0.49		
Monocalciumphosphate	220	0.05	0.11	0.33
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	32.42	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	2.00	1.32	3.34
Barley	16	20.00	3.20	8.10
Maize	5	9.42	0.47	1.19
Dist grains and sol		5.00		
Palm kern exp CF<180	294	4.00	11.76	29.75
Rapeseed exp	47	7.00	3.29	8.32
Soybm CF<45 CP>480	38	3.40	1.29	3.27
Wheat	25	35.00	8.75	22.14
Wheat middlings	115	7.27	8.36	21.15
Fat from Animals		2.09		
Sunfmeal CF<160	44	2.32	1.02	2.58
Calcium carbonate	279	0.02	0.07	0.17
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	39.53	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	2.50	1.65	3.83
Barley	16	20.00	3.20	7.43
Maize	5	6.93	0.35	0.80
Dist grains and sol		6.21		
Palm kern exp CF<180	294	5.00	14.70	34.13
Rapeseed exp	47	1.35	0.63	1.47
Wheat	25	35.00	8.75	20.32
Wheat gluten meal		3.04		
Wheat middlings	115	10.00	11.50	26.70
Fat from Animals		2.00		
Sunfmeal CF<160	44	4.98	2.19	5.09
Calcium carbonate	279	0.04	0.10	0.23
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	43.07	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	5.50	3.63	6.11
Barley	16	20.00	3.20	5.38
Maize	5	15.26	0.76	1.28
Maize germ meal extr	9	7.50	0.68	1.14
Sugarc mol SUG<475	24	0.10	0.02	0.04
Palm kern exp CF<180	294	5.00	14.70	24.74
Wheat	25	11.22	2.81	4.72
Wheat glutenfeed	79	5.00	3.95	6.65
Wheat middlings	115	7.50	8.63	14.51
Wheat bran	135	12.50	16.88	28.40
Fat from Animals		1.91		
Sunfmeal CF<160	44	6.11	2.69	4.53
Phytase		1.50		
Calcium carbonate	279	0.48	1.34	2.26
L-Lysine HCl		0.24		
Monocalciumphosphate	220	0.07	0.15	0.24
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	59.43	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	2.41	1.59	3.15
Barley	16	20.00	3.20	6.33
Maize	5	10.00	0.50	0.99
Palm kern exp CF<180	294	4.00	11.76	23.27
Rapeseed exp	47	6.00	2.82	5.58
Soybean exp	50	1.39	0.70	1.38
Soybm CF<45 CP>480	38	5.13	1.95	3.85
Wheat	25	23.43	5.86	11.59
Wheat glutenfeed	79	10.00	7.90	15.63
Wheat middlings	115	7.50	8.63	17.07
Fat from Animals		2.16		
Sunfmeal CF<160	44	4.22	1.86	3.67
Phytase		1.50		
Calcium carbonate	279	1.02	2.85	5.64
L-Lysine HCl		0.34		
Monocalciumphosphate	220	0.42	0.93	1.85
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	50.53	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	20.00	1.00	3.51
Rapeseed exp	47	5.00	2.35	8.26
Soybeans not heat tr	34	0.69	0.23	0.83
Soybm CF<45 CP>480	38	19.79	7.52	26.42
Wheat	25	35.62	8.91	31.29
Wheat gluten meal		5.75		
Fat from Animals		2.00		
Sunfmeal CF<160	44	7.94	3.49	12.28
Calcium carbonate	279	1.34	3.74	13.12
L-Lysine HCl		0.07		
Monocalciumphosphate	220	0.56	1.22	4.30
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	28.47	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Chicken reared for laying (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	15.00	0.75	2.16
Dist grains and sol		2.50		
Rapeseed exp	47	5.00	2.35	6.76
Soybm CF<45 CP>480	38	2.95	1.12	3.23
Wheat	25	41.54	10.38	29.88
Wheat gluten meal		10.00		
Wheat bran	135	7.50	10.13	29.13
Fat from Animals		2.00		
Sunfmeal CF<160	44	10.00	4.40	12.66
Calcium carbonate	279	1.79	4.98	14.33
L-Lysine HCl		0.23		
Monocalciumphosphate	220	0.29	0.65	1.86
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	34.76	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	20.00	1.00	2.33
Dist grains and sol		4.00		
Soybeans not heat tr	34	8.36	2.84	6.62
Soybm CF<45 CP>480	38	5.93	2.25	5.25
Wheat	25	38.18	9.55	22.22
Wheat gluten meal		0.47		
Fat from Animals		2.87		
Sunfmeal CF<160	44	10.00	4.40	10.24
Calcium carbonate	279	7.78	21.71	50.55
L-Lysine HCl		0.23		
Monocalciumphosphate	220	0.55	1.20	2.79
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	42.96	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	20.00	1.00	2.28
Dist grains and sol		4.00		
Soybean exp	50	7.80	3.90	8.89
Soybm CF<45 CP>480	38	6.34	2.41	5.49
Wheat	25	30.36	7.59	17.29
Wheat gluten meal		7.41		
Fat from Animals		3.40		
Sunfmeal CF<160	44	10.00	4.40	10.02
Calcium carbonate	279	8.48	23.66	53.90
L-Lysine HCl		0.20		
Monocalciumphosphate	220	0.43	0.94	2.13
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	43.90	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	30.00	1.50	5.49
Maize gluten meal	4	2.50	0.10	0.37
Soybeans not heat tr	34	15.00	5.10	18.66
Soybm CF<45 CP>480	38	18.41	7.00	25.60
Wheat	25	28.16	7.04	25.76
Fat from Animals		1.50		
Calcium carbonate	279	1.62	4.52	16.54
L-Lysine HCl		0.44		
Monocalciumphosphate	220	0.94	2.07	7.58
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	27.33	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	15.00	0.75	2.56
Maize gluten meal	4	1.56	0.06	0.21
Rapeseed exp	47	2.50	1.18	4.02
Soybeans not heat tr	34	10.00	3.40	11.63
Soybm CF<45 CP>480	38	20.22	7.68	26.27
Wheat	25	42.41	10.60	36.26
Fat from Animals		4.44		
Calcium carbonate	279	1.38	3.86	13.20
L-Lysine HCl		0.33		
Monocalciumphosphate	220	0.78	1.71	5.85
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	29.24	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize gluten meal	4	0.68	0.03	0.09
Rapeseed exp	47	2.50	1.18	3.77
Soybeans not heat tr	34	10.16	3.45	11.08
Soybm CF<45 CP>480	38	19.32	7.34	23.55
Wheat	25	57.84	14.46	46.39
Fat from Animals		6.00		
Calcium carbonate	279	1.38	3.86	12.38
L-Lysine HCl		0.28		
Monocalciumphosphate	220	0.39	0.85	2.74
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	31.17	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	20.00	1.00	2.94
Soybm CF<45 CP>480	38	42.45	16.13	47.37
Wheat	25	25.35	6.34	18.61
Fats/oils vegetable		1.83		
Fish meal CP630-680	17	5.00	0.85	2.50
Calcium carbonate	279	1.99	5.56	16.32
L-Lysine HCl		0.34		
Monocalciumphosphate	220	1.90	4.18	12.27
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.82	34.06	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	6.94	0.35	1.00
Soybeans not heat tr	34	2.00	0.68	1.96
Soybm CF<45 CP>480	38	41.24	15.67	45.07
Wheat	25	40.00	10.00	28.76
Fats/oils vegetable		5.00		
Calcium carbonate	279	1.15	3.21	9.23
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	220	2.21	4.86	13.98
Salt		0.30		
Total		100.00	34.77	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	11.74	0.59	1.77
Soybm CF<45 CP>480	38	39.50	15.01	45.32
Wheat	25	40.00	10.00	30.20
Fats/oils vegetable		4.60		
Calcium carbonate	279	1.30	3.63	10.95
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	220	1.77	3.89	11.76
Salt		0.30		
Total		100.00	33.12	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	5	69.44	3.47	10.73
Soybm CF<45 CP>480	38	11.40	4.33	13.38
Feather meal hydr	18	2.00	0.36	1.11
Calcium carbonate	279	7.60	21.20	65.51
Dicalcium Phosphate	300	1.00	3.00	9.27
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	32.37	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Soybm CF<45 CP>480	38	15.00	5.70	14.49
Wheat	25	68.91	17.23	43.81
Wheat middlings	115	9.00	10.35	26.32
Fats/oils veg h %d		3.87		
Calcium carbonate	279	1.20	3.35	8.51
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	300	0.90	2.70	6.87
Premix		0.50		
Salt		0.37		
Total		100.02	39.33	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	10.00	1.60	6.23
Maize	5	34.00	1.70	6.62
Soybm CF<45 CP>480	38	33.00	12.54	48.82
Wheat	25	20.00	5.00	19.46
Calcium carbonate	279	1.20	3.35	13.03
Dicalcium Phosphate	300	0.50	1.50	5.84
Premix		1.00		
Salt		0.30		
Total		100.00	25.69	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	38	10.00	3.80	55.02
Wheat gluten meal		5.00		
Fat from Animals		6.25		
Whey p l lac ASH<210	4	15.00	0.60	8.69
Whey powder	1	30.65	0.31	4.44
Cheese whey CP>275	20	11.00	2.20	31.85
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	6.91	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	5.50	3.63	4.02
Citrus pulp, dried	10	8.00	0.80	0.89
Barley	16	0.54	0.09	0.10
Linseed	20	1.25	0.25	0.28
Sugarbeet molasses	24	1.00	0.24	0.27
Palm kern exp CF<180	294	5.50	16.17	17.92
Rapeseed	35	3.50	1.23	1.36
Rapeseed extr CP>380	68	1.94	1.32	1.46
Soybeans heat tr	34	5.37	1.83	2.02
Wheat middlings	115	7.00	8.05	8.92
Wheat feedfl CF<35	65	8.00	5.20	5.76
Vinasse Sugb CP>250	66	1.50	0.99	1.10
Grass hay good qual	98	50.00	49.00	54.31
Calcium carbonate	279	0.51	1.43	1.58
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	90.22	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	11.00	7.26	8.81
Citrus pulp, dried	10	16.00	1.60	1.94
Barley	16	1.08	0.17	0.21
Linseed	20	2.50	0.50	0.61
Sugarbeet molasses	24	2.00	0.48	0.58
Palm kern exp CF<180	294	11.00	32.34	39.23
Rapeseed	35	7.00	2.45	2.97
Rapeseed extr CP>380	68	3.88	2.64	3.20
Soybeans heat tr	34	10.74	3.65	4.43
Wheat middlings	115	14.00	16.10	19.53
Wheat feedfl CF<35	65	16.00	10.40	12.62
Vinasse Sugb CP>250	66	3.00	1.98	2.40
Calcium carbonate	279	1.02	2.86	3.47
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	82.43	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	10.01	6.61	13.40
Barley	16	18.90	3.02	6.13
Linseed	20	7.51	1.50	3.05
Sugarbeet molasses	24	0.98	0.24	0.48
Soybm CF<45 CP>480	38	10.99	4.18	8.47
Wheat	25	17.50	4.38	8.87
Fats/oils veg h %d		1.60		
Grass sil average	98	30.00	29.40	59.61
Premix		2.50		
Total		99.99	49.32	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	14.30	9.44	33.17
Barley	16	27.00	4.32	15.18
Linseed	20	10.70	2.14	7.52
Sugarbeet molasses	24	1.40	0.34	1.18
Soybm CF<45 CP>480	38	15.70	5.97	20.97
Wheat	25	25.00	6.25	21.97
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	28.45	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	2.61	1.72	3.04
Maize glfd CP200-230	21	0.95	0.20	0.35
Maize feed meal		1.15		
Sugarbeet molasses	24	0.24	0.06	0.10
Palm kern exp CF<180	294	1.78	5.23	9.25
Rapeseed exp	47	0.59	0.28	0.49
Rapeseed extr CP>380	68	6.18	4.20	7.43
Soybm CF<45 CP>480	38	7.83	2.98	5.26
Wheat middlings	115	0.96	1.10	1.95
Vinasse Sugb CP>250	66	0.36	0.24	0.42
Grass sil average	98	26.89	26.35	46.56
Maize sil DM280-320	28	50.23	14.06	24.85
Calcium carbonate	279	0.06	0.17	0.30
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.95	56.59	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	4.72	3.12	4.08
Maize glfd CP200-230	21	1.72	0.36	0.47
Maize feed meal		2.08		
Sugarbeet molasses	24	0.43	0.10	0.14
Palm kern exp CF<180	294	3.22	9.47	12.39
Rapeseed exp	47	1.07	0.50	0.66
Rapeseed extr CP>380	68	4.39	2.99	3.91
Soybm CF<45 CP>480	38	3.97	1.51	1.98
Wheat middlings	115	1.74	2.00	2.62
Vinasse Sugb CP>250	66	0.64	0.42	0.55
Grass sil average	98	49.18	48.20	63.10
Maize sil DM280-320	28	26.46	7.41	9.70
Calcium carbonate	279	0.11	0.31	0.40
Premix		0.21		
Magnesiumoxide		0.06		
Total		99.94	76.38	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	22.00	14.52	16.15
Maize glfd CP200-230	21	8.00	1.68	1.87
Maize feed meal		9.70		
Sugarbeet molasses	24	2.00	0.48	0.53
Palm kern exp CF<180	294	15.00	44.10	49.04
Rapeseed exp	47	5.00	2.35	2.61
Rapeseed extr CP>380	68	15.00	10.20	11.34
Soybm CF<45 CP>480	38	10.30	3.91	4.35
Wheat middlings	115	8.10	9.32	10.36
Vinasse Sugb CP>250	66	3.00	1.98	2.20
Calcium carbonate	279	0.50	1.40	1.55
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.60	89.93	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize starch		0.17		
Calcium carbonate	279	30.50	85.10	59.30
Dicalcium Phosphate	300	8.80	26.40	18.40
Salt		22.60		
Diammonium phosphate	500	6.40	32.00	22.30
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	143.50	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	2.00	0.32	0.44
Alf meal CP160-180	38	40.00	15.20	21.06
Soybm CF<45 CP>480	38	9.00	3.42	4.74
Wheat germfeed	103	46.00	47.38	65.64
Calcium carbonate	279	2.10	5.86	8.12
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	72.18	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG150-200	66	10.00	6.60	12.67
Barley	16	23.00	3.68	7.07
Alf meal CP160-180	38	35.00	13.30	25.54
Soybm CF<45 CP>480	38	5.00	1.90	3.65
Wheat bran	135	12.00	16.20	31.11
Fat from Animals		2.00		
Sunfmeal CF 200-240	47	10.00	4.70	9.02
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	300	1.90	5.70	10.94
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	52.08	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat	25	14.90	3.73	28.29
Fish meal CP630-680	17	55.53	9.44	71.71
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		89.35	13.17	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Soybm CF<45 CP>480	38	20.00	7.60	41.56
Wheat	25	7.42	1.86	10.14
Fish meal CP630-680	17	51.96	8.83	48.30
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	18.29	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	38	55.00	20.90	90.62
Wheat	25	2.87	0.72	3.11
Wheat gluten meal		11.80		
Fat from Animals		16.00		
Fish meal CP630-680	17	8.50	1.45	6.27
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	23.06	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Sugarb p SUG100-150	80	4.30	3.44	11.59
Meat meal CFAT<100	54	40.62	21.93	73.93
Maize	5	27.80	1.39	4.69
Maize starch		2.78		
Rice wtht hulls	8	7.30	0.58	1.97
Fat from Animals		9.60		
Brewers y CP400-500	8	1.10	0.09	0.30
Calcium carbonate	279	0.80	2.23	7.52
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	29.67	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Brewers' yeast dried	6	1.80	0.11	0.49
Meat meal Dutch	34	1.33	0.45	2.03
Greaves		29.76		
Linseed	20	3.00	0.60	2.70
Wheat	25	12.21	3.05	13.72
Wheat glutenfeed	79	2.06	1.63	7.31
Wheat feedfl CF<35	65	20.00	13.00	58.43
Feather meal hydr	18	18.00	3.24	14.56
Fat from Animals		7.97		
Fish meal CP630-680	17	1.00	0.17	0.76
Meat bone m CFAT>100		1.00		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	22.25	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	34.93	5.59	24.21
Maize	8	10.00	0.80	3.47
Wheat, soft	34	16.68	5.67	24.57
Wheat middlings	100	5.00	5.00	21.66
Soybean, full fat, extruded	23	15.10	3.47	15.04
Soybean meal, 50	34	7.50	2.55	11.05
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	23.08	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	15.00	2.40	7.13
Maize	8	15.81	1.26	3.76
Wheat, soft	34	27.50	9.35	27.78
Wheat middlings	100	2.00	2.00	5.94
Wheat gluten feed, starch 28%	81	10.00	8.10	24.07
Corn distillers	19	3.00	0.57	1.69
Palm kernel meal, expeller	131	4.00	5.24	15.57
Rapeseed cake		6.00		
Soybean meal, 50	34	7.86	2.67	7.94
Sunflower meal, undecorticated	27	2.55	0.69	2.04
Tallow		3.00		
Phytase		1.50		
Calcium carbonate	279	0.45	1.26	3.75
L-Lysine HCl		0.49		
Monocalciumphosphate	220	0.05	0.11	0.32
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	33.65	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	20.00	3.20	9.83
Maize	8	9.42	0.75	2.31
Wheat, soft	34	35.00	11.90	36.55
Wheat middlings	100	7.27	7.27	22.33
Corn distillers	19	5.00	0.95	2.92
Palm kernel meal, expeller	131	4.00	5.24	16.09
Rapeseed cake		7.00		
Soybean meal, 50	34	3.40	1.16	3.55
Sunflower meal, undecorticated	27	2.32	0.63	1.92
Beet pulp, dried	70	2.00	1.40	4.30
Tallow		2.09		
Calcium carbonate	279	0.02	0.07	0.21
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	32.56	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	20.00	3.20	8.20
Maize	8	6.93	0.55	1.42
Wheat, soft	34	35.00	11.90	30.48
Wheat middlings	100	10.00	10.00	25.62
Wheat gluten feed, starch 28%	81	3.04	2.46	6.30
Corn distillers	19	6.21	1.18	3.02
Palm kernel meal, expeller	131	5.00	6.55	16.78
Rapeseed cake		1.35		
Sunflower meal, undecorticated	27	4.98	1.34	3.44
Beet pulp, dried	70	2.50	1.75	4.48
Tallow		2.00		
Calcium carbonate	279	0.04	0.10	0.26
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	39.04	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	20.00	3.20	6.63
Maize	8	15.26	1.22	2.53
Wheat, soft	34	11.22	3.82	7.90
Wheat bran	112	12.50	14.00	29.00
Wheat middlings	100	7.50	7.50	15.53
Wheat gluten feed, starch 28%	81	5.00	4.05	8.39
Maize germ meal, expeller	12	7.50	0.90	1.86
Palm kernel meal, expeller	131	5.00	6.55	13.57
Sunflower meal, undecorticated	27	6.11	1.65	3.42
Beet pulp, dried	70	5.50	3.85	7.98
Molasses, sugarcane	59	0.10	0.06	0.12
Tallow		1.91		
Phytase		1.50		
Calcium carbonate	279	0.48	1.34	2.78
L-Lysine HCl		0.24		
Monocalciumphosphate	220	0.07	0.15	0.30
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	48.28	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	20.00	3.20	7.72
Maize	8	10.00	0.80	1.93
Wheat, soft	34	23.43	7.97	19.20
Wheat middlings	100	7.50	7.50	18.08
Wheat gluten feed, starch 28%	81	10.00	8.10	19.53
Soybean, full fat, extruded	23	1.39	0.32	0.77
Palm kernel meal, expeller	131	4.00	5.24	12.63
Rapeseed cake		6.00		
Soybean meal, 50	34	5.13	1.74	4.20
Sunflower meal, undecorticated	27	4.22	1.14	2.74
Beet pulp, dried	70	2.41	1.69	4.07
Tallow		2.16		
Phytase		1.50		
Calcium carbonate	279	1.02	2.85	6.87
L-Lysine HCl		0.34		
Monocalciumphosphate	220	0.42	0.93	2.25
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	41.48	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	20.00	1.60	4.94
Wheat, soft	34	35.62	12.11	37.43
Wheat gluten feed, starch 28%	81	5.75	4.66	14.39
Soybean, full fat, extruded	23	0.69	0.16	0.49
Rapeseed cake		5.00		
Soybean meal, 50	34	19.79	6.73	20.80
Sunflower meal, undecorticated	27	7.94	2.14	6.63
Tallow		2.00		
Calcium carbonate	279	1.34	3.74	11.54
L-Lysine HCl		0.07		
Monocalciumphosphate	220	0.56	1.22	3.78
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	32.36	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	15.00	1.20	2.88
Wheat, soft	34	41.54	14.12	33.93
Wheat bran	112	7.50	8.40	20.18
Wheat gluten feed, starch 28%	81	10.00	8.10	19.46
Corn distillers	19	2.50	0.48	1.14
Rapeseed cake		5.00		
Soybean meal, 50	34	2.95	1.00	2.41
Sunflower meal, undecorticated	27	10.00	2.70	6.49
Tallow		2.00		
Calcium carbonate	279	1.79	4.98	11.96
L-Lysine HCl		0.23		
Monocalciumphosphate	220	0.29	0.65	1.55
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	41.63	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	20.00	1.60	3.53
Wheat, soft	34	38.18	12.98	28.67
Wheat gluten feed, starch 28%	81	0.47	0.38	0.85
Corn distillers	19	4.00	0.76	1.68
Soybean, full fat, extruded	23	8.36	1.92	4.25
Soybean meal, 50	34	5.93	2.02	4.46
Sunflower meal, undecorticated	27	10.00	2.70	5.96
Tallow		2.87		
Calcium carbonate	279	7.78	21.71	47.96
L-Lysine HCl		0.23		
Monocalciumphosphate	220	0.55	1.20	2.65
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	45.28	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	20.00	1.60	3.20
Wheat, soft	34	30.36	10.32	20.67
Wheat gluten feed, starch 28%	81	7.41	6.00	12.02
Corn distillers	19	4.00	0.76	1.52
Soybean, full fat, extruded	23	7.80	1.79	3.59
Soybean meal, 50	34	6.34	2.16	4.32
Sunflower meal, undecorticated	27	10.00	2.70	5.41
Tallow		3.40		
Calcium carbonate	279	8.48	23.66	47.38
L-Lysine HCl		0.20		
Monocalciumphosphate	220	0.43	0.94	1.87
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	49.93	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	30.00	2.40	8.43
Wheat, soft	34	28.16	9.58	33.62
Corn gluten meal	8	2.50	0.20	0.70
Soybean, full fat, extruded	23	15.00	3.45	12.11
Soybean meal, 50	34	18.41	6.26	21.98
Tallow		1.50		
Calcium carbonate	279	1.62	4.52	15.87
L-Lysine HCl		0.44		
Monocalciumphosphate	220	0.94	2.07	7.28
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	28.48	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	15.00	1.20	3.94
Wheat, soft	34	42.41	14.42	47.30
Corn gluten meal	8	1.56	0.12	0.41
Soybean, full fat, extruded	23	10.00	2.30	7.54
Rapeseed cake		2.50		
Soybean meal, 50	34	20.22	6.87	22.54
Tallow		4.44		
Calcium carbonate	279	1.38	3.86	12.66
L-Lysine HCl		0.33		
Monocalciumphosphate	220	0.78	1.71	5.61
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	30.49	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat, soft	34	57.84	19.66	58.99
Corn gluten meal	8	0.68	0.05	0.16
Soybean, full fat, extruded	23	10.16	2.34	7.01
Rapeseed cake		2.50		
Soybean meal, 50	34	19.32	6.57	19.70
Tallow		6.00		
Calcium carbonate	279	1.38	3.86	11.57
L-Lysine HCl		0.28		
Monocalciumphosphate	220	0.39	0.85	2.56
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	33.34	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	20.00	1.60	4.61
Wheat, soft	34	25.35	8.62	24.84
Soybean meal, 50	34	42.45	14.43	41.61
Fish meal, protein 70%	6	5.00	0.30	0.86
Calcium carbonate	279	1.99	5.56	16.02
L-Lysine HCl		0.34		
Monocalciumphosphate	220	1.90	4.18	12.05
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.82	34.69	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	6.94	0.56	1.51
Wheat, soft	34	40.00	13.60	37.05
Soybean, full fat, extruded	23	2.00	0.46	1.25
Soybean meal, 50	34	41.24	14.02	38.20
Calcium carbonate	279	1.15	3.21	8.74
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	220	2.21	4.86	13.25
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	36.71	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	11.74	0.94	2.65
Wheat, soft	34	40.00	13.60	38.32
Soybean meal, 50	34	39.50	13.43	37.84
Calcium carbonate	279	1.30	3.63	10.22
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	220	1.77	3.89	10.97
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	35.49	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	69.44	5.56	16.37
Soybean meal, 50	34	11.40	3.88	11.42
Feather meal	15	2.00	0.30	0.88
Calcium carbonate	279	7.60	21.20	62.48
Dicalcium Phosphate	300	1.00	3.00	8.84
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	33.94	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat, soft	34	68.91	23.43	53.77
Wheat middlings	100	9.00	9.00	20.65
Soybean meal, 50	34	15.00	5.10	11.70
Calcium carbonate	279	1.20	3.35	7.68
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	300	0.90	2.70	6.20
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	43.58	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	10.00	1.60	5.88
Maize	8	34.00	2.72	10.00
Wheat, soft	34	20.00	6.80	25.01
Soybean meal, 50	34	33.00	11.22	41.27
Calcium carbonate	279	1.20	3.35	12.31
Dicalcium Phosphate	300	0.50	1.50	5.52
Premix		1.00		
Salt		0.30		
Total		100.00	27.19	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat gluten feed, starch 25%	83	5.00	4.15	81.86
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	3	30.65	0.92	18.14
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	5.07	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	0.54	0.09	0.16
Wheat middlings	100	7.00	7.00	13.21
Wheat feed flour	50	8.00	4.00	7.55
Linseed, full fat	29	1.25	0.36	0.68
Rapeseed, full fat	34	3.50	1.19	2.25
Soybean, full fat, toasted	28	5.37	1.50	2.84
Palm kernel meal, expeller	131	5.50	7.21	13.60
Rapeseed meal	52	1.94	1.01	1.90
Beet pulp, dried	70	5.50	3.85	7.27
Citrus pulp, dried	7	8.00	0.56	1.06
Molasses, beet	29	1.00	0.29	0.55
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	49	50.00	24.50	46.24
Calcium carbonate	279	0.51	1.43	2.70
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	52.99	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	1.08	0.17	0.30
Wheat middlings	100	14.00	14.00	24.57
Wheat feed flour	50	16.00	8.00	14.04
Linseed, full fat	29	2.50	0.73	1.27
Rapeseed, full fat	34	7.00	2.38	4.18
Soybean, full fat, toasted	28	10.74	3.01	5.28
Palm kernel meal, expeller	131	11.00	14.41	25.29
Rapeseed meal	52	3.88	2.02	3.54
Beet pulp, dried	70	11.00	7.70	13.52
Citrus pulp, dried	7	16.00	1.12	1.97
Molasses, beet	29	2.00	0.58	1.02
Vinasse, different origins		3.00		
Calcium carbonate	279	1.02	2.86	5.01
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	56.97	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	18.90	3.02	8.20
Wheat, soft	34	17.50	5.95	16.13
Linseed, full fat	29	7.51	2.18	5.91
Soybean meal, 50	34	10.99	3.74	10.13
Beet pulp, dried	70	10.01	7.01	19.00
Molasses, beet	29	0.98	0.28	0.77
Grass silage	49	30.00	14.70	39.86
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	36.88	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	27.00	4.32	13.64
Wheat, soft	34	25.00	8.50	26.83
Linseed, full fat	29	10.70	3.10	9.80
Soybean meal, 50	34	15.70	5.34	16.85
Beet pulp, dried	70	14.30	10.01	31.60
Molasses, beet	29	1.40	0.41	1.28
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	31.68	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat middlings	100	0.96	0.96	3.35
Corn gluten feed	18	0.95	0.17	0.60
Corn gluten meal	8	1.15	0.09	0.32
Palm kernel meal, expeller	131	1.78	2.33	8.13
Rapeseed meal	52	6.18	3.21	11.20
Rapeseed cake		0.59		
Soybean meal, 50	34	7.83	2.66	9.28
Beet pulp, dried	70	2.61	1.83	6.37
Molasses, beet	29	0.24	0.07	0.24
Vinasse, different origins		0.36		
Grass silage	49	26.89	13.18	45.93
Corn silage	8	50.23	4.02	14.01
Calcium carbonate	279	0.06	0.17	0.58
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	28.69	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat middlings	100	1.74	1.74	4.35
Corn gluten feed	18	1.72	0.31	0.77
Corn gluten meal	8	2.08	0.17	0.42
Palm kernel meal, expeller	131	3.22	4.22	10.54
Rapeseed meal	52	4.39	2.28	5.70
Rapeseed cake		1.07		
Soybean meal, 50	34	3.97	1.35	3.37
Beet pulp, dried	70	4.72	3.30	8.26
Molasses, beet	29	0.43	0.12	0.31
Vinasse, different origins		0.64		
Grass silage	49	49.18	24.10	60.22
Corn silage	8	26.46	2.12	5.29
Calcium carbonate	279	0.11	0.31	0.77
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	40.02	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat middlings	100	8.10	8.10	13.81
Corn gluten feed	18	8.00	1.44	2.46
Corn gluten meal	8	9.70	0.78	1.32
Palm kernel meal, expeller	131	15.00	19.65	33.51
Rapeseed meal	52	15.00	7.80	13.30
Rapeseed cake		5.00		
Soybean meal, 50	34	10.30	3.50	5.97
Beet pulp, dried	70	22.00	15.40	26.26
Molasses, beet	29	2.00	0.58	0.99
Vinasse, different origins		3.00		
Calcium carbonate	279	0.50	1.40	2.38
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	58.64	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize starch		0.17		
Calcium carbonate	279	30.50	85.10	59.30
Dicalcium Phosphate	300	8.80	26.40	18.40
Salt		22.60		
Diammonium phosphate	500	6.40	32.00	22.30
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	143.50	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	2.00	0.32	0.42
Wheat bran	112	46.00	51.52	68.19
Soybean meal, 50	34	9.00	3.06	4.05
Alfalfa, dehydrated	37	40.00	14.80	19.59
Calcium carbonate	279	2.10	5.86	7.75
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	75.56	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Barley	16	23.00	3.68	7.80
Wheat bran	112	12.00	13.44	28.49
Soybean meal, 50	34	5.00	1.70	3.60
Sunflower meal, undecorticated	27	10.00	2.70	5.72
Beet pulp, dried	70	10.00	7.00	14.84
Lard		2.00		
Alfalfa, dehydrated	37	35.00	12.95	27.45
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	300	1.90	5.70	12.08
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	47.17	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat, soft	34	14.90	5.07	60.33
Fish meal, protein 70%	6	55.53	3.33	39.67
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	8.40	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat, soft	34	7.42	2.52	20.28
Soybean meal, 50	34	20.00	6.80	54.65
Fish meal, protein 70%	6	52.00	3.12	25.07
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	12.44	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat, soft	34	2.87	0.98	4.62
Corn gluten meal	8	11.80	0.94	4.47
Soybean meal, 50	34	55.00	18.70	88.50
Maize starch		3.00		
Fish meal, protein 70%	6	8.50	0.51	2.41
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	21.13	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Maize	8	27.80	2.22	11.18
Rice, brown	25	7.30	1.83	9.18
Maize starch		2.78		
Beet pulp, dried	70	4.30	3.01	15.14
Brewers' yeast, dried	40	1.10	0.44	2.21
Lard		9.60		
Meat and bone meal, fat <7.5%	25	40.62	10.16	51.07
Calcium carbonate	279	0.80	2.23	11.22
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	19.89	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Mn/kg feed material	% feed material	mg Mn/kg complete feedingstuff	Mn (% contribution)
Wheat, soft	34	12.21	4.15	14.70
Wheat feed flour	50	20.00	10.00	35.42
Wheat gluten feed, starch 25%	83	2.06	1.71	6.06
Linseed, full fat	29	3.00	0.87	3.08
Brewers' yeast, dried	40	1.80	0.72	2.55
Fish meal, protein 70%	6	1.00	0.06	0.21
Feather meal	15	18.00	2.70	9.56
Meat and bone meal, fat <7.5%	25	29.76	7.44	26.35
Meat and bone meal, fat >7.5%	25	2.33	0.58	2.06
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	28.23	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Mercury

Executive summary of the monograph for mercury

EU legislation governs the maximum content for mercury in products intended for animal feed and in foodstuffs. Mercury is not considered an essential element for animals. Mercury uptake by plants from soil is limited and most pastures and crops contain less than 0.1 mg/kg DM. The most common source of mercury for farmed animals is fishmeal where it is predominantly present as methylmercury. Additionally, animals may ingest mercury from the consumption of soil. Because of differing bioavailabilities and tissue distribution, the toxicological properties of inorganic and organic mercury differ. Hence, NRC established maximum tolerable levels for livestock for both types of mercury compounds. Chronic exposure to inorganic mercury results in clinical symptoms including progressive anemia and nephrotoxicity. Effects of methylmercury exposure in animals include ataxia, muscle spasms, paralysis, impaired vision, loss of coordination and hind limb crossing. The absorption, distribution, metabolism and excretion of mercury are largely dependent on its chemical form. Inorganic mercury is absorbed to a limited extent (10 – 30 %) while methylmercury is absorbed extensively (typically 80 %) following oral exposure. Inorganic mercury does not easily cross membranes, but concentrates in the kidney. Methylmercury distributes in all tissues and is able to cross the blood-brain and placental barriers. Fish and seafood are the main sources of human dietary exposure to mercury, and this is predominantly as methylmercury. Inorganic and organic mercury compounds have shown to be genotoxic *in vitro*. Nephrotoxicity is the most sensitive endpoint following chronic ingestion of inorganic mercury. Methylmercury is the form of greatest toxicological concern. Development of the central nervous system is affected by chronic exposure to methylmercury. The cardiovascular, immune and reproductive systems are also affected at higher doses. IARC classified methylmercury compounds as possibly carcinogenic to humans (Group 2B) and metallic mercury and inorganic mercury compounds as not classifiable as to their carcinogenicity to humans (Group 3). NRC and JECFA established provisional tolerable weekly intakes for mercury of 0.7 µg/(kg bw.week) and 1.6 µg/(kg bw.week). Inhalation exposure is the most common route of inorganic mercury uptake by humans. The toxic properties of mercury vapour are due to mercury accumulation in the brain causing neurobiological signs. At high exposure levels, mercurial tremor is seen accompanied by severe behavioural and personality changes, increased excitability, loss of memory, and insomnia. The implementation of the actual EU legislation, fixing maximum mercury levels in feedingstuffs, limits the contribution of mercury originating from animal excreta to the environment.

Mercury Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Most mercury encountered in the atmosphere is elemental mercury gas, whereas in all other environmental compartments inorganic mercury salts and organomercurials predominate. By far the most common organic mercury compound in the food chain is methylmercury and this is the predominant form to which humans are exposed via food. The methylation of mercury occurs almost solely in aquatic systems, consequently, aquatic biota and fish eating animals usually contain much higher levels of mercury then terrestrial animals (EFSA, 2008).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Presently, in the EU the Directive 2002/32/EC[1] amended by Directive 2010/6/EC[2] on undesirable substances in animal feed governs the maximum tolerable levels of mercury in feedingstuffs (Table 1).

Table 1 Maximum allowed mercury content (*, **) in products intended for animal feed in the EU according to Directive 2002/32/EC[1] amended by Directive 2010/6/EC[2]

Products intended for animal feed	**Maximum content in mg/kg relative to a feedingstuff with a moisture content of 12%**
Feed materials with the exception of:	0.1
– Feedingstuffs produced from fish or by the processing of fish or other aquatic animals,	0.5
– Calcium carbonate.	0.3
Compound (complementary and complete) feedingstuffs with the exception of:	0.1
– Mineral feed,	0.2
– Compound feedingstuffs for fish,	0.2
– Compound feedingstuffs for dogs, cats and fur animals.	0.3

(*) The maximum levels refer to total mercury. (**) Maximum levels refer to an analytical determination of mercury, whereby extraction is performed in nitric acid (5 % w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure has an equal extraction efficiency.

[1] OJ L 140, 30.5.2002, p. 10

[2] OJ L 37, 10.2.2010, p. 29

2.2 Human nutrition

In the EU, Regulation EC 1881/2006[3] ammended by Regulation EC 629/2008[4] sets maximum levels (ML) for mercury in certain foodstuffs, as summarized in Table 2.

Table 2 Maximum Levels (ML) for mercury (mg/kg) in foodstuffs in the EU set by Regulations EC 1881/2006[3] and EC 629/2008[4]

Foodstuffs	**ML**
Fishery products and muscle meat of fish. The maximum level applies to crustaceans, excluding the brown meat of crab and excluding head and thorax meat of lobster and similar large crustaceans (*Nephropidae* and *Palinuridae*). Excluding muscle meat of the following fish:	0.50
Angler fish (*Lophius species*), Atlantic catfish (*Anarhias lupus*), Bonito (*Sarda sarda*),Eel (*Anguilla* species), Emperor, orange roughy, rosy soldier fish (*Hoplostethus species*), Grenadier (*Coryphaenoides rupestris*), Halibut (*Hippoglossus hippoglossus*), Kingklip (*Genypterus capensis*), Marlin (*Makaira species*), Megrim (*Lepidorhombus species*), Mullet (*Mullus species*), Pink cusk eel (*Genypterus blacodes*), Pike (*Esox lucius*), Plain bonito (*Orcynopsis unicolor*), Poor cod (*Tricopterus minutes*), Portuguese dogfish (*Centroscymnus coelolepsis*), Rays (*Raja species*), Redfish (*Sebastes marinus, S. mentella, S. viviparous*), Sail fish (*Istiophorus platypterus*), Scabbard fish (*Lepidopus caudatus, Aphanopus carbo*), Seabream, pandora (*Pagellus species*), Shark (all species)Snake mackerel or butterfish (*Lepidocybium flavobrunneum, Ruvettus pretiosus*, *Gempylus serpens*), Sturgeon (*Acipenser species*), Swordfish (*Xiphias gladius*), Tuna (*Thunnus species, Euthynnus species, Katsuwonus pelamis*).	1.0
Food supplements (*)	0.10

(*) The maximum level applies to food supplements as sold

3 Essential functions

Mercury is not considered an essential nutrient for animals (NRC, 2005).

[3] OJ L 364, 20.12.2006, p. 19

[4] OJ L 173, 3.7.2008, p. 6

4 Other functions

It has been demonstrated that low levels of inorganic mercury increased growth rate in rodents, pigs and chicks. However, these results were not consistent in all considered experiments (NRC, 2005).

5 Antimicrobial properties

Inorganic mercury compounds have been extensively included in antiseptics or disinfectants, e.g., mercurochrome. Excessive dermal application of these products has occasionally resulted in toxicities in animals (EFSA, 2008; NRC, 2005).

There was no information found on antimicrobial properties of mercury relevant for animal husbandry in principal literature sources.

6 Typical deficiency symptoms

Mercury is not an essential trace element and no deficiency symptoms haven been described (NRC, 2005).

7 Animal requirements, allowances and use levels

Mercury is not an essential trace element and no requirements have been established by scientific bodies.

8 Concentration of the element in feed materials

Mercury uptake by plants from soil is limited and most pastures and crops contain less than 0.1 mg/kg DM. It has been shown that nearly all of the mercury found in foliage originates from the atmosphere. Fishmeal is the most common source of mercury for farmed animals under normal farming conditions. Additionally, animals may ingest mercury from the consumption of soil (EFSA, 2008; NRC, 2005; SCAN, 2003). EFSA (2008) compiled mercury concentrations in feed materials which were provided by EU countries that acquired the data as part of routine surveillance programmes (Table 3).

Table 3 Average mercury concentrations (mg/kg) in feed materials (EFSA, 2008)

Feed material	n	Hg concentration
Barley	29	0.006
Wheat	48	0.003
Oil seed rape	42	0.007
Sunflower meal	13	0.003
Soya bean meal	13	0.022
Distillers dried grains	8	0.047

Table 3 (continued) Average mercury concentrations (mg/kg) in feed materials (EFSA, 2008)

Feed material	n	Hg concentration
Maize gluten feed	15	0.026
Vegetable oils	16	0.021
Forage crops [1]	368	0.02
Minerals and mineral feedingstuff [1]	530	0.02
Calcium carbonate [1]	42	0.01
Additives and premixtures [1]	290	0.03
Complementary feed [1]	228	0.02
Fish meal [1]	193	0.10
Fish and bone meal [1]	13	0.15
Fish oil [1]	63	0.03
Fish silage [1]	23	0.06

[1]: moisture content 12 %

9 Concentration of the element in complete feedingstuffs

Typically, animal feed derived from plants contains mercury levels between 0.001 – 0.03 mg/kg DM (SCAN, 2003). Mercury concentrations in complete feedingstuffs are given in Table 4 (EFSA, 2008).

Table 4 Average mercury concentrations (mg/kg) in complete feedingstuffs (EFSA, 2008)

Complete feedingstuff for:	n	Hg concentration
Pigs	123	0.032
Poultry	96	0.039
Ruminants, complete and complementary feedingstuffs	56	0.012
Horses	9	0.022
Mink	39	0.053
Rabbits	18	0.031
Rodents	25	0.050
Fish	280	0.06
Dogs and cats	126	0.02

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Because of differing bioavailabilities and tissue distribution, the toxicity profiles of inorganic mercury and organic mercury differ. MTL values for inorganic and organic mercury compounds established by NRC (2005) are compiled in Table 5.

Table 5 Maximum Tolerable Levels (MTL) for mercury (mg/kg DM) (NRC, 2005)

Species	MTL	Additional Remark
Inorganic mercury		
Rodents, poultry	0.2	
Swine, horses	0.2	Value derived from interspecies extrapolation
Cattle, sheep, fish	-	Available data were considered insufficient to set a MTL
Organic mercury		A margin of safety should be added for pregnant animals to assure normal neurodevelopment of the fetus
Cattle, sheep	2	
Swine	2	Value derived from interspecies extrapolation
Rodents, poultry, fish	1	
Horses	1	Value derived from interspecies extrapolation

Additionally to the mercury MTL values, NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Chronic exposure to inorganic mercury results in progressive anemia, nephrotoxicity, gastric disorders, salivation, metallic taste in the mouth, inflammation, tenderness of gums, tremors, inactivity and an abnormal gait. The kidney is particularly sensitive to inorganic mercury.

The most sensitive endpoint for oral exposure to organic forms of mercury is the nervous system. A developing nervous system is considerably more sensitive than an adult's. Clinical symptoms of methyl mercury exposure in animals include ataxia, muscle spasms, paralysis, impaired vision, loss of coordination, and hind limb crossing (NRC, 2005). Liver failure was identified as the most sensitive endpoint in pigs. In poultry, exposure to organic forms of mercury has provoked a drop in egg production, infertility and embryo toxicity. New-born animals are more susceptible to methylmercury intoxication as compared to adults (EFSA, 2008).

12 Bioavailability

12.1 General

Absorption of mercury is largely dependent on its chemical form. Elemental mercury and mercurous salts, e.g., Hg_2Cl_2, are poorly absorbable (< 0.10 %). Mercuric salts, e.g., $HgCl_2$, are more readily absorbed than mercurous compounds because of their higher solubility. For these salts absorbabilities have been reported of 20 % for adult mice, 30 % for goats and 7 % for humans. Age is the primary factor determining the absorption of inorganic mercury. Phytate, proteins, amino acids and selenium are amongst the nutritional factors that influence absorption (EFSA, 2008).
Ingested organic mercurials are absorbed much more extensively and rapidly compared to inorganic mercury compounds. For methylmercury and phenylmercury absorbabilities > 80 % have been observed in humans, laboratory animals and livestock species (EFSA, 2008).

12.2 *Mercury status indicators / biomarkers of mercury exposure*

Blood and urine mercury levels have been used as biomarkers of high level exposure in acute and chronic studies for both inorganic and organic mercury. Hair has been used as a biomarker for chronic low level organic mercury exposure, with an awareness of the potential for external contamination (ATSDR, 1999).

13 Metabolism

Absorbed inorganic mercury is equally divided between plasma and red blood cells. Methylmercury in blood is primarily (≈ 90%) found in red blood cells. Methylmercury associates with thiol-containing amino acids because of the high affinity of the methylmercuric cation (CH_3Hg^+) for sulfhydryl groups (EFSA, 2008; NRC, 2005). In mammals, methylmercury has been shown to cross the blood-brain and placental barriers, the mammary gland and the pilous follicles. Methylmercury and phenylmercury can be converted into divalent inorganic mercury in the microsomes of liver and other tissues. Excretion of inorganic mercury is predominantly via urine and feces. Methylmercury is excreted more slowly than inorganic mercury, and the major route of excretion is via bile (EFSA, 2008; NRC, 2005).

14 Distribution in the animal body

The tissue distribution of mercury differs depending upon the form of mercury ingested. Following absorption of mercuric chloride, the liver and kidneys have the highest mercury levels, whereas the brain and muscle have substantially lower levels. Methylmercury distributes readily to all tissues, including the brain and muscles. This relatively uniform tissue distribution originates from its ability to cross cell membranes without difficulty. The continual demethylation in tissues over time results in a shift in distribution because inorganic mercury accumulates in the kidney and liver (NRC, 2005).

In mice after oral administration of methylmercury the mercury was distributed among the tissues as follows: 65 – 75 % carcass and hair, 8 – 10 % liver, 5 – 20 % kidneys and 10 % brain (EFSA, 2008).

15 Deposition (typical concentration) in edible tissues and products

Fish and seafood are the main sources of human dietary exposure to mercury, and this is predominantly as methylmercury. Mercury concentrations in edible tissues and products are reported in Annex 1 and mercury concentrations in edible tissues and products linked with the dietary intake of several mercury compounds and doses are reported in Annex 2.

16 Acute toxicity

In humans, oral exposure to inorganic mercury has been reported to cause death due to shock, cardiovascular collapse, acute renal failure, and severe gastrointestinal damage with gastrointestinal lesions. Reported lethal doses of single intakes of mercuric chloride ranged between 29 - > 50 mg Hg/kg bw. In rats, oral LD_{50} values of mercuric chloride varied between 25.9 - 77.7 mg Hg/kg bw. Lethal doses for humans of organic mercury have been estimated to be in the range of 10 - 60 mg Hg/kg bw (ATSDR, 1999).

17 Genotoxicity and Mutagenicity

Mercury has a direct effect on chromosomes, resulting in clastogenic effects in eukaryotes. Additionally, it disturbs the spindle mechanism, owing to its high affinity for the sulfhydryl groups contained in the spindle fibre proteins. Organomercury compounds have shown to inhibit the spindle mechanism even more strongly than colchicines, but, in contrast to colchicine, produce a gradual transition to c-mitosis at sub-lethal doses, which may result in aneuploidy and/or polyploidy. In general, inorganic mercury compounds are less effective than ionisable organomercury compounds in inducing genetic effects *in vitro* (IARC, 1993). ATSDR (1999) collected a substantial body of evidence showing the induction of primary DNA damage in mammalian and bacterial cells and weak mutagenesis in mammalian cells and suggesting that that inorganic and organic mercury compounds have some genotoxic potential.

18 Subchronic toxicity

The ATSDR Toxicological profile for mercury includes information on the subchronic toxicity of several mercury compounds on several organ systems and by several exposure routes (ATSDR, 1999).

19 Chronic toxicity, including carcinogenicity

The three forms of mercury, namely elemental, inorganic and organic mercury have different toxicological properties (EFSA, 2008).

Most chronic poisoning by inorganic mercury exposure involves a mixture of mercury vapour and mercuric mercury. With chronic exposure to mercuric mercury, the kidney is the critical organ. Two types of renal injury occur namely, glomerular injury caused by the toxic effect of mercury on the cells of the basal membrane of the glomeruli, which induces an autoimmune reaction and a nephritic syndrome develops with proteinuria and the classical signs of glomerular nephritis. Additionally, mercury accumulation causes tubular damage (Berlin *et al*., 2007).

The brain and central nervous system are the primary target sites where adverse effects of methylmercury are manifested. Chronic poisoning results in degeneration and atrophy of the sensory cerebral cortex, paresthesia, ataxia, hearing and visual impairment. Other sensitive targets of methylmercury include the cardiovascular system, the immune and reproductive systems (Berlin *et al*., 2007; NRC, 2000).

IARC (1993) classified methylmercury compounds as possibly carcinogenic to humans (Group 2B) and metallic mercury and inorganic mercury compounds as not classifiable as to their carcinogenicity to humans (Group 3).

20 Reproduction toxicity

Methylmercury is the best-documented example of a metal compound that disrupts normal development. There is a difference in the response of adult and developing tissues. Methyl mercury crosses the human placenta to the fetus. Methylmercury effects the development of the brain in humans and animals. Observed symptoms in humans exposed *in utero* include mental retardation, cerebral palsy, deafness, blindness, and dysarthria. Chronic, low-dose prenatal methylmercury exposure from maternal consumption of fish has been associated with more subtle endpoints of neurotoxicity in children. These effects included poor performance on neurobehavioural tests, fine motor function, language, visual-spatial abilities, and verbal memory (Apostoli *et al*., 2007; NRC, 2000).

21 Non observed adverse effect level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

The developing brain is the most sensitive target organ for methylmercury toxicity and *in utero* exposure is considered to be the critical period for methylmercury neurodevelopment toxicity (EFSA, 2004; NRC, 2000). NRC and JECFA established provisional tolerable weekly intakes (PTWI) for mercury based on three large epidemiological studies on brain development following long-term exposure to small amounts of methylmercury. NRC (2000) identified a NOAEL value of 12 µg mercury/kg maternal hair and adopted a combined uncertainty factor of 10 to derive a PTWI value of 0.7 µg/(kg bw.week). JECFA identified a NOAEL value of 14 mg/kg for concentrations of mercury in maternal hair which was calculated to arise from a daily intake of methylmercury of 1.5 µg/kg bw. Subsequently, a total uncertainty factor was applied of 6.4 and a PTWI value of 1.6 µg/(kg bw.day) was set. Additionally, it was stated that in the case of adults, intakes of up to about two times higher than the PTWI of 1.6 µg/(kg bw.week) would not pose any risk of neurotoxicity, although in the case women of childbearing age, it should be borne in mind that intake should not exceed the PTWI (WHO, 2007). ATSDR (1999) established oral minimal risk levels for mercury (Table 6).

Table 6 Oral exposure minimal risk levels (MRL) for mercury (ATSDR, 1999)

Compound	**Duration of oral exposure**	**MRL (mg Hg/(kg bw.day))**
Inorganic mercury	Acute, < 14 days	0.007
Inorganic mercury	Intermediate, 15 – 364 days	0.002
Methylmercury	Chronic, > 365 days	0.0003

23 Toxicological risks for user/workers

Inhalation exposure is the most common route of inorganic mercury uptake by humans. Metallic mercury is highly lipophilic, and absorption of the inhaled vapour, followed by rapid diffusion across the alveolar membranes of the lungs into the blood, has been reported to be substantial. There is indirect evidence indicating that organic mercury can be readily absorbed through the lungs (ATSDR, 1999). The toxic properties of mercury vapour are due to mercury accumulation in the brain causing neurobiological signs, involving an unspecific psychoasthenic and vegetative syndrome (micromercurialism). At high exposure levels, mercurial tremor is seen accompanied by severe behavioural and personality changes, increased excitability, loss of memory, and insomnia (Berlin *et al*., 2007). ATSDR (1999) established a minimal risk level for chronic duration (≥ 365 d) inhalation exposure to metallic mercury vapour of 0.0002 mg/m^3.

24 Toxicological risks for the environment

The implementation of the actual EU legislation, fixing maximum mercury levels in feedingstuffs, limits the contribution of mercury originating from animal excreta to the environment.

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Annex 1: Mercury concentrations in edible tissues and products

Table 1.1 Mercury concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pork	5	0.0188 - 0.237			Bordajandi *et al*. (2004)
Pork		< 0.007	< 0.007	0.008	Larsen *et al*. (2002) [a]
Pigs (6 m)	62	0.001	0.001	0.002	López-Alonso *et al*. (2007)

[a]: Total diet study

Table 1.2 Mercury concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Cattle	118	< 0.002 - 0.0058				Blanco-Penedo *et al.* (2010)
Beef		< 0.007	< 0.007	< 0.007		Larsen *et al*. (2002)[a]
Calf		< 0.007	< 0.007	< 0.007		
Lamb		< 0.007				
Dairy cattle	16				0.003	Leblanc *et al*. (2005)[a]
Calves	312	0.000475	0.00167	0.0081		Miranda *et al*. (2003)
Dairy cattle					0.0004	Ysart *et al*. (2000) [a]

[a]: Total diet study

Table 1.3 Mercury concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken and eggs		0.0199 - 0.0276	0.0035		0.0568	Bordajandi *et al*. (2004)
Chicken		< 0.007	< 0.007			Larsen *et al*. (2002)[a]
Turkey		< 0.007	< 0.007			
Poultry		0.005 [b]			0.004 [c]	Leblanc *et al*. (2005)[a]
Hens, private owners	22				0.00205	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.00051	
Hens, eggs collected in autumn	40				0.00315	Waegeneers *et al*. (2008)
Hens, eggs collected in spring	58				0.00444	
Poultry and eggs		0.002			0.0013	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Mercury concentrations in edible tissues (mg/kg) of fish

Species - category	**n**	**Muscle**	**Reference**
Pacific cod	140	0.17	Burger *et al*. (2007)
Halibut	8	0.290	Knowles *et al*. (2003)
Hoki	2	0.186	
Monkfish	2	0.198	
Orange roughy	6	0.595	
Pollack	4	0.012	
Salmon	14	0.050	
Sea bass	4	0.065	
Sea bream	4	0.053	
Shark	5	1.521	
Bill fish	20	1.340	
Trout	14	0.060	
Tuna	20	0.401	
Lobster	4	0.075	
Prawns	14	0.048	
Mussels	4	0.030	
Fish	62	0.062	Leblanc *et al*. (2005) [a]
Shellfish	18	0.017	

[a]: Total diet study

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Annex 2: Mercury concentrations in edible tissues and products linked with the dietary intake of several mercury compounds and doses

Table 1 Mercury concentrations in edible tissues and products (mg/kg)

Species / category	Source of Hg supplemented	Dose of Hg supplemented (mg Hg/kg)	Hg content of complete feed (mg Hg/kg)	Duration of study	Liver	Kidney	Muscle [1]	Eggs	Reference
Chicks		< LOD		56 d	0.56 DM	0.66 DM	0.42 DM		March *et al*. (1983)
	Methyl mercuric chloride	0.05			1.51 DM	1.64 DM	0.69 DM		
		0.15			2.68 DM	2.84 DM	1.15 DM		
		0.45			5.12 DM	5.14 DM	2.74 DM		
		1.35			8.51 DM	7.14 DM	5.47 DM		

[1]: Pectoral muscle

Table 1 (continued) Mercury concentrations in edible tissues and products (mg/kg)

Species / category	Source of Hg supplemented	Dose of Hg supplemented (mg Hg/kg)	Hg content of complete feed [1] (mg Hg/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Cattle			< 0.02 DM	106 d	< 0.01 DM	0.09 DM	< 0.01 DM		Johnson *et al*. (1981)
	Sewage sludge		2.6 DM		0.27 DM **	2.04 DM **	0.02 DM *		
Fattening Lambs	Control group, pasture		< 0.02 DM [2]	14 w	0.014	0.178	0.001		van der Veen & Vreman (1986)
	Mercury acetate, pasture		0.08 DM [2]		0.013	0.143	0.003		
	Control group, indoors		< 0.02 DM [2]		0.016	0.238	0.002		
	Mercury acetate, indoors		0.14 DM [2]		0.028	0.36	0.001		
	Harbour sludge, indoors		0.27 DM [2]		0.037	0.265	0.001		
	Sewage sludge, indoors		0.17 DM [2]		0.034	0.254	0.001		

1: Data from feed analysis; [2]: element concentrations in whole ration

Statistics:

Johnson *et al*. (1981): **: means within a column differ significantly at $P < 0.01$; *: means within a column differ significantly at $P < 0.05$.

Table 1 (continued) Mercury concentrations in edible tissues and products (mg/kg)

Species / category	**Source of Hg supplemented**	**Hg Intake (mg Hg/(cow.day))**	**Duration of study**	**Liver**	**Kidney**	**Muscle**	**Milk**	**Reference**
Dairy Cattle, grazing		0.2	3 m	0.007	0.009	0.003	0.0023	Vreman *et al* . (1986)
	Mercury acetate	1.7		0.010	0.024	0.004	0.0009	
Dairy cattle, indoors		0.2		0.003	0.005	0.002	< 0.0005	
	Mercury acetate	1.7		0.026	0.079	0.002	0.0006	
	Harbour sludge	3.1		0.014	0.050	0.001	0.0024	
	Sewage sludge	1.2		0.009	0.027	0.002	0.0013	

Table 1 (continued) Mercury concentrations in edible tissues and products (mg/kg)

Species / category	**Hg^{2+} concentration in aquaria (µg/L)**	**Duration of study**	**Liver**	**Kidney**	**Muscle**	**Reference**
Catfish, *Ictalurus melas*	0.0	10 d	0.15 [b]	0.14 [b]	0.09 [b]	Elia *et al* . (2003)
	35		6.42 [a]	11.78 [a]	0.74 [a]	
	70		4.82 [a]	9.82 [a]	0.61 [a]	
	140		8.06 [a]	17.82 [a]	0.80 [a]	
Matrinxa [1]	0	4 d	< 0.05		< 0.05	Monteiro *et al* . (2010)
	110		10.46 *		0.63 *	

[1]: Fresh water fish, *Brycon amazonicus*

Statistics:

Elia *et al* . (2003):Superscripts indicate treatments to differ significantly from controls at $P< 0.05$

Monteiro *et al* . (2010): *: means differ significantly from control at $P< 0.05$

Table 1 (continued) Mercury concentrations in edible tissues and products (mg/kg)

Species / category	**Source of Hg supplemented**	**Hg concentration in aquaria (µg/L)**	**Duration of study**	**Muscle**	**Reference**
Rainbow trout			60 d	0.033	Niimi & Kissoon (1994)
	$HgCl_2$	64		6.2	
	MeHgCl	4		31	

Annex 2: References

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Molybdenum

Executive summary of the monograph for molybdenum

The molybdenum compounds, ammonium molybdate and sodium molybdate, are presently authorized in the EU as food and feed additives. Molybdenum is an essential element which has been identified as a component of three mammalian enzymes: xanthine dehydrogenase, aldehyde oxidase and sulphite oxidase. Molybdenum requirements of livestock are low easily met by feeding practical diets. Induced molybdenum deficiency has been studied in chickens and goats. The deficiency symptoms included growth retardation, anaemia, reproductive failure. Ruminant species are less tolerant for excess dietary molybdenum compared to non ruminant species. This higher susceptibility originates from the formation of thiomolybdates in the rumen. Maximum tolerable levels established by NRC vary between 5 mg Mo/kg DM for ruminant livestock and 100 - 150 mg Mo/kg DM for poultry and swine. The clinical signs of molybdenosis are essentially these of secondary copper deficiency manifested by diarrhoea, anorexia, depigmentation of hair or wool, anaemia, neurologic disturbances, impaired reproduction and premature death. Hexavalent molybdenum is readily absorbed from the duodenum and the proximal jejunum. Absorption of water soluble molybdates, thiomolybdates, oxothiomolybdates and molybdenum in herbage and green vegetables was shown to range between 75 – 97 % in laboratory animals and ruminants. Contrarily, insoluble MoS_2 is not absorbed and tetravalent molybdenum compounds are not readily absorbed. Molybdenum is excreted primarily through urine. It has been demonstrated for various molybdenum compounds and in several livestock species that molybdenum concentrations in muscle, liver, kidney, eggs and milk can be significantly increased through dietary molybdenum supplementation (Annex 2). There is limited information on the genotoxicity of molybdenum and the results of the available studies are conflicting. There are no relevant studies available on the carcinogenicity of molybdenum in animals or humans. Generally, the toxicity of molybdenum compounds in humans appears to be low. Reproductive and developmental effects of excess dietary molybdenum were demonstrated in ewes, mice and rats. SCF and IOM identified reproduction and foetal development as the most sensitive toxicological endpoint. An UL of 0.6 mg/day and 2 mg/day for adults was established by SCF and IOM, respectively. No indications have been reported on environmental consequences related to the presence of molybdenum in livestock diets.

Molybdenum monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Molybdenum exists in several valency states, e.g., $Mo^{II}O$, $Mo^{IV}S_2$, $Mo^{VI}O_3$, and as the stable $(NH_4)_2Mo^{VI}O_4$ (ammonium molybdate), $(NH_4)_6Mo^{VI}_7\ O_{24}.4H_2O$ (ammonium molybdate tetrahydrate) and $Na_2Mo^{VI}O_4.2H_2O$ (sodium molybdate dehydrate). In plant feeds molybdenum exists as water soluble sodium and ammonium salts and water insoluble molybdenum oxide, calcium molybdate, and molybdenum sulphide. Animal tissues and milk usually contain low levels of molybdenum mainly as molybdopterin (NRC, 2005). Ammonium molybdate and sodium molybdate are molybdenum compounds presently authorized as feed and food additives in the EU.

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Molybdenum compounds presently authorized in the EU as additives (Council Directive 70/524/EEC[1]) are listed in Table 1.

Table 1 Conditions of use of molybdenum compounds as additives in feedingstuffs according to the Council Directive 70/524/EEC[1]

Additive	**Chemical formula**	**Maximum content of the element in the complete feedingstuff (mg/kg)**
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.4H_2O$	2.5 (total)
Sodium molybdate	$Na_2MoO_4.2H_2O$	

In the US, sodium molybdate is allowed in animal feeds (AAFCO Official Publication §57: Mineral Products) (AAFCO, 2010).

2.2 Human nutrition

Molybdenum compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Commission Regulation 953/2009[2]. The authorized molybdenum (VI) compounds are: ammonium molybdate, sodium molybdate.

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[1] OJ C 50, 25.2.2004, p. 1.

[2] OJ L 269, 14.10.2009, p. 9.

- As food supplements under Regulation 1170/2009[3]. The authorized molybdenum compounds are: ammonium molybdate (molybdenum (VI)), sodium molybdate (molybdenum (VI)), potassium molybdate (molybdenum (VI)).

- As substances which may be added to foods under Regulation 1925/2006[4] as amended by Regulation 1170/2009[3]. The authorized molybdenum compounds are: ammonium molybdate (molybdenum (VI)), sodium molybdate (molybdenum (VI)).

- Directive 2008/100/EC[5] lays down a Recommended Daily Allowance (RDA) for molybdenum of 50 µg.

3 Essential functions

Molybdenum is an essential element (SCF, 2000; NRC, 2005). It has been identified as a component of six enzymes including three mammalian enzymes namely, xanthine dehydrogenase, aldehyde oxidase and sulphite oxidase. All known molybdenum metalloenzymes, with the exception of nitrogenase (a plant enzyme), use molybdenum in the form of the molybdenum cofactor, a complex of molybdenum and the organic component molybdopterin (McDowell, 2003; SCF, 2000; Turnlund & Friberg, 2007). Xanthine dehydrogenase converts tissue purines, pyrimidines, pteridins, and pyridins by oxidative hydroxylation to uric acid as an irreversible process. Its normal action is that of a dehydrogenase, but when reacting with oxygen during proteolysis, freezing/thawing, or in the presence of reactive -SH reagents it changes to into xanthine oxidase. Xanthine oxidase produces free oxygen radicals known to be involved in tissue damage following physical injury, reperfusion, injury by toxins or molybdenum excess. Avian xanthine dehydrogenase is stable, hence birds excrete uric acid (SCF, 2000). Aldehyde oxidase is structurally and chemically similar to xanthine oxidase, has a similar tissue distribution and shares some substrates with xanthine oxidase, e.g., aldehydes, substituted pyridines, pyrimidines, quinolines, and purine derivatives (SCF, 2000). Sulphite oxidase is a heam containing molybdoprotein located in the intermembraneous space of mitochondria. Sulphite oxidase converts sulphite to sulphate (SCF, 2000).

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[3] OJ L 314, 1.12.2009, p. 36.

[4] OJ L 404, 30.12.2006, p. 26.

[5] OJ L 285, 29.10.2008, p. 9.

4 Other functions

There was no information available on other functions of molybdenum in principal literature sources.

5 Antimicrobial properties

There was no information available on antimicrobial properties of molybdenum in principal literature sources.

6 Typical deficiency symptoms

The molybdenum requirements in livestock are easily met by feeding practical diets. Molybdenum deficiency can be induced under experimental conditions (NRC, 2005). In chickens molybdenum deficiency has been observed to cause growth retardation, anaemia, lower tissue molybdenum values and a reduced capacity to convert xanthine to uric acid. Growth retardation, reduced appetite, reproductive failure have been observed in molybdenum deficient goats. Molybdenum deficiency through pregnancy and lactation led to increased mortality or poor growth in subsequent generations in goats (Underwood & Suttle, 1999).

7 Animal requirements, allowances and use levels

A requirement of 0.1 mg/kg DM for beef cattle was set by GfE (1995). NRC (2001) considered it very unlikely that dairy cattle, when fed practical diets, would develop molybdenum deficiency. Hence, it was suggested not to supplement molybdenum. For sheep and goats NRC (2007) issued no requirements but general recommendations of 0.5 mg/kg DM for sheep and 0.1 to 1 mg/kg DM for goats.

8 Concentration of the element in feed materials

Molybdenum concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Molybdenum concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Cattle are the least tolerant species for molybdenum, followed closely by sheep, while pigs are the most tolerant of domestic livestock. The differences between ruminants and non-ruminants are probably explained by the ease with which thiomolybdates, i.e., powerful antagonists of copper metabolism, are generated in the rumen and then exert harmful effects on the intestinal mucosa (Underwood & Suttle, 1999). Differences between non ruminant species are harder to explain, but they may also involve antagonisms of copper metabolism. Molybdenum is more toxic when given to a non-ruminant of low than of high copper status (Underwood & Suttle, 1999). MTL values established by NRC (2005) are compiled in Table 2.

Table 2 Maximum Tolerable Levels (MTL) (mg/kg DM) of molybdenum (NRC, 2005)

Species	**MTL**	**Additional remarks**
Swine	150	Value was derived from interspecies extrapolation
Poultry	100	
Fish	10	
Rodents	7	
Cattle, sheep	5	
Horses	5	Value was derived from interspecies extrapolation

11 Typical symptoms of toxicosis

There is considerable variability in the toxicity of molybdenum, depending on the chemical form and the animal species. Clinical manifestations of excessive dietary molybdenum intake include weight loss and anorexia. In ruminants molybdenum toxicosis is known as molybdenosis, teart or peat scours (NRC, 2005; Underwood & Suttle, 1999). Effects in cattle comprise scouring, weight loss, difficulty with conceiving, lacking libido, testicular damage and little spermatogenesis in bulls. In sheep diarrhea, joint abnormalities, lameness, osteoporosis and spontaneous bone fractures have been observed. Ruminants subjected to less excessive dietary molybdenum present symptoms that are generally indistinguishable from those caused by copper deprivation and are attributable to molybdenum induced copper deficiency (Underwood & Suttle, 1999). The formation of trithiomolybdates by ruminants seems to be primarily responsible for the biochemical pathogenesis leading to the symptoms of molybdenosis. Trithiomolybdates and tetrathiomolybdates have powerful effects on copper metabolism. These effects seem to be explained by alterations in the affinity of ligands, such as albumin, for copper. Hence, changes in copper distribution lead to copper depletion (Turnlund & Friberg, 2007).

12 Bioavailability

12.1 General

The rate of gastrointestinal absorption of molybdenum depends on its valence and on the animal species. Hexavalent molybdenum is readily absorbed from the duodenum and the proximal jejunum (SCF, 2000). Absorption of water soluble molybdates, thiomolybdates, oxothiomolybdates and molybdenum in herbage and green vegetables was shown to range between 75 – 97 % in laboratory animals and ruminants. Contrarily, insoluble MoS_2 is not absorbed and tetravalent molybdenum compounds are not readily absorbed (SCF, 2000). In humans, absorption determined by use of stable isotopes as tracers was reported to range from 88 – 93 % with dietary intakes of 22 – 1400 µg/day (Turnlund & Friberg, 2007). Intestinal absorption is inhibited by high intraluminal sulphate concentrations, probably because of competition for the common carrier. Silicates also inhibit the absorption of dietary molybdates (SCF, 2000).

Jongbloed *et al*. (2002) concluded that there were no studies available for the evaluation of the bioavailability of various molybdenum compounds in pigs and poultry. For ruminants based on the results of Pott *et al*. (1999) the following values for relative biological value of molybdenum compounds compared to sodium molybdate were calculated: 114 % for ammonium molybdate, 121 % for molybdenum trioxide and 60 % for molybdenum metal (Jongbloed *et al*. 2002).

12.2 *Indicators of molybdenum status*

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of molybdenum compounds in ruminants (Table 3).

Table 3 Ranking of adequacy of response criterions for assessing the relative biological value of molybdenum compounds in ruminants [1] (Jongbloed *et al*., 2002)

Supplementation level →	**Suboptimal**	**Above requirement**
Criterion		
Mo true absorption	5	5
Mo apparent absorption	4	4
Mo tissue accumulation	3	3
Performance	2	2
Mo retention	2	2

[1]: the highest values correspond to the best adequacy

A biochemical marker for molybdenum status has not yet been identified. Insights about markers for defining optimal molybdenum nutriture are provided by studies with animals and human subjects with inherited disorders in the synthesis of the molybdenum cofactor. Decreased urinary levels of sulphate and uric acid in conjunction with elevated levels of sulphite, hypoxanthine, xanthine and other sulphur metabolites are indicative of impaired activities for the molybdo-enzymes (Failla, 1999).

Urinary excretion and blood plasma concentrations reflect recent dietary intake but do not necessarily reflect molybdenum status (Turnlund & Friberg, 2007).

13 Metabolism

Hexavalent molybdenum is readily absorbed from the duodenum and the proximal jejunum (SCF, 2000). In the blood, molybdenum is bound in the form of molybdate, specifically to α_2-macroglobulin, and in erythrocytes to proteins of the erythrocyte membrane (Turnlund & Friberg, 2007). Molybdenum is primarily excreted through urine. Molybdenum excreted via the faeces is partly unabsorbed molybdenum and partly endogenous secreted molybdenum through the bile (Turnlund & Friberg, 2007).

14 Distribution in the animal body

Molybdenum was reported to accumulate in the kidneys, liver and bone in rats, guinea pigs, cows and goats (Turnlund and Friberg, 2007).

15 Deposition (typical concentration) in edible tissues and products

A compilation of molybdenum concentrations in edible tissues and products is given in Annex 1. Molybdenum concentrations in edible tissues and products linked with the dietary intake of various molybdenum compounds and doses is given in Annex 2.

16 Acute toxicity

Signs of acute molybdenosis include gastrointestinal irritation, diarrhea, coma and death from cardiac failure. Injuries in the liver, kidney, adrenals and spleen may also occur in intoxicated animals (NRC, 2005). Oral LD_{50} values are given in Table 4.

Table 4 Oral LD_{50} and LD_{100} values (mg Mo/kg bw) for various molybdenum compounds (NRC, 2005)

Molybdenum compound	**Species**	**LD_{50}**
Molybdenum trioxide	Rats	125
Ammonium molybdate	Rats	370
		LD_{100}
Ammonium molybdate	Guinea pigs	1200
Ammonium molybdate	Rabbits	1020
Ammonium molybdate	Cats	1310

17 Genotoxicity and Mutagenicity

SCF (2000) and BfR (2006) selected two studies that investigated the genotoxicity of molybdenum compounds. $(NH_4)_6Mo_7O_{24}$ was mutagenic in two of three *E. coli* strains. $MoCl_5$ was negative and $(NH_4)_6Mo_7O_{24}$ was positive in the *Bacillus subtilis rec*-assay using strains H17 (repair competent) and M45 (repair deficient). Ammonium and sodium molybdate were neither mutagenic nor recombinogenic in *Saccharomyces cereviseae* reverse mutation and gene conversion assays (BfR, 2006; SCF, 2000). Ammonium molybdate and sodium molybdate were shown to increase the incidence of micronucleated cells in cytokinesis blocked cultured human lymphocytes of a female and male donor. The largest effect was elicited by ammonium molybdate (EFSA, 2009). EFSA (2009) concluded that the available information on the genotoxicity of molybdates is conflicting.

18 Subchronic toxicity

There are no data available on subchronic toxicity of molybdenum compounds in principal literature sources.

19 Chronic toxicity, including carcinogenicity

Molybdenum compounds appear to have low toxicity in humans. Hyperuricemia and arthralgias have been observed in Armenians who consumed 10 to 15 mg Mo/day from food. Increased molybdenum serum concentrations, increased serum uric acid concentrations and decreased serum copper concentrations have been observed in humans exposed to high dietary molybdenum but these effects were not consistent between studies (IOM, 2001).

SCF (2000), IOM (2001), BfR (2006) and EFSA (2009) found no relevant studies on the carcinogenicity of molybdenum in animals or humans. Intraperitoneal administration to strain A mice of MoO_3 was reported to significantly increase the incidence of lung adenomas (SCF, 2000; BfR, 2006).

20 Reproduction toxicity

Studies investigating reproductive and developmental effects of oral molybdenum exposure were summarized by SCF (2000) (Table 5).

Table 5 Reproductive and developmental effects of oral molybdenum exposure (SCF, 2000 [a])

Species	Molybdenum compound	Dose	Duration	Reproductive or developmental effect
Ewes	Ammonium molybdate	50 mg Mo/day		Lambs showed ataxia, cortical degeneration, demyelination of the cortex and spinal cord
Mice	Molybdate	1.5 mg Mo/(kg bw.day)	6 m	Excess pup deaths, infertility
Rats		14 mg Mo/(kg bw.day)	13 w	Depressed male fertility, degeneration of seminiferous tubules
Rats	Sodium molybdate	1.6 mg Mo/(kg bw.day)	9 w	Prolonged oestrus cycle, reduced gestational weight, litter size, foetal weights and increased foetal resorption

[a]: References herein; m: months; w: weeks

21 Non observed effect level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels for molybdenum are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

SCF (2000) and IOM (2001) selected a study on reproductive toxicity of molybdenum in rats to establish an UL. This study was chosen taking into account it provides a clear dose-response relationship and the number of test animals was adequate. Furthermore, reproduction and fetal development were found to be the most sensitive toxicological endpoints (IOM, 2001). The strategies adopted by SCF (2000) and IOM (2001) to establish an UL for molybdenum are given in Table 6. UL values for molybdenum for several live stage groups are given in Table 6.

Table 6 Non Observed Adverse Effect Level (NOAEL), Uncertainty Factors (UF) and Upper Intake Levels (UL) of molybdenum chosen and established by SCF (2000) and IOM (2001)

SCF (2000)		
Toxicological endpoint: reproductive and developmental toxicity		
Species: Rats		
NOAEL = 0.9 mg/(kg bw.day)	UF_{TOTAL} = 100 UF = 10: protection of sensitive human subpopulations; UF = 10 :extrapolation from experimental animals to humans	UL = 0.6 mg/day Adults; pregnant and lactating women
IOM (2001)		
Toxicological endpoint: reproductive and developmental toxicity		
Species: Rats		
NOAEL = 0.9 mg/(kg bw.day)	UF_{TOTAL} = 30 UF = 3 : intraspecies variation UF = 10 : extrapolation from experimental animals to humans	UL = 2 mg/day; Adults

Table 7 Upper Intake Levels (UL) (mg/day) for several life stage groups of molybdenum (IOM, 2001; SCF, 2000)

	UL (IOM, 2001)		UL (SCF, 2000)
1 - 3 years	0.3	1 - 3 years	0.1
4 - 8 years	0.6	4 - 6 years	0.2
9 - 13 years	1.1	7 - 10 years	0.25
		11 - 14 years	0.4
14 - 18 years	1.7	15 - 17 years	0.5
Adults	2.0	Adults	0.6
Pregnancy: 14 - 18 years	1.7		
Pregnancy: 19 - 50 years	2.0		
Lactation: 14 - 18 years	1.7		
Lactation: 19 - 50 years	2.0		

EVM (2003) considered the combined available data from human and animal studies insufficient to establish an UL for molybdenum. BfR (2006) adopted the UL values established by SCF (2000).

23 Toxicological risks for user/workers

There are no human data on absorption of molybdenum after inhalation. Hexavalent molybdenum compounds were reported to be absorbed to an appreciable extent. Molybdenum disulphide was shown not to be absorbed after inhalation exposure to 285mg Mo/m^3 in guinea pigs (Turnlund & Friberg, 2007).

24 Toxicological risks for the environment

No relevant information was found in principal literature sources on environmental consequences of the use of molybdenum as a feed supplement.

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Annex 1 Molybdenum concentrations in edible tissues and products

Table 1.1 Molybdenum concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pork		Neck steak: 0.02 Chop: 0.013 Loin: 0.011			Gerber *et al*. (2009)
Pigs (6 m)	62	0.140	1.62	0.683	López-Alonso *et al*. (2007)

Table 1.2 Molybdenum concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Dairy cattle	48				0.022	Anderson (1992)
Calves (6 - 12 m)	195		1.39	0.537		Blanco-Penedo *et al.* (2006) [b]
Lamb		Chop: 0.011 Loin: 0.011				Gerber *et al*. (2009)
Beef cattle		Sirloin: 0.009 - 0.014 Rib-eye: 0.014 - 0.015 Braising steak: 0.011				
Dairy cattle	16				0.039	Leblanc *et al*. (2005)[a]

[a]: Total diet study; [b]: calves grazing on pastures fertilized with pig slurry

Table 1.3 Molybdenum concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken		Breast: 0.024 - 0.032 Leg: 0.028				Gerber *et al*. (2009)
Poultry		0.166 [b]			0.067 [c]	Leblanc *et al*. (2005)[a]
Hens, private owners	22				0.0264	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.0495	

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Molybdenum concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentarchus labrax*)	3	0.70 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentarchus labrax*)	3	0.59 DM	
Fish	62	0.065	Leblanc *et al*. (2005) [a]
Shellfish	18	0.129	

[a]: Total diet study

Table 1.5 Molybdenum concentrations in honey (mg/kg)

Description	n	Honey	Reference
Origin: Holzing (AU)	23	0.0050	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.0049	
Origin: Hollabrunn (AU)	19	0.0046	

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Annex 2: Molybdenum concentrations in edible tissues and products linked with the dietary intake of various molybdenum compounds and doses

Table 1 Molybdenum concentrations in edible tissues and products (mg/kg)

Species / category	Source of Mo supplemented	Dose of Mo supplemented (mg Mo/kg)	Mo content of complete feed[1] (mg Mo/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Dairy cattle				180 d	3.6 DM	1.7 DM	0.5 DM	0.03	Huber *et al* . (1971)
	Sodium molybdate		53		10.4 DM	42.3 DM	6.4 DM	1.03	
	Sodium molybdate		173		32.4 DM	62.6 DM	14.0 DM	1.83	
Sheep (wethers)			0.4 DM	221 d	1.28 DM	1.62 DM			Ivan & Veira (1985)
	Ammonium molybdate		8.4 DM		2.57 DM	7.87 DM			
Lambs			1.2 DM	28 d	6.31 DM	2.84 DM	0.08 DM		Pott *et al* . (1999)
	Sodium molybdate	15			5.97 DM	3.62 DM	0.24 DM		
	Sodium molybdate	30			11.85 DM	9.01 DM	0.30 DM		
	Sodium molybdate	45			10.60 DM	14.39 DM	0.57 DM		
Lambs			1.1 DM	28 d	3.34 DM	1.64 DM	0.11 DM		Pott *et al.* (1999 b)
	Sodium molybdate	15			6 DM	2.8 DM	0.28 DM		
	Sodium molybdate	30			7.52 DM	4.3 DM	0.44 DM		
	Sodium molybdate	45			7.77 DM	10.64 DM	0.67 DM		
	Ammonium molybdate	30			8.38 DM	6.05 DM	0.49 DM		
	Molybdenum trioxide	30			9.24 DM	6.90 DM	0.56 DM		
	Molybdenum metal	30			5.51 DM	1.7 DM	0.27 DM		

[1]: Data from feed analysis;

Statistics: Ivan & Veira (1985): Liver and kidney Mo concentrations are differ significantly between diets ($P < 0.01$);

Pott *el al* . (1999): Mo concentrations in liver, kidney and muscle differ ($P < 0.0001$), Anova.

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Annex 4. Molybdenum concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	
Potato prot ASH>10	
Potato starch dried	
Potato sta heat tr	
Potato pulp CP<95	
Potato pulp CP>95	
Potatoes sweet dried	
Bone meal	
Brewers' grains dr	
Brewers' yeast dried	1.1
Sugarb pulp SUG<100	0.4
Sugarb p SUG100-150	0.3
Sugarb p SUG150-200	
Sugarb pulp SUG>200	
Biscuits CFAT<120	
Biscuits CFAT>120	
Blood meal spray dr	
Buckwheat	
Beans phas heat tr	
Bread meal	
Casein	
Chicory pulp dried	0.8
Citrus pulp dried	
Meat meal Dutch	
Meat meal CFAT<100	0.6
Meat meal CFAT>100	
Peas	3
Barley	0.2
Barley feed h grade	
Barley mill byprod	
Grass meal CP<140	2.2
Grass meal CP140-160	2.2
Grass meal CP160-200	2.2
Grass meal CP>200	2.2
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	2.1
Peanut exp p with sh	
Peanut exp with sh	
Peanut extr wtht sh	
Peanut extr with sh	
Oats grain	0.7
Oats grain peeled	0.2
Oats husk meal	
Oats mill fd h grade	
Hempseed	
Carob	

INRA	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	0.44	
Maize	0.41	
Oats	0.83	
Oats groats	0.19	
Rice, brown	0.75	
Rye	0.55	
Sorghum	1	
Triticale	0.44	
Wheat, durum		
Wheat, soft	0.46	
WHEAT BY-PRODUCTS		
Wheat bran	1.4	
Wheat middlings	2	
Wheat shorts	0.07	
Wheat feed flour		
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%		
Wheat gluten feed, starch 28%		
MAIZE BY-PRODUCTS		
Corn distillers	1.7	
Corn gluten feed	1.6	
Corn gluten meal	0.82	
Maize bran		
Maize feed flour		
Maize germ meal, expeller		
Maize germ meal, solvent extracted		
Hominy feed	1.1	
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	1.1	
Brewers' dried grains	1.3	
Rice bran, extracted		
Rice bran, full fat	1.6	
Rice, broken	0.08	
LEGUME AND OIL SEEDS		
Chickpea		
Cottonseed, full fat	1.5	
Faba bean, coloured flowers	0.63	
Faba bean, white flowers	0.63	
Linseed, full fat	0.2	
Lupin, blue	2	
Lupin, white	2	
Pea	2	
Rapeseed, full fat		
Soybean, full fat, extruded	4	
Soybean, full fat, toasted	4	
Sunflower seed, full fat	1.7	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	
Cottons exp p with h	
Cottons exp with h	
Cottons extr wtht h	
Cotts extr p with h	
Cottons extr with h	
Coconut exp CFAT<100	
Coconut exp CFAT>100	
Coconut extr	0.6
Linseed	0.2
Linseed exp	0.5
Linseed extr	0.7
Lentils	
Lupins CP<335	
Lupins CP>335	
Alf meal CP<140	
Alf meal CP140-160	
Alf meal CP160-180	0.5
Alf meal CP>180	
Poppyseed	
Macoya fruit exp	
Maize	0.3
Maize chem-h treated	0.3
Maize gluten meal	0.6
Maize glfeed CP<200	
Maize glfd CP200-230	
Maize glfeed CP>230	
Maize germ meal extr	
Maize germ m fd exp	
Maize germ m fd extr	
Dist grains and sol	
Maize feedflour	
Maize feed meal	
Maize feed meal extr	
Maize bran	
Maize starch	
Sugarbeet molasses	0.2
Sugarc mol SUG<475	
Sugarc mol SUG>475	
Milk powder skimmed	
Milk powder whole	
Millet	

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	0.61	
Cottonseed meal, crude fibre 7-14%	0.8	
Cottonseed meal, crude fibre 14-20%	3	
Grapeseed oil meal, solvent extracted		
Groundnut meal, detoxified, crude fibre < 9%	1.7	
Groundnut meal, detoxified, crude fibre > 9%	2	
Linseed meal, expeller	0.52	
Linseed meal, solvent extracted	1	
Palm kernel meal, expeller	0.4	
Rapeseed meal	1.6	
Sesame meal, expeller	1.9	0.1
Soybean meal, 46		
Soybean meal, 48	4	
Soybean meal, 50	3	
Sunflower meal, partially decorticated	1.6	
Sunflower meal, undecorticated	0.7	
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	0.05	
Cassava, starch 72%		
Maize starch		
Potato tuber, dried	1.2	
Sweet potato, dried		
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	0.67	
Beet pulp dried, molasses added	0.29	
Beet pulp, pressed		
Brewers' yeast, dried	1.1	
Buckwheat hulls		
Carob pod meal		
Citrus pulp, dried	0.19	
Cocoa hulls		
Grape marc, dried		
Grape seeds		
Liquid potato feed		
Molasses, beet	0.26	
Molasses, sugarcane	1.3	
Potato protein concentrate		
Potato pulp, dried		
Soybean hulls	1.2	
Vinasse, different origins		
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production		
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	
Malt culms CP>200	
Nigerseed	
Horsebeans	0.4
Horsebeans white	0.4
Palm kernels	
Palm kern exp CF<180	0.5
Palm kern exp CF>180	0.5
Palm kernel extr	
Rapeseed	
Rapeseed exp	1.1
Rapeseed extr CP<380	0.8
Rapeseed extr CP>380	
Rapes meal Mervobest	0.8
Rice wtht hulls	
Rice with hulls	
Rice husk meal	
Rice bran meal extr	
Rice feed m ASH<90	
Rice feed m ASH>90	
Rye	1.1
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	
Semameseed meal extr	2.8
Soybeans heat tr	
Soybeans not heat tr	
Soybean hulls CF<320	
Soyb hulls CF320-360	
Soybean hulls CF>360	
Soybean exp	
Soybm CF<45 CP<480	3.8
Soybm CF<45 CP>480	3.8
Soybm CF45-70 CP<450	3.9
Soybm CF45-70 CP>450	3.9
Soyb meal CF>70	3.8
Soyb meal Mervobest	3.8
Soyb meal Rumi S	3.5
Sorghum	
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	
Tapioca STA 625-675	
Tapioca STA 675-725	
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	1.4	
Alfalfa, dehydrated, protein 17-18% dry matter	1.4	
Alfalfa, dehydrated, protein 18-19% dry matter	1.4	
Alfalfa, dehydrated, protein 22-25% dry matter	1.4	
Grass, dehydrated	2	
Wheat straw	1.2	
DAIRY PRODUCTS		
Milk powder, skimmed	0.24	
Milk powder, whole	0.4	
Whey powder, acidic	5	
Whey powder, sweet	5	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	0.1	
Fish meal, protein 65%	0.21	
Fish meal, protein 70%	0.18	
Fish solubles, condensed, defatted		
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	0.21	
Feather meal	0.9	
Meat and bone meal, fat <7.5%	1	
Meat and bone meal, fat >7.5%	1	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	1.1
Wheat gluten meal	
Wheat glutenfeed	
Wheat middlings	0.7
Wheat germ	
Wheat germfeed	
Wheat feedfl CF<35	
Wheat feedfl CF35-55	
Wheat feed meal	
Wheat bran	0.6
Triticale	0.4
Feather meal hydr	
Fat from Animals	
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	
Vinasse Sugb CP>250	
Fish meal CP<580	
Fish meal CP580-630	
Fish meal CP630-680	
Fish meal CP>680	
Meat bone m CFAT<100	
Meat bone m CFAT>100	
Whey p l lac ASH<210	
Whey p l lac ASH>210	
Whey powder	
Sunflowers deh	
Sunflowers p deh	
Sunflowers w hulls	
Sunfls exp deh	
Sunfls exp p deh	
Sunfls exp w hulls	
Sunfmeal CF<160	
Sunfmeal CF 160-200	
Sunfmeal CF 200-240	
Sunfmeal CF>240	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	
Potato pulp pr NL	
Potato pulp pressed	
Potato cut raw	
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	
Pot sta STA 650-775	
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	
Pot s g STA 425-550	
Pot s g STA 550-675	
Pot sta gel STA>675	
Brewers gr 22% DM	
Brewers gr 27% DM	
Brewers yeast CP<400	
Brewers y CP400-500	
Brewers yeast CP>500	
Beetp pressed f+sil	0.4
CCM CF<40	0.4
CCM CF 40-60	
CCM CF>60	
Chicory pulp f+sil	0.7
Distillers sol f	
Cheese whey CP<175	
Cheese w CP175-275	
Cheese whey CP>275	
Maize glutenf f+sil	
Maize solubles	
Wheat st FR STAt 300	
Wheat st STAtot 400	
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	1.4
Beet rests siliIed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	1.3
Barley straw	
Grass fr April l y.	2.7
Grass fr April n y.	2.7
Grass fr April h y.	2.7
Grass fr May l y.	2.7
Grass fr May n y.	2.7
Grass fr May h y.	2.7
Grass fr June l y.	2.7
Grass fr June n y.	2.7
Grass fr June h y.	2.7

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	2.7
Grass fr July n y.	2.7
Grass fr July h y.	2.7
Grass fr Aug l y.	2.7
Grass fr Aug n y.	2.7
Grass fr Aug h y.	2.7
Grass fr Sept l y.	2.7
Grass fr Sept n y.	2.7
Grass fr Sept h y.	2.7
Grass fr Oct l y.	2.7
Grass fr Oct n y.	2.7
Grass fr Oct h y.	2.7
Grass average	2.7
Grass horse gr past	2.7
Grass horse same fld	2.7
Grass sil May 2000	2.1
Grass sil May 3500	2.1
Grass sil May 5000	2.1
Grass sil June 2000	2.1
Grass sil June 3000	2.1
Grass sil June 4000	2.1
Grass sil Ju-Au 2000	2.1
Grass sil Ju-Au 3000	2.1
Grass sil Ju-Au 4000	2.1
Grass sil Se-Oc 2000	2.1
Grass sil Se-Oc 3000	2.1
Grass sil average	2.1
Grass sil horse fine	2.1
Grass sil horse midd	2.1
Grass sil horse crs	2.1
Grass hay good qual	2.1
Grass hay av qual	2.1
Grass hay poor qual	2.1
Grass hay horse fine	2.1
Grass hay horse midd	2.1
Grass hay horse crs	2.1
Grass bales ad	2.4
Grass seeds straw	2.2
Oat straw	
Clover red fresh	
Clover red silage	2.6
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	
Lucerne hay	
Lucerne (alfalfa) ad	2.2
Maize Cob with leaves silage	
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	1.8
Maize fod fr DM<240	0.4
Maize f fr DM240-280	0.4
Maize f fr DM280-320	0.4
Maize fod fr DM 320	0.4
Maize sil DM < 240	0.4
Maize sil DM240-280	0.4
Maize sil DM280-320	0.4
Maize sil DM 320	0.4
Maize (Fodder) ad	0.4
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	
Chicory rts not frcd	
Chicory rts frcd cleaned	
Chicory rts frcd dirty	
Carrots	
Sunflower silage	

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	
Calcium carbonate	
Diammonium phosphate	
Difluorinated phosphate	
Dicalcium phosphate	
Mono-dicalcium phosphate	
Monoammonium phosphate	
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of molybdenum in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	74.1	89.2	5	6	0.603	1.200
Piglet Starter II (complete feed)	20	78.2	77.7	7	8	0.779	0.618
Pig Grower (complete feed)	19	86.1	88.4	7	9	0.730	0.666
Pig Finisher (complete feed)	18	78.3	90.6	6	8	0.556	0.655
Sows, gestating (complete feed)	18	71.5	83.2	6	9	0.362	0.628
Sows, lactating (complete feed)	20	76.1	78.1	7	9	0.661	0.658
Starter Chicks (complete feed)	15	80.4	84.0	4	5	1.259	0.923
Chicken reared for laying (complete feed)	17	72.0	79.5	5	6	0.714	0.559
Layer Phase I (complete feed)	16	64.1	86.5	3	6	0.705	0.908
Layer Phase II (complete feed)	16	56.7	78.5	3	6	0.635	0.862
Broiler Starter (complete feed)	14	79.1	94.1	4	5	1.115	1.425
Broiler Grower (complete feed)	15	81.7	89.2	5	5	1.317	1.276
Broiler Finisher (complete feed)	15	80.3	88.0	4	4	1.402	1.258
Turkey Starter (complete feed)	14	87.8	92.8	3	4	1.952	1.481
Turkey Grower (complete feed)	13	88.2	90.2	3	4	2.028	1.530
Turkey Finisher (complete feed)	11	91.2	91.2	3	3	1.976	1.417
Turkey Breeder (complete feed)	8	80.8	82.8	2	3	0.642	0.645
Duck, grower/finisher (complete feed)	10	92.9	92.9	3	3	1.391	0.947
Geese, grower/finisher (complete feed)	8	97.0	97.0	4	4	1.596	1.265
Calf, milk replacer (complete feed)	10	10.0	30.7	1	1	0.380	1.533
Calf concentrate (complete feed)	17	65.3	86.1	6	10	1.132	1.467
Calf concentrate (complementary feed)	16	30.6	72.2	5	9	0.164	0.935
Cattle concentrate (complete feed)[4]	9	85.9	95.9	6	7	1.295	1.178
Cattle concentrate (complementary feed)	8	79.8	94.1	5	6	0.950	0.826
Dairy cows TMR (based on corn silage)[4]	15	88.5	98.8	7	10	1.086	1.147
Dairy cows TMR (based on grass silage)[4]	15	86.1	97.9	7	10	1.330	1.406
Dairy concentrate (complementary feed)	13	40.4	90.1	5	8	0.582	1.131
Dairy cows mineral feed (min. 40% crude ash)	8	0.0	0.0	0	0	0.000	0.000
Rabbit, breeder (complete feed)	8	51.0	97.0	3	4	0.546	1.483
Rabbit, grower/finisher (complete feed)	14	75.0	95.0	4	6	0.483	1.046
Salmon feed (wet)[4]	4	14.9	70.4	1	2	0.164	0.168
Salmon feed (dry)	6	27.4	79.4	2	3	0.842	0.728
Trout feed (dry)	12	57.9	78.2	2	4	2.122	1.775
Dog food (dry)	12	72.7	81.1	3	5	0.340	0.616
Cat food (dry)	16	17.0	68.1	3	7	0.160	0.567

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Molybdenum: Addendum to the monograph

Abstract

This addendum to the molybdenum monograph substantiates the data reported in Annex 5 of the molybdenum monograph in which molybdenum background levels are reported. The addendum provides the following information for each calculated background level: (1) the molybdenum concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no molybdenum concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated molybdenum content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.20	34.93	0.070	11.58
Maize	0.30	10.00	0.030	4.97
Soybeans heat tr		15.10		
Soybm CF<45 CP>480	3.80	7.50	0.285	47.24
Wheat	1.10	16.68	0.183	30.41
Wheat middlings	0.70	5.00	0.035	5.80
Fat from Animals		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	0.603	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.20	15.00	0.030	3.85
Maize	0.30	15.81	0.047	6.09
Dist grains and sol		3.00		
Palm kern exp CF<180	0.50	4.00	0.020	2.57
Rapeseed exp	1.10	6.00	0.066	8.48
Soybm CF<45 CP>480	3.80	7.86	0.299	38.37
Wheat	1.10	27.50	0.303	38.85
Wheat gluten meal		10.00		
Wheat middlings	0.70	2.00	0.014	1.80
Fat from Animals		3.00		
Sunfmeal CF<160		2.55		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate		0.05		
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.779	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		2.00		
Barley	0.20	20.00	0.040	5.48
Maize	0.30	9.42	0.028	3.87
Dist grains and sol		5.00		
Palm kern exp CF<180	0.50	4.00	0.020	2.74
Rapeseed exp	1.10	7.00	0.077	10.54
Soybm CF<45 CP>480	3.80	3.40	0.129	17.68
Wheat	1.10	35.00	0.385	52.72
Wheat middlings	0.70	7.27	0.051	6.97
Fat from Animals		2.09		
Sunfmeal CF<160		2.32		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.730	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		2.50		
Barley	0.20	20.00	0.040	7.20
Maize	0.30	6.93	0.021	3.74
Dist grains and sol		6.21		
Palm kern exp CF<180	0.50	5.00	0.025	4.50
Rapeseed exp	1.10	1.35	0.015	2.67
Wheat	1.10	35.00	0.385	69.29
Wheat gluten meal		3.04		
Wheat middlings	0.70	10.00	0.070	12.60
Fat from Animals		2.00		
Sunfmeal CF<160		4.98		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.556	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		5.50		
Barley	0.20	20.00	0.040	11.06
Maize	0.30	15.26	0.046	12.66
Maize germ meal extr		7.50		
Sugarc mol SUG<475		0.10		
Palm kern exp CF<180	0.50	5.00	0.025	6.91
Wheat	1.10	11.22	0.123	34.12
Wheat glutenfeed		5.00		
Wheat middlings	0.70	7.50	0.053	14.52
Wheat bran	0.60	12.50	0.075	20.74
Fat from Animals		1.91		
Sunfmeal CF<160		6.11		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate		0.07		
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.362	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		2.41		
Barley	0.20	20.00	0.040	6.05
Maize	0.30	10.00	0.030	4.54
Palm kern exp CF<180	0.50	4.00	0.020	3.03
Rapeseed exp	1.10	6.00	0.066	9.99
Soybean exp		1.39		
Soybm CF<45 CP>480	3.80	5.13	0.195	29.46
Wheat	1.10	23.43	0.258	38.99
Wheat glutenfeed		10.00		
Wheat middlings	0.70	7.50	0.053	7.94
Fat from Animals		2.16		
Sunfmeal CF<160		4.22		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate		0.42		
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.661	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	20.00	0.060	4.77
Rapeseed exp	1.10	5.00	0.055	4.37
Soybeans not heat tr		0.69		
Soybm CF<45 CP>480	3.80	19.79	0.752	59.74
Wheat	1.10	35.62	0.392	31.12
Wheat gluten meal		5.75		
Fat from Animals		2.00		
Sunfmeal CF<160		7.94		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate		0.56		
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	1.259	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)		Chicken reared for laying (complete feed)		
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	15.00	0.045	6.30
Dist grains and sol		2.50		
Rapeseed exp	1.10	5.00	0.055	7.70
Soybm CF<45 CP>480	3.80	2.95	0.112	15.71
Wheat	1.10	41.54	0.457	63.99
Wheat gluten meal		10.00		
Wheat bran	0.60	7.50	0.045	6.30
Fat from Animals		2.00		
Sunfmeal CF<160		10.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.29		
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.714	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	20.00	0.060	8.51
Dist grains and sol		4.00		
Soybeans not heat tr		8.36		
Soybm CF<45 CP>480	3.80	5.93	0.225	31.96
Wheat	1.10	38.18	0.420	59.54
Wheat gluten meal		0.47		
Fat from Animals		2.87		
Sunfmeal CF<160		10.00		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.55		
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.705	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	20.00	0.060	9.45
Dist grains and sol		4.00		
Soybean exp		7.80		
Soybm CF<45 CP>480	3.80	6.34	0.241	37.95
Wheat	1.10	30.36	0.334	52.60
Wheat gluten meal		7.41		
Fat from Animals		3.40		
Sunfmeal CF<160		10.00		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate		0.43		
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.635	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	30.00	0.090	8.08
Maize gluten meal	0.60	2.50	0.015	1.35
Soybeans not heat tr		15.00		
Soybm CF<45 CP>480	3.80	18.41	0.700	62.78
Wheat	1.10	28.16	0.310	27.80
Fat from Animals		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate		0.94		
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	1.115	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	15.00	0.045	3.42
Maize gluten meal	0.60	1.56	0.009	0.71
Rapeseed exp	1.10	2.50	0.028	2.09
Soybeans not heat tr		10.00		
Soybm CF<45 CP>480	3.80	20.22	0.768	58.35
Wheat	1.10	42.41	0.467	35.44
Fat from Animals		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate		0.78		
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	1.317	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize gluten meal	0.60	0.68	0.004	0.29
Rapeseed exp	1.10	2.50	0.028	1.96
Soybeans not heat tr		10.16		
Soybm CF<45 CP>480	3.80	19.32	0.734	52.36
Wheat	1.10	57.84	0.636	45.38
Fat from Animals		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate		0.39		
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	1.402	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	20.00	0.060	3.07
Soybm CF<45 CP>480	3.80	42.45	1.613	82.64
Wheat	1.10	25.35	0.279	14.28
Fats/oils vegetable		1.83		
Fish meal CP630-680		5.00		
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate		1.90		
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.82	1.952	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	6.94	0.021	1.03
Soybeans not heat tr		2.00		
Soybm CF<45 CP>480	3.80	41.24	1.567	77.28
Wheat	1.10	40.00	0.440	21.70
Fats/oils vegetable		5.00		
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		2.21		
Salt		0.30		
Total		100.00	2.028	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	11.74	0.035	1.78
Soybm CF<45 CP>480	3.80	39.50	1.501	75.95
Wheat	1.10	40.00	0.440	22.26
Fats/oils vegetable		4.60		
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		1.77		
Salt		0.30		
Total		100.00	1.976	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.30	69.44	0.208	32.47
Soybm CF<45 CP>480	3.80	11.40	0.433	67.53
Feather meal hydr		2.00		
Calcium carbonate		7.60		
Dicalcium Phosphate		1.00		
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.642	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Soybm CF<45 CP>480	3.80	15.00	0.570	40.98
Wheat	1.10	68.91	0.758	54.49
Wheat middlings	0.70	9.00	0.063	4.53
Fats/oils veg h %d		3.87		
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate		0.90		
Premix		0.50		
Salt		0.37		
Total		100.02	1.391	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.20	10.00	0.020	1.25
Maize	0.30	34.00	0.102	6.39
Soybm CF<45 CP>480	3.80	33.00	1.254	78.57
Wheat	1.10	20.00	0.220	13.78
Calcium carbonate		1.20		
Dicalcium Phosphate		0.50		
Premix		1.00		
Salt		0.30		
Total		100.00	1.596	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	3.80	10.00	0.380	100.00
Wheat gluten meal		5.00		
Fat from Animals		6.25		
Whey p l lac ASH<210		15.00		
Whey powder		30.65		
Cheese whey CP>275		11.00		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	0.380	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		5.50		
Citrus pulp, dried		8.00		
Barley	0.20	0.54	0.001	0.10
Linseed	0.20	1.25	0.003	0.22
Sugarbeet molasses	0.20	1.00	0.002	0.18
Palm kern exp CF<180	0.50	5.50	0.028	2.43
Rapeseed		3.50		
Rapeseed extr CP>380		1.94		
Soybeans heat tr		5.37		
Wheat middlings	0.70	7.00	0.049	4.33
Wheat feedfl CF<35		8.00		
Vinasse Sugb CP>250		1.50		
Grass hay good qual	2.10	50.00	1.050	92.75
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	1.132	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		11.00		
Citrus pulp, dried		16.00		
Barley	0.20	1.08	0.002	1.31
Linseed	0.20	2.50	0.005	3.05
Sugarbeet molasses	0.20	2.00	0.004	2.44
Palm kern exp CF<180	0.50	11.00	0.055	33.50
Rapeseed		7.00		
Rapeseed extr CP>380		3.88		
Soybeans heat tr		10.74		
Wheat middlings	0.70	14.00	0.098	59.70
Wheat feedfl CF<35		16.00		
Vinasse Sugb CP>250		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	0.164	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		10.01		
Barley	0.20	18.90	0.038	2.92
Linseed	0.20	7.51	0.015	1.16
Sugarbeet molasses	0.20	0.98	0.002	0.15
Soybm CF<45 CP>480	3.80	10.99	0.418	32.25
Wheat	1.10	17.50	0.193	14.87
Fats/oils veg h %d		1.60		
Grass sil average	2.10	30.00	0.630	48.65
Premix		2.50		
Total		99.99	1.295	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		14.30		
Barley	0.20	27.00	0.054	5.69
Linseed	0.20	10.70	0.021	2.25
Sugarbeet molasses	0.20	1.40	0.003	0.29
Soybm CF<45 CP>480	3.80	15.70	0.597	62.81
Wheat	1.10	25.00	0.275	28.95
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	0.950	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		2.61		
Maize glfd CP200-230		0.95		
Maize feed meal		1.15		
Sugarbeet molasses	0.20	0.24	<0.001	0.04
Palm kern exp CF<180	0.50	1.78	0.009	0.82
Rapeseed exp	1.10	0.59	0.006	0.60
Rapeseed extr CP>380		6.18		
Soybm CF<45 CP>480	3.80	7.83	0.298	27.40
Wheat middlings	0.70	0.96	0.007	0.62
Vinasse Sugb CP>250		0.36		
Grass sil average	2.10	26.89	0.565	52.01
Maize sil DM280-320	0.40	50.23	0.201	18.51
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.95	1.086	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		4.72		
Maize glfd CP200-230		1.72		
Maize feed meal		2.08		
Sugarbeet molasses	0.20	0.43	0.001	0.06
Palm kern exp CF<180	0.50	3.22	0.016	1.21
Rapeseed exp	1.10	1.07	0.012	0.88
Rapeseed extr CP>380		4.39		
Soybm CF<45 CP>480	3.80	3.97	0.151	11.34
Wheat middlings	0.70	1.74	0.012	0.92
Vinasse Sugb CP>250		0.64		
Grass sil average	2.10	49.18	1.033	77.63
Maize sil DM280-320	0.40	26.46	0.106	7.96
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		99.94	1.330	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		22.00		
Maize glfd CP200-230		8.00		
Maize feed meal		9.70		
Sugarbeet molasses	0.20	2.00	0.004	0.69
Palm kern exp CF<180	0.50	15.00	0.075	12.88
Rapeseed exp	1.10	5.00	0.055	9.45
Rapeseed extr CP>380		15.00		
Soybm CF<45 CP>480	3.80	10.30	0.391	67.24
Wheat middlings	0.70	8.10	0.057	9.74
Vinasse Sugb CP>250		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	0.582	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)		Dairy cows mineral feed (min. 40% crude ash)		
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate		8.80		
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00		

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.20	2.00	0.004	0.73
Alf meal CP160-180	0.50	40.00	0.200	36.63
Soybm CF<45 CP>480	3.80	9.00	0.342	62.64
Wheat germfeed		46.00		
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	0.546	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG150-200		10.00		
Barley	0.20	23.00	0.046	9.52
Alf meal CP160-180	0.50	35.00	0.175	36.23
Soybm CF<45 CP>480	3.80	5.00	0.190	39.34
Wheat bran	0.60	12.00	0.072	14.91
Fat from Animals		2.00		
Sunfmeal CF 200-240		10.00		
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate		1.90		
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	0.483	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat	1.10	14.90	0.164	100.00
Fish meal CP630-680		55.53		
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		99.99	0.164	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Soybm CF<45 CP>480	3.80	20.00	0.760	90.30
Wheat	1.10	7.42	0.082	9.70
Fish meal CP630-680		51.96		
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	0.842	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	3.80	55.00	2.090	98.51
Wheat	1.10	2.87	0.032	1.49
Wheat gluten meal		11.80		
Fat from Animals		16.00		
Fish meal CP630-680		8.50		
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	2.122	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Sugarb p SUG100-150	0.30	4.30	0.013	3.79
Meat meal CFAT<100	0.60	40.62	0.244	71.68
Maize	0.30	27.80	0.083	24.53
Maize starch		2.78		
Rice wtht hulls		7.30		
Fat from Animals		9.60		
Brewers y CP400-500		1.10		
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.340	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Brewers' yeast dried	1.10	1.80	0.020	12.37
Meat meal Dutch		1.33		
Greaves		29.76		
Linseed	0.20	3.00	0.006	3.75
Wheat	1.10	12.21	0.134	83.89
Wheat glutenfeed		2.06		
Wheat feedfl CF<35		20.00		
Feather meal hydr		18.00		
Fat from Animals		7.97		
Fish meal CP630-680		1.00		
Meat bone m CFAT>100		1.00		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.160	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	34.93	0.154	12.80
Maize	0.41	10.00	0.041	3.42
Wheat, soft	0.46	16.68	0.077	6.39
Wheat middlings	2.00	5.00	0.100	8.33
Soybean, full fat, extruded	4.00	15.10	0.604	50.31
Soybean meal, 50	3.00	7.50	0.225	18.75
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	1.200	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	15.00	0.066	10.68
Maize	0.41	15.81	0.065	10.49
Wheat, soft	0.46	27.50	0.127	20.47
Wheat middlings	2.00	2.00	0.040	6.47
Wheat gluten feed, starch 28%		10.00		
Corn distillers	1.70	3.00	0.051	8.25
Palm kernel meal, expeller	0.40	4.00	0.016	2.59
Rapeseed cake		6.00		
Soybean meal, 50	3.00	7.86	0.236	38.17
Sunflower meal, undecorticated	0.70	2.55	0.018	2.89
Tallow		3.00		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate		0.05		
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.618	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	20.00	0.088	13.22
Maize	0.41	9.42	0.039	5.80
Wheat, soft	0.46	35.00	0.161	24.19
Wheat middlings	2.00	7.27	0.145	21.85
Corn distillers	1.70	5.00	0.085	12.77
Palm kernel meal, expeller	0.40	4.00	0.016	2.40
Rapeseed cake		7.00		
Soybean meal, 50	3.00	3.40	0.102	15.32
Sunflower meal, undecorticated	0.70	2.32	0.016	2.43
Beet pulp, dried	0.67	2.00	0.013	2.01
Tallow		2.09		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.666	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	20.00	0.088	13.44
Maize	0.41	6.93	0.028	4.34
Wheat, soft	0.46	35.00	0.161	24.59
Wheat middlings	2.00	10.00	0.200	30.55
Wheat gluten feed, starch 28%		3.04		
Corn distillers	1.70	6.21	0.106	16.13
Palm kernel meal, expeller	0.40	5.00	0.020	3.06
Rapeseed cake		1.35		
Sunflower meal, undecorticated	0.70	4.98	0.035	5.33
Beet pulp, dried	0.67	2.50	0.017	2.56
Tallow		2.00		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.655	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	20.00	0.088	14.01
Maize	0.41	15.26	0.063	9.96
Wheat, soft	0.46	11.22	0.052	8.22
Wheat bran	1.40	12.50	0.175	27.86
Wheat middlings	2.00	7.50	0.150	23.88
Wheat gluten feed, starch 28%		5.00		
Maize germ meal, expeller		7.50		
Palm kernel meal, expeller	0.40	5.00	0.020	3.18
Sunflower meal, undecorticated	0.70	6.11	0.043	6.81
Beet pulp, dried	0.67	5.50	0.037	5.87
Molasses, sugarcane	1.30	0.10	0.001	0.20
Tallow		1.91		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate		0.07		
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.628	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	20.00	0.088	13.38
Maize	0.41	10.00	0.041	6.23
Wheat, soft	0.46	23.43	0.108	16.38
Wheat middlings	2.00	7.50	0.150	22.80
Wheat gluten feed, starch 28%		10.00		
Soybean, full fat, extruded	4.00	1.39	0.056	8.46
Palm kernel meal, expeller	0.40	4.00	0.016	2.43
Rapeseed cake		6.00		
Soybean meal, 50	3.00	5.13	0.154	23.37
Sunflower meal, undecorticated	0.70	4.22	0.030	4.49
Beet pulp, dried	0.67	2.41	0.016	2.46
Tallow		2.16		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate		0.42		
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.658	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	20.00	0.082	8.88
Wheat, soft	0.46	35.62	0.164	17.75
Wheat gluten feed, starch 28%		5.75		
Soybean, full fat, extruded	4.00	0.69	0.028	2.99
Rapeseed cake		5.00		
Soybean meal, 50	3.00	19.79	0.594	64.34
Sunflower meal, undecorticated	0.70	7.94	0.056	6.02
Tallow		2.00		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate		0.56		
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.923	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	15.00	0.062	11.01
Wheat, soft	0.46	41.54	0.191	34.20
Wheat bran	1.40	7.50	0.105	18.80
Wheat gluten feed, starch 28%		10.00		
Corn distillers	1.70	2.50	0.043	7.61
Rapeseed cake		5.00		
Soybean meal, 50	3.00	2.95	0.089	15.85
Sunflower meal, undecorticated	0.70	10.00	0.070	12.53
Tallow		2.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.29		
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.559	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	20.00	0.082	9.03
Wheat, soft	0.46	38.18	0.176	19.34
Wheat gluten feed, starch 28%		0.47		
Corn distillers	1.70	4.00	0.068	7.49
Soybean, full fat, extruded	4.00	8.36	0.335	36.84
Soybean meal, 50	3.00	5.93	0.178	19.60
Sunflower meal, undecorticated	0.70	10.00	0.070	7.71
Tallow		2.87		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate		0.55		
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.908	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	20.00	0.082	9.51
Wheat, soft	0.46	30.36	0.140	16.20
Wheat gluten feed, starch 28%		7.41		
Corn distillers	1.70	4.00	0.068	7.89
Soybean, full fat, extruded	4.00	7.80	0.312	36.20
Soybean meal, 50	3.00	6.34	0.190	22.07
Sunflower meal, undecorticated	0.70	10.00	0.070	8.12
Tallow		3.40		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate		0.43		
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.862	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	30.00	0.123	8.63
Wheat, soft	0.46	28.16	0.130	9.09
Corn gluten meal	0.82	2.50	0.021	1.44
Soybean, full fat, extruded	4.00	15.00	0.600	42.09
Soybean meal, 50	3.00	18.41	0.552	38.75
Tallow		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate		0.94		
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	1.425	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	15.00	0.062	4.82
Wheat, soft	0.46	42.41	0.195	15.29
Corn gluten meal	0.82	1.56	0.013	1.00
Soybean, full fat, extruded	4.00	10.00	0.400	31.35
Rapeseed cake		2.50		
Soybean meal, 50	3.00	20.22	0.606	47.53
Tallow		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate		0.78		
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	1.276	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat, soft	0.46	57.84	0.266	21.15
Corn gluten meal	0.82	0.68	0.006	0.45
Soybean, full fat, extruded	4.00	10.16	0.406	32.32
Rapeseed cake		2.50		
Soybean meal, 50	3.00	19.32	0.580	46.08
Tallow		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate		0.39		
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	1.258	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	20.00	0.082	5.54
Wheat, soft	0.46	25.35	0.117	7.87
Soybean meal, 50	3.00	42.45	1.274	85.98
Fish meal, protein 70%	0.18	5.00	0.009	0.61
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate		1.90		
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.82	1.481	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	6.94	0.028	1.86
Wheat, soft	0.46	40.00	0.184	12.03
Soybean, full fat, extruded	4.00	2.00	0.080	5.23
Soybean meal, 50	3.00	41.24	1.237	80.88
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		2.21		
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	1.530	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	11.74	0.048	3.40
Wheat, soft	0.46	40.00	0.184	12.98
Soybean meal, 50	3.00	39.50	1.185	83.62
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate		1.77		
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	1.417	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	69.44	0.285	44.16
Soybean meal, 50	3.00	11.40	0.342	53.05
Feather meal	0.90	2.00	0.018	2.79
Calcium carbonate		7.60		
Dicalcium Phosphate		1.00		
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.645	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat, soft	0.46	68.91	0.317	33.47
Wheat middlings	2.00	9.00	0.180	19.01
Soybean meal, 50	3.00	15.00	0.450	47.52
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate		0.90		
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	0.947	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	10.00	0.044	3.48
Maize	0.41	34.00	0.139	11.02
Wheat, soft	0.46	20.00	0.092	7.27
Soybean meal, 50	3.00	33.00	0.990	78.24
Calcium carbonate		1.20		
Dicalcium Phosphate		0.50		
Premix		1.00		
Salt		0.30		
Total		100.00	1.265	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat gluten feed, starch 25%		5.00		
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	5.00	30.65	1.533	100.00
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	1.533	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	0.54	0.002	0.16
Wheat middlings	2.00	7.00	0.140	9.54
Wheat feed flour		8.00		
Linseed, full fat	0.20	1.25	0.003	0.17
Rapeseed, full fat		3.50		
Soybean, full fat, toasted	4.00	5.37	0.215	14.64
Palm kernel meal, expeller	0.40	5.50	0.022	1.50
Rapeseed meal	1.60	1.94	0.031	2.12
Beet pulp, dried	0.67	5.50	0.037	2.51
Citrus pulp, dried	0.19	8.00	0.015	1.04
Molasses, beet	0.26	1.00	0.003	0.18
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	2.00	50.00	1.000	68.15
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	1.467	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	1.08	0.005	0.51
Wheat middlings	2.00	14.00	0.280	29.95
Wheat feed flour		16.00		
Linseed, full fat	0.20	2.50	0.005	0.53
Rapeseed, full fat		7.00		
Soybean, full fat, toasted	4.00	10.74	0.430	45.97
Palm kernel meal, expeller	0.40	11.00	0.044	4.71
Rapeseed meal	1.60	3.88	0.062	6.64
Beet pulp, dried	0.67	11.00	0.074	7.88
Citrus pulp, dried	0.19	16.00	0.030	3.25
Molasses, beet	0.26	2.00	0.005	0.56
Vinasse, different origins		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	0.935	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	18.90	0.083	7.06
Wheat, soft	0.46	17.50	0.081	6.83
Linseed, full fat	0.20	7.51	0.015	1.28
Soybean meal, 50	3.00	10.99	0.330	27.99
Beet pulp, dried	0.67	10.01	0.067	5.69
Molasses, beet	0.26	0.98	0.003	0.22
Grass silage	2.00	30.00	0.600	50.93
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	1.178	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	27.00	0.119	14.39
Wheat, soft	0.46	25.00	0.115	13.93
Linseed, full fat	0.20	10.70	0.021	2.59
Soybean meal, 50	3.00	15.70	0.471	57.05
Beet pulp, dried	0.67	14.30	0.096	11.60
Molasses, beet	0.26	1.40	0.004	0.44
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	0.826	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat middlings	2.00	0.96	0.019	1.67
Corn gluten feed	1.60	0.95	0.015	1.33
Corn gluten meal	0.82	1.15	0.009	0.82
Palm kernel meal, expeller	0.40	1.78	0.007	0.62
Rapeseed meal	1.60	6.18	0.099	8.62
Rapeseed cake		0.59		
Soybean meal, 50	3.00	7.83	0.235	20.49
Beet pulp, dried	0.67	2.61	0.017	1.53
Molasses, beet	0.26	0.24	0.001	0.05
Vinasse, different origins		0.36		
Grass silage	2.00	26.89	0.538	46.90
Corn silage	0.41	50.23	0.206	17.96
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	1.147	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat middlings	2.00	1.74	0.035	2.47
Corn gluten feed	1.60	1.72	0.028	1.96
Corn gluten meal	0.82	2.08	0.017	1.21
Palm kernel meal, expeller	0.40	3.22	0.013	0.92
Rapeseed meal	1.60	4.39	0.070	4.99
Rapeseed cake		1.07		
Soybean meal, 50	3.00	3.97	0.119	8.47
Beet pulp, dried	0.67	4.72	0.032	2.25
Molasses, beet	0.26	0.43	0.001	0.08
Vinasse, different origins		0.64		
Grass silage	2.00	49.18	0.984	69.94
Corn silage	0.41	26.46	0.108	7.71
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	1.406	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat middlings	2.00	8.10	0.162	14.32
Corn gluten feed	1.60	8.00	0.128	11.32
Corn gluten meal	0.82	9.70	0.080	7.03
Palm kernel meal, expeller	0.40	15.00	0.060	5.30
Rapeseed meal	1.60	15.00	0.240	21.22
Rapeseed cake		5.00		
Soybean meal, 50	3.00	10.30	0.309	27.32
Beet pulp, dried	0.67	22.00	0.147	13.03
Molasses, beet	0.26	2.00	0.005	0.46
Vinasse, different origins		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	1.131	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)		Dairy cows mineral feed (min. 40% crude ash)		
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate		8.80		
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00		

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	2.00	0.009	0.59
Wheat bran	1.40	46.00	0.644	43.43
Soybean meal, 50	3.00	9.00	0.270	18.21
Alfalfa, dehydrated	1.40	40.00	0.560	37.77
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	1.483	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Barley	0.44	23.00	0.101	9.67
Wheat bran	1.40	12.00	0.168	16.06
Soybean meal, 50	3.00	5.00	0.150	14.34
Sunflower meal, undecorticated	0.70	10.00	0.070	6.69
Beet pulp, dried	0.67	10.00	0.067	6.40
Lard		2.00		
Alfalfa, dehydrated	1.40	35.00	0.490	46.84
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate		1.90		
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	1.046	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat, soft	0.46	14.90	0.069	40.68
Fish meal, protein 70%	0.18	55.53	0.100	59.32
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	0.168	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat, soft	0.46	7.42	0.034	4.69
Soybean meal, 50	3.00	20.00	0.600	82.45
Fish meal, protein 70%	0.18	52.00	0.094	12.86
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	0.728	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat, soft	0.46	2.87	0.013	0.74
Corn gluten meal	0.82	11.80	0.097	5.45
Soybean meal, 50	3.00	55.00	1.650	92.94
Maize starch		3.00		
Fish meal, protein 70%	0.18	8.50	0.015	0.86
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	1.775	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Maize	0.41	27.80	0.114	18.51
Rice, brown	0.75	7.30	0.055	8.89
Maize starch		2.78		
Beet pulp, dried	0.67	4.30	0.029	4.68
Brewers' yeast, dried	1.10	1.10	0.012	1.96
Lard		9.60		
Meat and bone meal, fat <7.5%	1.00	40.62	0.406	65.96
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.616	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Mo/kg feed material	% feed material	mg Mo/kg complete feedingstuff	Mo (% contribution)
Wheat, soft	0.46	12.21	0.056	9.91
Wheat feed flour		20.00		
Wheat gluten feed, starch 25%		2.06		
Linseed, full fat	0.20	3.00	0.006	1.06
Brewers' yeast, dried	1.10	1.80	0.020	3.49
Fish meal, protein 70%	0.18	1.00	0.002	0.32
Feather meal	0.90	18.00	0.162	28.59
Meat and bone meal, fat <7.5%	1.00	29.76	0.298	52.52
Meat and bone meal, fat >7.5%	1.00	2.33	0.023	4.11
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.567	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Nickel

Executive summary of the monograph for nickel

Nickel is generally not accepted as an essential nutrient for higher animals and humans because of the lack of a clearly defined specific biochemical function. However, under experimental conditions, nickel deprivation resulted in several subnormal functions including depressed growth, hematocrits and reproductive performance. In bacteria, seven nickel containing enzymes have been identified. Extended periods of time consuming relatively high amounts of nickel are required before signs of chronic toxicosis are seen in animals. The most commonly reported signs of nickel toxicosis include depressed growth, feed intake, and feed efficiency, hematological changes, kidney damage, and impaired reproductive performance characterized by increased deaths of offspring. In humans 1 – 25 % of ingested nickel is reported to be absorbed. The presence of food significantly reduces the nickel absorbability. The kidney, lung, brain, and pancreas are considered the main target tissues for nickel retention. Absorbed nickel is primarily excreted via urine. The acute toxicity of nickel is low. Clinical symptoms associated with acute nickel exposure include gastrointestinal disturbances, visual disturbance, headache, giddiness, wheezing and cough. Nickel has fairly non-specific toxic effects. The most commonly reported adverse effect associated with nickel exposure is contact dermatitis. After an individual becomes sensitized to nickel, dermal contact with a small amount of nickel or oral exposure to fairly low doses of nickel can result in dermatitis. IARC classified nickel compounds as carcinogenic to humans (Group 1) and metallic nickel as possibly carcinogenic to humans (Group 2B). Animal studies indicate that the developing fetus and neonates are sensitive targets of nickel toxicity. IOM found no available evidence for adverse effects in humans associated with the exposure to nickel through the consumption of a normal diet. IOM established an upper intake level for nickel of 1 mg/day for adults that applies to excess nickel intake as soluble salts. EVM calculated a guidance level for nickel of 0.00043 mg/(kg bw.day). EFSA considered the available data inadequate to derive an upper intake level. The carcinogenicity of nickel has been well documented in occupationally exposed individuals. Significant increases in the risk of mortality from lung and nasal cancers were observed in several cohorts of nickel refinery workers. There were no indications that the presence of nickel in animal diets would have an environmental impact.

Nickel Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Nickel is an abundant metallic element which can exist in oxidation forms -1, 0, +1, +2, +3 and +4. In biological systems, Ni^{2+} predominates. Proteins containing the amino acid histidine are the apparent key biological ligands. The form of nickel in foods and feeds has not been determined (NRC, 2005).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorization of use of the element in human or animal nutrition.

3 Essential functions

NRC (2005) classified nickel as a possibly essential element. It is generally not accepted as an essential nutrient for higher animals, apparently because of the lack of a clearly defined specific biochemical function and no enzymes or cofactors are known that include nickel in higher organisms. EFSA (2005) considers the essentiality of nickel for humans not to be demonstrated. However, under experimental conditions, nickel deprivation resulted in several subnormal functions in higher animals (NRC, 2005; Denkhaus & Salnikow, 2002). Nickel containing enzymes are well known in bacteria. Seven microbial nickel-containing enzymes have been identified. Hence, it is conceivable that nickel, not being essential in the body of humans and animals, is needed for the normal development of the gut's microflora (Denkhaus & Salnikow, 2002).

4 Other functions

Functions of nickel that might be classified as 'other functions' of the element are reported in Chapter 6.

5 Antimicrobial properties

There was no information available on antimicrobial properties of nickel in principal literature sources.

6 Typical deficiency symptoms

Although nickel is generally not accepted as an essential nutrient, deficiency symptoms have been induced under experimental conditions (Table 1) (Nielsen, 1996; NRC, 2005).

Table 1 Effects of induced nickel deficiency in various species (Nielsen, 1996)

Species	Observed effects
Chicks	Depressed hematocrits, and ultrastructural abnormalities in the liver
Cows	Depressed ruminal urease activity, serum urea nitrogen and growth
Goats	Depressed growth, hematocrits, reproductive performance
Pigs	Depressed growth, and altered distribution and proper functioning of other nutrients including zinc and calcium
Rat	Depressed growth, hematocrits and plasma glucose, and altered distribution and proper functioning of other nutrients including iron and vitamin B_{12}
Sheep	Depressed growth, total serum protein, erythrocyte counts, ruminal urease activity, total hepatic lipids and cholesterol, and altered tissue distribution of copper and iron

7 Animal requirements, allowances and use levels

Animal requirements for nickel have not been established by scientific bodies.

8 Concentration of the element in feed materials

NRC reported the following nickel concentrations in feedmaterials: 0.08 – 0.3 mg/kg for wheat, 0.20 mg/kg for corn, 0.71 – 2.09 mg/kg for oats, 5.24 mg/kg for linseed meal, 7.91 mg/kg for soybean meal, 7.78 mg/kg for sunflower meal, and 0.5 – 3.5 mg/kg DM for common pasture plants (NRC, 2005). Nickel concentrations reported by Spears (1984) and RIKILT (2008) are given in Table 2.

Table 2 Nickel concentrations in feed materials

Feed material	Nickel conc. (mg/kg)	Reference
Corn	0.36 – 0.90	Spears (1984)
Oats	1.00	
Barley	0.04	
Wheat	0.56	
Soybean meal	3.91	
Corn gluten meal	1.65	
Feather meal	0.77	
Blood meal	0.66	
Urea	1.52	

Table 2 (continued) Nickel concentrations in feed materials

Feed material	Nickel conc. (mg/kg)	Reference
Corn silage	1.28	Spears (1984)
Alfalfa pellets	3.69	
Coastal bermudagrass pellets	0.44	
Tall fescue hay	1.00	
Cottonseed hulls	0.26	
Additional cattle feed, n = 26	0.28	RIKILT (2008)
Mineral mix cattle, n = 19	93	
Premix, n = 48	26.05	
Mineral mix additional cattle feed, n = 44	21	

9 Concentration of the element in complete feedingstuffs

Data on nickel concentrations in complete feedingstuffs are compiled in Table 3.

Table 3 Mean nickel concentrations in complete feedingstuffs (Nicholson *et al*., 1999)

Complete feedingstuffs	n	Ni concentration (mg/kg DM)
Rearer-creep	4	2.3
Rearer-weaner	4	2.3
Rearer-grower	5	3.1
Rearer-finisher	7	2.8
Sow-dry	3	2.7
Sow-lactating	3	1.2
Broiler-starter	4	2.0
Broiler-grower	4	2.0
Broiler-finisher	3	2.1
Layer	4	2.6
Dairy cake/nuts	15	2.8
Beef cake/nuts/pellets	9	3.1

10 Tolerance of animal species and maximum tolerable levels (MTL)

MTL values for nickel established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels (MTL) for nickel (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Poultry, swine	250	
Cattle	100	
Sheep	100	Value derived from interspecies extrapolation
Rodents, fish	50	
Horses	50	Value derived from interspecies extrapolation

11 Typical symptoms of toxicosis

Extended periods of time consuming relatively high amounts of nickel are required before signs of chronic toxicosis are seen in animals. The most commonly reported signs of nickel toxicosis include depressed growth, feed intake, and feed efficiency, hematological changes, kidney damage, and impaired reproductive performance characterized by increased deaths of offspring (NRC, 2005).

12 Bioavailability

12.1 General

In humans, under normal dietary conditions 1 – 25 % of ingested nickel is reported to be absorbed. The presence of food significantly reduces the absorbability of nickel and after an overnight fast, an absorbed amount of 40 % of the ingested nickel dose has been observed (Denkhaus & Salnikow, 2002; EFSA, 2005).

12.2 Indicators of nickel status

Levels of nickel in urine and serum are can provide the most information about levels of nickel exposure if the route, sources, and duration of exposure are known, if the chemical identities and physico-chemical properties of the nickel compounds are known, and if physiological information of the exposed population is known (ATSDR, 2005). Klein and Costa (2007) concluded that there are no good and well-validated biomarkers for nickel exposure besides direct measures of nickel in serum and urine. There are no specific biomarkers for nickel adverse health effects (ATSDR, 2005).

13 Metabolism

Absorbed nickel binds to albumin, histidine and α_2-macroglobulin and is widely distributed in the organism. The kidney, lung, brain, and pancreas are considered the main target tissues for nickel retention following high levels of nickel exposure. Absorbed nickel is primarily excreted via urine, but to a minor extent also in bile and sweat and human milk. Estimates of the half-life of urinary removal of nickel range from 20 to 60 h. These relatively short half-life times do not exclude the storage of insoluble nickel deposits in the body with much longer biological half-lives and it was shown that adults store considerable amounts of nickel in the body gradually filling a ‘nickel pool’ (Denkhaus & Salnikow, 2002; EFSA, 2005).

14 Distribution in the animal body

Nickel is widely distributed in tissues in concentrations generally between 0.01 and 0.2 mg/kg when dietary nickel is not excessive (< 25 mg/kg). The kidneys are most sensitive to an increased ingestion of nickel (NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

NRC (2005) concluded that the available data indicate that edible tissues and products do not contain enough nickel to be of toxicological concern for humans. RIKILT (2008) assessed that the additional intake of nickel originating from mineral feed mixes to the human daily nickel intake is marginal. A compilation of nickel concentrations in edible tissues and products is given in Annex 1. Nickel concentrations in edible tissues and products linked with the dietary intake of various nickel compounds and doses are given in Annex 2.

16 Acute toxicity

The acute toxicity of nickel is low. It has been suggested that this may be the result of nickel binding to basolateral metal carriers in the gastrointestinal tract, which blocks its own basolateral transfer (NRC, 2005). Clinical symptoms associated with acute nickel exposure include gastrointestinal disturbances, visual disturbance, headache, giddiness, wheezing and cough (EVM, 2003). Oral LD_{50} values for nickel compounds are reported in Table 5.

Table 5 Oral LD_{50} values for several nickel compounds (ATSDR, 2005)

Species	**Ni compound**	**LD_{50} (mg/kg bw)**
Rats, male	Nickel sulphate	46
Rats, female	Nickel sulphate	39
Rats, female	Nickel acetate	116
Mice, male	Nickel acetate	136
Rats	Nickel oxide	> 3930
Rats	Nickel subsulphide	> 3665

17 Genotoxicity and Mutagenicity

The mutagenicity of nickel compounds has been investigated in bacteria with overall negative results. The induction of chromosomal aberrations has been studied with nickel chloride and nickel sulphate in cultured mammalian cells. Positive results, although weak, were seen in almost all studies in the range of 0.59 – 59 mg Ni/L. A weak increase in sister chromatid exchange, disturbances of spindle function, the inhibition of DNA synthesis / repair and the induction of cell transformation have also been observed in *in vitro* tests with nickel compounds (EFSA, 2005). Chromosome aberrations have been observed *in vivo* in both humans and laboratory animals following exposure to nickel by inhalation (EVM, 2003). An extensive overview of studies that examined the genotoxicity and mutagenicity of nickel compounds is reported by ATSDR (2005).

18 Subchronic toxicity

EFSA (2005) reported on animal experiments investigating subchronic toxicity of various nickel compounds. A concise overview is given in Table 6.

Table 6 Subchronic toxicity of several nickel compounds (EFSA, 2005)

Species	Ni compound	Dose - duration	Effect
Rats, male	Nickel sulphate	9.5 mg Ni/(kg bw.day) - 120 d	Severe lesions in germ cells
Rats	Nickel chloride	Dietary conc: 20 mgNi/kg - 42 d	Decreased body weight gain, slightly lowered haemoglobin levels
Rats	Nickel chloride	Drinking water: 2.5 – 10 mg Ni/L - 28 d	Reduced body weight gain, elevated serum glucose
Rats	Nickel sulphate	5 mg/(kg bw.day) - 7m	Lack of weight gain, extensive proliferation of lymphoid cells and histiocytes and micronecrosis in the intestine

19 Chronic toxicity, including carcinogenicity

Humans have only been rarely exposed to high levels of nickel in water or food. Hence, much of the knowledge of the harmful effects of nickel is based on animal studies. In animals nickel has fairly non-specific toxic effects (EVM, 2003). Lungs, stomach, blood, liver and kidneys were found to be affected in dogs, rats and mice after ingestion of high nickel doses (ATSDR, 2005). In rats exposure to soluble nickel salts was associated with clinical signs of general systemic toxicity ,e.g., lethargy, ataxia, irregular breathing, hypothermia, and salivation, decreased body weight gains, and changes in absolute and relative organ weights (IOM, 2001). Nickel is a potent skin sensitizer and dietary nickel can cause flare-ups of dermatitis (EVM, 2003). IARC (1997) evaluated the carcinogenic risks of nickel. This risk assessment resulted in IARC (1997) classifying nickel compounds as carcinogenic to humans (Group 1) and metallic nickel as possibly carcinogenic to humans (Group 2B).

20 Reproduction toxicity

ATSDR (2005) did not locate any studies in humans regarding reproductive and developmental effects after oral exposure to nickel. EFSA (2005) reported on three reproductive toxicity studies in rats. In these studies the nickel supplementation significantly increased the number of still born pups or pups dying shortly after birth. ATSDR concluded from the available animal studies that the developing fetus and neonates are sensitive targets of nickel toxicity. The most commonly reported endpoints are fetal loss and decreased survival (ATSDR, 2005).

21 Non observed adverse effect level (NOAEL)

There were no NOAEL values identified to establish upper intake levels by the considered scientific bodies.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

IOM (2001) found no available evidence for adverse effects in humans associated with exposure to nickel through the consumption of a normal diet. Hence, a UL value was derived that applies to excess nickel intake as soluble nickel salts. A NOAEL value of 5 mg/(kg bw.day) was identified in two rat studies on the basis of decreased body weight gains and signs of systemic toxicity at higher dose levels. A combined uncertainty factor (UF) of 300 was applied to calculate the UL. The $UF_{combined}$ accounts for extrapolation from the rat study to humans (UF = 100), potential variation within the human population (UF = 100) and for the potential reproductive toxicity of nickel at lower levels (UF = 3). A UL for nickel of 1.0 mg/day for adults was established. Values for other livestage groups are given in Table 7. EVM (2003) identified a LOAEL for nickel of 1.3 mg/(kg bw.day) in a rat study on the basis of increased perinatal mortality. A combined UF of 300 was applied that accounts for LOAEL to NOAEL extrapolation (UF = 3), interspecies variation (UF = 10) and intra-individual variation (UF = 10). A guidance level for nickel of 0.0043 mg/(kg bw.day) was calculated. This level of nickel intake is expected not to results in harmful effects in non-sensitised individuals (EVM, 2003). EFSA (2005) considered the available animal studies inadequate to identify a NOAEL value for nickel and to establish an UL value. For the same reason ATSDR (2005) did not establish oral minimal risk levels for nickel.

Table 7 Upper Intake Levels (UL) for nickel as soluble nickel salts for several life stage groups (IOM, 2001)

Life stage group	**UL (mg Ni/day)**
1 – 3 years	0.2
4 – 8 years	0.3
9 – 13 years	0.6
14 – 18 years	1.0
Adults, ≥ 19 years	1.0
Pregnancy, 14 – 50 years	1.0
Lactation, 14 – 50 years	1.0

23 Toxicological risks for user/workers

In humans, about 20 – 30 % of the inhaled nickel that is retained in the lungs is absorbed into the blood. The remainder is either swallowed, expectorated, or remains in the respiratory tract. Absorption from the respiratory tract is dependent on the solubility of the nickel compound, with higher urinary nickel levels observed in workers exposed to soluble nickel compounds (e.g., nickel chloride, nickel sulphate) than those exposed to less-soluble nickel compounds (nickel oxide, nickel subsulphide) (ATSDR, 2005). The carcinogenicity of nickel has been well documented in occupationally-exposed individuals. Significant increases in the risk of mortality from lung or nasal cancers were observed in several cohorts of nickel refinery workers. The conclusions drawn from occupational exposure studies are supported by animal inhalation studies. Significant increases in the incidence of lung tumors were observed in rats chronically exposed to nickel subsulphide or nickel oxide (ATSDR, 2005). The most commonly reported adverse health effect associated with nickel exposure is contact dermatitis. Contact dermatitis is the result of an allergic reaction to nickel that has been reported in the general population and in workers exposed via dermal contact with airborne nickel, liquid nickel solution, or prolonged contact with metal items. After an individual becomes sensitized to nickel, dermal contact with a small amount of nickel or oral exposure to fairly low doses of nickel can result in dermatitis (ATSDR, 2005). ATSDR (2005) derived inhalation exposure minimal risk levels for nickel of 0.0002 mg Ni/m^3 and 9 10^{-5} mg Ni/m^3 for intermediate-duration and chronic-duration exposure, respectively.

24 Toxicological risks for the environment

There was no information available in principal literature sources on the environmental consequences of the presence of nickel in animal feeds.

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Annex 1: Nickel concentrations in edible tissues and products

Table 1.1 Nickel concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Hogs	326	0.82	2.14	0.57	Coleman *et al*. (1992)
Boars / sows	280	0.24	0.26	0.29	
Pigs	34	< 0.010	0.011	0.012	Jorhem & Sundström (1993)
Pork	60	< 0.025	0.017	0.042	Larsen *et al*. (2002) [a]
Pigs (6 m)	62	0.026	0.009	0.027	López-Alonso *et al*. (2007)

[a]: Total diet study

Table 1.2 Nickel concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Calves	327	0.3	0.29	0.35		Coleman *et al*. (1992)
Heifers / Steers	287	0.27	0.27	0.29		
Bulls / Cows	95	10.2	0.23	0.28		
Lambs	165	0.23	0.25	0.36		
Mature sheep	34	0.25	0.24	0.47		
Cattle		0.036			0.009	Dabeka & McKenzie (1995)
Cattle	5	0.011	< 0.010	0.015		Jorhem & Sundström (1993)
Beef	48	0.014	< 0.014	< 0.014		Larsen *et al*. (2002)[a]
Calf	26	0.017	0.024	0.016		
Lamb		0.018				
Dairy cattle	16				0.07	Leblanc *et al*. (2005)[a]
Dairy cattle	3				0.0011 - 0.012	Santos *et al*. (2004)[a]
Dairy cattle					0.005	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: calves grazing on pastures fertilized with pig slurry; [c]: n= 187

Table 1.3 Nickel concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken and eggs						Bordajandi *et al*. (2004)
Chickens (young)	311	0.26	0.28	0.35		Coleman *et al*. (1992)
Chickens (mature)	308	0.23	0.27	0.36		
Ducks	111	0.52	0.25	0.36		
Chicken		0.027			< 0.007	Dabeka & McKenzie (1995)
Chicken	28	0.017	0.026			Larsen *et al*. (2002)[a]
Turkey	6	0.031	< 0.014			
Poultry		0.02 [b]			0.03 [c]	Leblanc *et al*. (2005)[a]
Hens, private owners	22				0.03658	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.02241	
Poultry and eggs		0.024			0.017	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 1.4 Nickel concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	4.89 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	3.43 DM	
Atlantic herring	3	0.009	Engman & Jorhem (1998)
Baltic herring	3	0.015	
Burbot	2	< 0.004	
Cod	4	0.003	
Eel	3	0.006	
Mackerel	2	< 0.006	
Perch	3	< 0.005	
Picked dogfish	2	< 0.004	
Pike	5	< 0.004	
Plaice	4	0.013	
Pollack	2	< 0.004	
Salmon	3	< 0.005	
Turbot	3	0.005	
Whitefish	3	0.004	
Chub mackerel	60	0.10 - 0.18	Ersoy & Celik (2009)
Mediterranean horse mackerel	60	0.13 - 0.24	
Golden grey mullet	60	0.12 - 0.18	
Round herring	60	0.11 - 0.24	
Hake	3	7.67 DM	Lavilla *et al*. (2008)
Sole	3	5.17 DM	
Schrimp	3	4.9 DM	
Fish	62	0.05	Leblanc *et al*. (2005) [a]
Shellfish	18	0.23	
Fish	3	0.013 - 0.050	Santos *et al*. (2004) [a]
Brushtooth lizardfish, *Saurida undosquamis*	45	6.531 DM	Türkmen *et al*. (2005)
Red mullet *Mullus barbatus*	45	1.359 DM	
Gilthead seabream *Sparus aurata*	45	2.537 DM	
Clarias gariepinus	38	0.009	Türkmen *et al*. (2007)
Carasobarbus luteus	23	0.011	

[a]: Total diet study

Table 1.5 Nickel concentrations in honey (mg/kg)

Description	n	Honey	Reference
Czech honey	24	0.43	Lachman *et al.* (2007)
Origin: Siena County (It)	51	0.308	Pisani *et al*. (2008)
Origin: Turkey	75	0.0026 - 0.0299	Tuzen *et al*. (2007)

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Annex 2: Nickel concentrations in edible tissues and products linked with the dietary intake of several nickel compounds and doses

Table 1 Nickel concentrations in edible tissues and products (mg/kg)

Species / category	Source of Ni supplemented	Dose of Ni supplemented (mg Ni/kg)	Ni content of complete feed (mg Ni/kg)	Duration of study	Liver	Kidney	Muscle	Reference
Pigs	Corn based diet		1.60 DM	([2])	0.97 DM [x]	2.12 DM [x]	0.94 DM [x]	Lisk *et al*. (1982)
	SA - corn based diet		3.30 DM		0.94 DM [x]	4.02 DM [y]	0.94 DM [x]	
Pigs			0.12 [3]	49 d	0.190 DM	0.138 DM [a]	0.125 DM [a]	Spears *et al*. (1984)
	$NiCl_2.6H_2O$	5			0.245 DM	0.218 DM [a]	0.118 DM [a]	
	$NiCl_2.6H_2O$	25			0.248 DM	0.808 DM [b]	0.215 DM [b]	
Calves , male Holstein			~ 1.0 DM	8 w	0.76 DM	2.08 DM [b]	Heart: 1.11 DM	O'Dell *et al*. (1971)
	Nickelous carbonate	62.5			0.88 DM	1.85 DM [b]	Heart: 0.00 DM	
		250			0.37 DM	2.26 DM [b]	Heart: 0.32 DM	
		1000			0.53 DM	22.83 DM [c]	Heart: 0.50 DM	
Calves , male Holstein				140 d	0.046 DM	0.046 DM [a]	0.046 DM	Spears *et al*. (1986)
	$NiCl_2.6H_2O$	5.0			0.060 DM	0.286 DM [b]	0.049 DM	
Chicks, male			([4])	21 d	0.10 [b]	0.13 [b]	0.14 [b]	Ling & Leach (1979)
	Nickel chloride	300			0.36 [b]	4.23 [c]	0.26 [b]	
		500			0.69 [c]	7.65 [d]	0.44 [bc]	
		700			0.99 [d]	9.73 [e]	0.60 [c]	
		900			2.04 [e]	11.15 [f]	1.52 [d]	
		1100			1.43 [f]	11.48 [f]	2.62 [e]	

SA: corn grown on sewage sludge amended soil ; [2]: pigs were fed the experimental diets from an average body weight of 17.6 kg to 90 kg;

3: the background level of the non supplemented feed was 0.16 ppm DM for the first 21 days.

[4]: chicks were fed a purified diet for which a negligible amount of nickel was assumed

Statistics:

Lisk *et al*. (1982): [x,y]: means with different superscripts within each column differ significantly at $P < 0.01$;

Spears *et al*. (1984): means within a column with different superscripts differ significantly at $P < 0.05$;

O'Dell *et al*. (1971): means within a column with different superscripts differ significantly at $P < 0.01$

Spears *et al*. (1986): means within a column with different superscripts differ significantly at $P < 0.05$

Ling & Leach (1979): means within a column not followed by the same letter differ significantly at $P < 0.05$

Annex 2: References

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Rubidium

Executive summary of the monograph for rubidium

NRC classified rubidium as a possible essential element. Under experimental conditions, rubidium deprivation of adult goats was observed to result in abortion, lower birth weight, an increased mortality among kids and reduced weaning weights. No other deficiency signs of rubidium have been reported. Rubidium toxicity signs in rats included depressed growth and failure to reproduce, poor hair coat, sore noses, sensitivity, extreme nervousness leading to convulsions in advanced stages and finally death. For rodents, NRC established a maximum tolerable level (MTL) for rubidium of 200 mg/kg DM. For livestock species the available data were considered insufficient to establish MTL values. The few available data on rubidium concentrations in feed indicate that concentrations are in the mg/kg range. Hence, NRC concluded that rubidium is unlikely to be of any toxicological concern for animals. The absorption, distribution and excretion of rubidium in animals are similar to potassium. Rubidium is highly and rapidly absorbed and is primarily excreted through urine, with a kidney clearance rate slightly less than potassium. No major assessment of the toxicity of rubidium has yet been done by an established body. In general, toxicity data for rubidium as well as monitoring data of rubidium exposure are scarce.

Rubidium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Rubidium was reported to occur in plant tissues as well as in edible animal tissues and products in the ppm range. Monitoring data for rubidium concentrations in food and feed are scarce (NRC, 2005).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorisation of use of rubidium in human and animal nutrition.

3 Essential functions

NRC (2005) classified rubidium as a possible essential element. Under experimental conditions, rubidium deprivation of adults female goats resulted in abortion, lower birth weight, an increased mortality among kids and reduced weaning weights (Underwood & Suttle, 1999).

4 Other functions

No information was available on other functions of rubidium in principal literature sources.

5 Antimicrobial properties

No information was available on antimicrobial properties of rubidium in principal literature sources.

6 Typical deficiency symptoms

Except in goats under experimental conditions (Chapter 3), no deficiency symptoms of rubidium have been reported in principal literature sources.

7 Animal requirements, allowances and use levels

No scientific bodies have established animal requirements for rubidium.

8 Concentration of the element in feed materials

Undewood & Suttle (1999) reported rubidium concentrations in grasses and cereals of respectively, 130 and 3-4 mg/kg DM.

9 Concentration of the element in complete feedingstuffs

Rubidium concentrations in pig feeds, piglet starter rations, and various mixed feeds were reported to range from 2.6 to 26.1 mg/kg DM (NRC, 2005).

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

MTL values for rubidium established by NRC (2005) are compiled in Table 1.

Table 1 Maximum Tolerable Levels (MTL) for rubidium (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Rodents	200	
Poultry, swine, horses, cattle, sheep, fish	-	Available data were considered insufficient to establish a MTL value

11 Typical symptoms of toxicosis

In rats, excessive rubidium ingestion led to depressed growth and failure to reproduce. Rubidium toxicity signs included also poor hair coat, sore noses, sensitivity, extreme nervousness leading to convulsions in advanced stages, and finally death. Rubidium was considered not to be a toxicological concern for animals since the MTL is estimated to be 20 to 100 times greater than levels normally found in animal diets (NRC, 2005).

12 Bioavailability

Rubidium is rapidly and highly absorbed by mammals. It was demonstrated that rubidium and potassium use the same transport system (NRC, 2005).

13 Metabolism

The absorption, distribution and excretion of rubidium in animals are similar to potassium. Absorbed rubidium is primarily excreted through urine, with a kidney clearance rate slightly less than potassium. It was estimated in humans that 30 % of ingested rubidium is excreted through the feces and 70 % through urine (NRC, 2005).

14 Distribution in the animal body

In humans, the following rubidium concentrations were measured: liver, 8 mg/kg; kidney, 6.5 mg/kg; bones: 1 mg/kg. Rubidium tissue levels are influenced by rubidium intake. In rats fed 0.54 and 8.12 mg/kg, rubidium levels were respectively: heart: 0.74 and 9.83 mg/kg; liver: 1.49 and 20.5 mg/kg; kidney: 1.09 and 13.8 mg/kg; muscle, 1.18 and 15.0; tibia, 0.97 and 4.27 and blood, 0.46 and 5.5 mg/L (NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

Rubidium concentrations reported by NRC (2005) are given in Table 2.

Table 2 Rubidium concentrations (mg/kg DM) in edible tissues and products (NRC, 2005)

Species	**Liver**	**Kidney**
Cattle	36	31.6
Sheep	33.6	40.3
Pigs	13.6	14.3

16 Acute toxicity

No information was available on the acute toxicity of rubidium in principal literature sources.

17 Genotoxicity and Mutagenicity

No information was available on the genotoxicity and mutagenicity of rubidium in principal literature sources.

18 Subchronic toxicity

No information was available on subchronic toxicity of rubidium in principal literature sources.

19 Chronic toxicity, including carcinogenicity

No information was available on the chronic toxicity or carcinogenicity of rubidium in principal literature sources.

20 Reproduction and developmental toxicity

No information was available on the reproduction and developmental toxicity of rubidium in principal literature sources.

21 Non Observed Adverse Effect Level (NOAEL)

Upper intake levels have not been established by scientific bodies for rubidium, hence, no NOAEL level was identified to serve as the basis to establish an upper intake level.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

No scientific body has yet established an UL for rubidium.

23 Toxicological risks for user/workers

No information was available on the toxicological risks for users or workers in principal literature sources.

24 Toxicological risks for the environment

To toxicological risks for the environment have been described linked to the presence of rubidium in animal feed in principal literature sources.

25 References

NRC (National Research Council of the National Academies). 2005. Mineral Tolerance of Animals, 2 nd Revised Edition. The National Academies Press, Washington D.C., U.S.

Underwood E.J. and Suttle N.F. 1999. The mineral nutrition of livestock, 3rd Edition. CAB International, Wallingford, UK.

Selenium

Executive summary of the monograph for selenium

Selenium compounds are presently authorized as feed and food additives in the EU. Selenium is an essential element which functions are mediated via selenoproteins, hydrogen selenide and methylated selenium compounds. Over thirty distinctive selenoproteins have been identified of which the most important are peroxidises, deiodinases, and thioredoxin reductase. Selenium deficiency has been reported to induce myodystrophy, exudative diathesis, impaired liver and pancreas function and depressed reproductive ability.

Subclinical selenium deficiency may cause delayed development of immunocompetence and raise susceptibility of animals to infectious diseases.

Young animals are more sensitive to selenium toxicity than adult or older animals. Fish and birds are more susceptible to the teratogenic effect of selenium than mammals. Maximum tolerable levels established by NRC range between 5 and 2 mg/kg DM for ruminants and fish, respectively. Depression of growth performance is a very sensitive indicator of chronic selenium toxicosis across different species. Other signs of chronic selenosis include breaks in hooves, loss of hair, impairment of the immune system. In poultry excess selenium causes reduced hatchability due to deformities of the embryos. In monogastric animals the apparent absorption of selenoamino acids, selenite and selenate falls within the range of 70 - 80 % of the ingested amount. In ruminants, apparent absorbability is reported to vary between 40 - 50 % and 50 - 60% for inorganic and organic selenium compounds, respectively. All tissues can accumulate more selenium with increasing dietary selenium supplementation. In various species, organic selenium sources are more effective than inorganic selenium salts in raising tissue selenium levels. It is well established that ingested selenomethionine is partly incorporated into proteins before entering the regular selenium metabolism.

A moderate genotoxic activity of selenium compounds has been found in several *in vitro* systems. Selenium is known to be chronically toxic and selenosis has been reported in humans and in food areas in seleniferous areas. The first signs of chronic toxicity appear to be pathological changes to hair and nails, followed by adverse effects on the nervous system. Epidemiological studies indicated that the highest long-term daily intake that can be ingested without the development of toxicity in most individuals is approximately 800 µg. SCF and EVM derived upper intake levels for adults of 300µg Se/day and 450 µg Se/day, respectively. The implementation of the actual EU legislation, fixing maximum selenium contents in complete feedingstuffs, limits the contribution of selenium originating from animal excreta in the soil and the aquatic environment.

Selenium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

In animal nutrition, the quantitatively important sources of selenium are the selenoamino acids, selenomethionine (SeMet) and selenocysteine (SeCys), and the inorganic selenium compounds, selenite and selenate. While selenoamino acids are the major selenium compounds in feedingstuffs of plant origin (50-85%), selenate and selenite are widely supplied to animals as inorganic salts via mineral mixes (Whanger, 2002; EFSA, 2006).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Selenium compounds presently authorized in the EU as additives (Council Directive 70/524/EEC [1], Commission Regulations EC 1750/2006[2], EC 634/2007[3], and EC 900/2009[4]) are listed in Table 1.

Table 1 Conditions of use of selenium compounds as additives in feedingstuffs according to the Council Directive 70/524/EEC[1] and Commission Regulations EC 1750/2006[2], EC 634/2007[3] and EC 900/2009[4]

Additive	Chemical formula / Characterisation of the additive	Maximum content of the element in the complete feedingstuff (mg/kg)
Sodium selenite	Na_2SeO_3	0.5 (total)
Sodium selenate	$NaSeO_4$	
Organic form of selenium produced by *Saccharomyces cerevisiae* CNCM I-3060 (selenised yeast inactivated)	Organic selenium mainly selenomethionine (63 %) and low molecular weight selenocomponents (34 – 36 %) content of 2000 – 2400 mg Se/kg (97 - 99 % of organic selenium)	
Selenomethionine produced by *Saccharomyces cerevisiae* NCYC R397 (selenised yeast inactivated)	Organic selenium mainly selenomethionine (63 %) content of 2000 – 2400 mg Se/kg (97 – 99 % of organic selenium)	

[1] OJ C 50, 25.2.2004, p.1

[2] OJ L 330, 28.11.2006, p.9

[3] OJ L 146, 8.6.2007, p.14

[4] OJ L 256, 29.9.2009, p. 12

Table 1 (continued)

Additive	Chemical formula / Characterisation of the additive	Maximum content of the element in the complete feedingstuff (mg/kg)
Selenomethionine produced by *Saccharomyces cerevisiae* CNCM I-3399 (selenised yeast inactivated)	Organic selenium mainly selenomethionine (63 %) content of 2000 – 2400 mg Se/kg (97 – 99 % of organic selenium)	0.50 (total)

In the US, the following selenium compounds are allowed in animal feeds: sodium selenate, sodium selenite and selenium yeast (AAFCO Official Publication §57: Mineral Products) (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

Table 2 Range of selenium guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	**Range (mg/kg)**
Chickens	NRS - 0.3 (added)
Turkeys	NRS - 0.3 (added)
Swine	NRS - 0.3 (added)
Dairy cattle	NRS - 0.3 (added)
Beef cattle	NRS - 0.3 (added)
Sheep	NRS - 0.3 (added)
Horses	NRS
Goats	NRS - 0.3 (added)
Ducks and geese	NRS - 0.3 (added)
Salmonid fish	NRS - 0.1
Mink	NRS
Rabbits	NRS – 0.1 (added)

NRS: No requirement specified

2.2 *Human nutrition*

Selenium compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Commission Regulation 953/2009[5]. The authorized selenium compounds are: sodium selenate, sodium hydrogen selenite, sodium selenite, selenium enriched yeast.

- As food supplements under Regulation 1170/2009[6]. The authorized selenium compounds are: L-selenomethionine, selenium enriched yeast, selenious acid, sodium selenate, sodium hydrogen selenite, sodium selenite.

- As substances which may be added to foods under Regulation 1925/2006[7] as amended by Regulation 1170/2009[6] . The authorized selenium compounds are: selenium enriched yeast, sodium selenate, sodium hydrogen selenite, sodium selenite.

- Directive 2008/100/EC[8] lays down a Recommended Daily Allowance (RDA) for selenium of 55 µg.

3 Essential functions

Selenium is an essential element which biological functions are mediated via specific selenoproteins/selenoenzymes, hydrogen selenide and methylated selenium compounds, respectively (EFSA, 2006; NRC, 2005). Over 30 distinctive selenoproteins have been identified, virtually all containing selenocyteine. The most important known selenoproteins comprise peroxidases, deiodinases, and thioredoxin reductase. Selenoproteins and their functions are listed in the reviews of Fairweather-Tait *et al* (2010) and Papas *et al*. (2008) (Table 3). The peroxidases utilize gluthatione as reducing substrate and help to protect the organism from peroxidative damage (Underwood & Suttle, 1999). A concise summary of the major biological functions of selenium was listed by EFSA (2006):

- Antioxidant to prevent oxidative stress
- Proper thyroid function
- Maintenance of cellular redox status
- Reduction of oxidized ascorbic acid, which in turn can recycle tocopheroxyl to tocopherol
- Development and maintenance of immunocompetence
- Detoxification of heavy metals and some xenobiotics

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[5] OJ L 269, 14.10.2009, p. 19

[6] OJ L 314, 1.12.2009, p. 40

[7] OJ L 404, 30.12.2006, p. 26

[8] OJ L 285, 29.10.2008, p. 9

- Anticancerogenic effects of some methylated selenium compounds

Table 3 Summary of the most important selenoproteins and associated essential functions (Pappas *et al*., 2008)

Selenoprotein	Abbreviation	Cellular distribution	Function
Cytosolic gluthathione peroxidase	GPx1	Cytosol	Antioxidant protection
GI gluthathione peroxidase	GPx2	Gastrointestinal tract	Antioxidant protection
Plasma gluthathione peroxidase	GPx3	Extracellular space and plasma	Maintenance of cellular redox status
Phospholipid hydroperoxide gluthathione peroxidase	GPx4	Cell membrane, many other tissues	Detoxification of lipid hydroperoxides
Epidimyal gluthathione peroxidase	GPx5	Restricted expression to epididymis	Antioxidant protection during spermiogenesis and sperm maturation
Olfactory gluthathione peroxidase	GPx6	Olfactory epithelium, embryonic tissues	Antioxidant protection
Non-selenocysteine containing phospholipid gluthathione peroxidase	GPx7	Many tissues	Unknown, possible role in alleviating oxidative stress in breast cancer cells
Thioredoxin reductase Type I	TRxR1	Cytosol, liver, kidney, heart	Part of thioredoxin system. Antioxidant defence, redox regulation, cell signaling
Thioredoxin reductase Type II	TRxR2	Mitochondria, liver, kidney	Part of thioredoxin system. Antioxidant defence, redox regulation, cell signaling
Thioredoxin reductase Type III	TRxR3	Testes	Part of thioredoxin system. Antioxidant defence, redox regulation, cell signaling

Table 3 (continued) Summary of the most important selenoproteins and associated essential functions (Pappas *et al*., 2008)

Selenoprotein	Abbreviation	Cellular distribution	Function
Iodothyronine deiodinase Type I	ID1	Many tissues including liver, kidney, thyroid	Conversion of T4 to T3 and T4 to reverse T3
Iodothyronine deiodinase Type II	ID2	Liver, kidney, thyroid, brown adipose tissue	Conversion of T4 to T3
Iodothyronine deiodinase Type III	ID3	Placenta, brain, skin	Conversion of T4 to reverse T3
Selenophosphate synthetase	SPS2	Testes, many other tissues	Synthesis of selenophosphate
15 kDa selenoprotein	Sel15	Endoplasmatic reticulum, T cells, many other tissues	Role in cell apoptosis and mediation of chemopreventive effects of Se
Selenoprotein H	SelH		Not fully known, possible upregulation of genes involved in gluthathione synthesis
Selenoprotein I	SelI		Studies with *E. coli* showed specific ethanolamine phosphatase activity
Selenoprotein K	SelK	Cardiomyocytes	Possible antioxidant protection in cardiomyocytes
Selenoprotein M	SelM	Brain and other tissues	Distantly related to Sel15. May be involved in cancer etiology
Selenoprotein N	SelN	Endoplasmatic reticulum	Linked with rigid spine syndrome
Selenoprotein O	SelO	Widely distributed	Unknown
Selenoprotein P	SelP	Plasma and other tissues	Involved in Se transport, antioxidant defense

Table 3 (continued) Summary of the most important selenoproteins and associated essential functions (Pappas *et al*., 2008)

Selenoprotein	Abbreviation	Cellular distribution	Function
Selenoprotein R	SelR	Cytosol, nucleus	Reduction of oxidized methionine residues in damaged proteins
Selenoprotein S	SelS	Endoplasmatic reticulum	Cellular redox balance. Possible influence of inflammatory response
Selenoprotein T	SelT	Ubiquitous	Role in regulation of Ca^{2+} homeostasis and neuroendocrine secretion
Selenoprotein V	SelV	Testes	Unknown, possible role in redox regulation
Selenoprotein W	SelW	Heart and other tissues	Antioxidant protection
Fish 15 kDa Selenoprotein	Fep 15	Endoplasmatic reticulum	Fish homologue of Sep 15
Selenoprotein J	SelJ	Restricted to actinopterygian fishes and sea urchin	Structural role
Selenoprotein U	SelU	Fish and chicken	Unknown

4 Other Effects

Literature data suggest increased oxidative status of the organisms and improved meat characteristics with increased selenium in the diet (Mikulski *et al*., 2009).

5 Antimicrobial properties

No information was available on antimicrobial properties of selenium in principal literature sources.

6 Typical deficiency symptoms

Selenium deficiency may be associated with clinical symptoms including myodystrophy (white muscle disease), exudative diathesis, impaired functions of liver and pancreas and a concomitant depression of production performance and reproductive ability (EFSA, 2006). Subclinical selenium deficiency may cause delayed development of immunocompetence and raise susceptibility of animals to infectious diseases (EFSA, 2006).

7 Animal requirements, allowances and use levels

Selenium requirements of livestock established by scientific bodies are compiled in Annex 3.1, use levels are compiled in Annex 3.2.

8 Concentration of the element in feed materials

Selenium concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Selenium concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Young animals are more sensitive to selenium toxicity than adult or older animals. Fish and birds including chicks and ducks are more susceptible to the teratogenic effect of selenium than mammals (NRC, 2005). MTL values for selenium established by NRC (2005) are compiled in Table 4.

Table 4 Maximum Tolerable Levels (MTL) for selenium (mg/kg DM) (NRC, 2005)

Species	**MTL**	**Additional remarks**
Cattle, sheep	5	
Rodents, horses	5	Values derived from interspecies extrapolation
Swine	4	
Poultry	3	
Fish	2	Value derived from interspecies extrapolation

Additionally to the selenium MTL values, NRC (2005) stated that these values are based on animal health and not human health and lower levels are necessary to avoid excessive accumulation in edible tissues.

11 Typical symptoms of toxicosis

Acute selenium toxicity is characterized by abnormal posture, unsteady walk, diarrhea, abdominal pain, increased pulse and respiration rates, hypotension due to vasodilatation, foamy nasal discharge, prostration and typical garlic smelt of breath due to presence of volatile dimethylselenide (DMSe) in expirated air. The primary targets of acute selenium toxicity in animals appear to be the cardiovascular, gastrointestinal, central nervous and hematopoietic systems (EFSA, 2006). The signs of chronic selenosis in cattle include deformities, cracking and loosing of hooves, lameness, stiffness of joints, dullness, lack of vitality, emaciation, loss of hair. In sows, chronic selenosis is accompanied by reduced performance of the reproductive system. Other observed selenosis clinical signs include, breaks in hooves, loss of hair, reddened skin, neurological symptoms and impairment of the immune system. Selenium intoxication in poultry has been observed to induce lower hatchability due to deformities of the embryos. Experimental selenium intoxication in growing chickens was shown to cause severe diarrhea, dyspnoea and somnolence of birds (EFSA, 2006). Depression of growth performance is a very sensitive indicator of chronic selenium toxicosis across different species (NRC, 2005).

12 Bioavailability

12.1 *General*

In monogastric animals the apparent absorption of selenoamino acids, selenite and selenate falls within the range of 70 – 80 % of the ingested amount. In ruminants, inorganic selenium compounds are partly reduced by ruminal microorganisms to unabsorbable elemental selenium which lowers apparent absorption to vary between 40 to 50 % of the intake. Selenoamino acids are to a lesser extent subject of microbial degradation compared to inorganic selenium compounds. The apparent absorption of selenoamino acids in ruminants ranges between 50 – 60 % (EFSA, 2006).
Differences in bioavailability between selenium compounds reported by Jongbloed *et al*. (2002) are listed in Table 5.

Table 5 Relative bioavailability assessments (%) of selenium compounds compared to sodium selenite in livestock (Jongbloed *et al*., 2002)

Selenium compound	Pigs	Broilers	Ruminants
Sodium selenate			107
Selenomethionine	102	78	124
Yeast selenium	108		109
Selenocysteine		80	

12.2 *Indicators of selenium status*

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of selenium compounds in livestock (Table 6).

Table 6 Ranking of adequacy of response criterions for assessing the relative biological value of selenium compounds [1] (Jongbloed *et al*., 2002)

	Pigs		**Poultry**		**Ruminants**	
Supplementation level →	Suboptimal	Above requirement	Suboptimal	Above requirement	Suboptimal	Above requirement
Criterion						
Gluthathione peroxidase activity	4	2	4	2		
Serum Se	3	1				
Liver Se accumulation	2	2	2	2	4	2
Kidney Se accumulation	2	2	2	2	3	1
Se absorption (true)	2	2	2	2	5	3

[1]: The highest values correspond to the best adequacy

The FEEDAP Panel considered the following parameters suitable for assessing selenium bioavailability: the selenium concentration in serum/plasma, red blood cells and liver as well as the activity of the selenium dependent protein GSH-Px in serum/plasma (EFSA, 2006, EFSA 2006 b, EFSA, 2009).

13 Metabolism

Selenoamino acids are released from dietary protein during the protein digestion process and are absorbed as amino acids. Selenomethionine (SeMet) is absorbed in the small intestine, predominantly in the duodenum, through a sodium dependent system which is shared competitively with methionine. Selenocysteine (SeCys) competes for transport routes with cysteine, lysine and arginine. Selenite and selenate are mainly absorbed in the ileum. Selenite is passively absorbed by simple diffusion whereas selenate is actively absorbed via a co-transport pathway with sodium ions. Consequently, the absorption of selenate may be inhibited by an overdose of sulphur compounds (EFSA, 2006).

The metabolic fate of selenium depends on the amount of absorbed selenium and its chemical form. Inorganic selenium species are directly reduced to selenide (Se^{2-}), while SeMet is transselenated to SeCys, which is subsequently metabolized to selenide by β-lyase. Selenide from all mentioned sources is considered to act as the key intermediate in selenium metabolism. Selenium compounds other than selenoamino acids, selenite or selenate are quickly transformed to selenide and hence metabolized similarly to selenite (EFSA, 2006).

A major pathway of surplus selenium follows methylation and subsequent excretion via urine or breath. When selenium intake is normal, monomethylselenol (MMSe) is the major selenium compound in urine. When the selenium intake is excessive trimethylselenonium (TMSe) in urine and/or dimethylselenide (DMSe) in expirated air appear. Contrarily to selenite, a considerable portion of selenate is directly excreted in urine without being metabolized (EFSA, 2006).

It is well established that ingested SeMet is partly, unspecifically incorporated into body proteins before entering the regular selenium metabolism. This additional metabolic fate of SeMet is based on the fact that $tRNA^{Met}$ in plants, bacteria, birds and mammals does not discriminate between SeMet and sulphur containing methionine. Hence, $tRNA^{Met}$ incorporates SeMet interchangeably into non-specific proteins in various tissues during protein synthesis. Furthermore, SeMet deposited in body tissues is considered to serve as a quantitatively important selenium store capable of releasing selenium during periods of insufficient dietary selenium supply (EFSA, 2006).

14 Distribution in the animal body

In most cases, kidney has the highest selenium concentration among all tissues assayed. Muscle has the lowest selenium concentration among all tissues across all species. Other soft tissues such as lung, heart, pancreas and brain have selenium concentrations that fall between liver and muscle (NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

Selenium concentrations in edible tissues and products are reported in Annex 1 and selenium concentrations linked with the dietary intake of various selenium compounds/doses are reported in Annex 2.

All tissues can accumulate more selenium with increasing dietary selenium supplementation and the elevation can reach 40- to 50 fold over the baseline normal levels. In various species, organic selenium sources are more effective than inorganic selenium salts in raising tissue selenium levels. SeMet seems to be most potent in that regard. It is now well established that ingested SeMet is partly incorporated into body proteins before entering the regular selenium metabolism (EFSA, 2006; NRC, 2005).

16 Acute toxicity

Selenite, selenate and selenomethionine are among the most acutely toxic selenium compounds. In humans an intake of 250 mg selenium as a single dose or multiple doses of 27 - 31 mg was reported to result in acute toxicity with nausea, vomiting, nail changes, dryness of hair, hair loss, tenderness and swelling of fingertips, fatigue, irritability and garlicky breath (SCF, 2000). Oral LD_{50} values for various selenium compounds are reported in Table 7.

Table 7 Oral LD_{50} (mg Se/kg bw) values for various selenium compounds

Se compound	Species	Oral LD_{50}	Reference
Sodium selenite	Rats	4.8 – 7.0	ATSDR (2003)
	Mice	3.2	
	Rabbits	1.0	
L - Selenocysteine	Mice	35.9	
Selenised yeast	Rats	> 5	EFSA (2006)
	Mice	> 4.1	

Sodium selenate and sodium selenite exhibit similar toxicity in female rats, but male rats appeared more susceptible to the toxicity of sodium selenite than selenate (ATSDR, 2003).

17 Genotoxicity and Mutagenicity

A moderate genotoxic activity of selenium compounds (i.e., selenite, selenate, selenide, selenocysteine, selenosulphide) has been found in several *in vitro* systems. *In vitro* studies indicate that the mutagenic effects of selenium salts are associated with the production of reactive oxygen radicals and that gluthathione promotes these reactions. It is well known that auto-oxidisable selenium metabolites, such as hydrogen selenide, can undergo redox cycling producing oxygen radicals and cause DNA strand breaks. Detoxification of selenide by methylation is saturable and depends on the supply of methyl donors (SCF, 2000). An extract of a selenium enriched yeast strain, which contains selenium predominantly in the form of selenomethionine (98 %), has been tested with negative results in the following genotoxicity assays: reversion in bacteria (Ames test); chromosomal aberrations in human lymphocytes *in vitro*; micronucleus test in mouse bone marrow. It was proposed that the greater ability of selenomethionine to be incorporated non-specifically in cellular proteins acts as a sink, and determines the lower toxicity and lack of genotoxicity of selenomethionine compared to other selenium compounds (EFSA, 2008).
Based on the results of *in vitro* and *in vivo* tests the FEEDAP Panel concluded that selenised yeasts are unlikely to have any genotoxic potential (EFSA, 2006; EFSA, 2006b; EFSA, 2009).

18 Subchronic toxicity

In a short term (28 day) toxicity study in Wistar rats, the oral administration of 1000 µg Se/(kg bw.day) as selenium yeast or as sodium selenite resulted in reduced weight gain and food consumption. Both selenium compounds induced hepatotoxicity, including vacuolization and necrosis of hepatocytes, increased apoptosis and acute inflammation. The reduced weight gain and hepatotoxicity were consistently less severe in the treatment groups receiving the selenium yeast (EFSA, 2008).

19 Chronic toxicity, including carcinogenicity

In humans endemic selenium intoxications due to high selenium in soil have been studied. The main symptoms were brittle hair with intact follicles, new hair with no pigment, and thickened nails as well as brittle nails with spots and longitudinal streaks on the surface. Skin lesions were also commonly observed (SCF, 2000).

Animal studies with the synthetic selenium compounds, selenium diethyldithiocarbamate, bis-amino-phenyl selenium dihydroxide and selenium sulphide have shown effects indicative of carcinogenicity (SCF, 2000). SCF (2000) concluded that the carcinogenicity of selenium compounds seems to be primarily associated with the nature of the compound and that the reported carcinogenicity studies did not evaluate the carcinogenicity of selenium compounds that occur in food, nor as nutrients.

20 Reproduction toxicity

ATSDR (2003) did not locate any studies regarding adverse effects on human reproduction following oral exposure to elemental selenium or to selenium compounds, nor any studies where a teratogenicity of selenium or its compounds was demonstrated in humans. SCF (2000) reported that no indication of teratogenicity in humans has been shown even in areas of high selenium intake in China. There is substantial evidence that excess selenium is a teratogen in birds and the sensitivity of the chick embryo to selenium to selenium poisoning has been well documented (ATSDR, 2003).

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake and Upper Intake Level (UL)

In humans, the first signs of chronic toxicity appear to be pathological changes to hair and nails, followed by adverse effects on the nervous system (EVM, 2003).

SCF (2000) used a NOAEL of 850 µg/day for clinical selenosis. This NOAEL value was derived from a study on a large number of individuals which was expected to include sensitive individuals (Yang *et al*., 1989). An uncertainty factor (UF) of 3 was used to account for remaining uncertainties. SCF (2000) derived for selenium an UL of 300 µg/day for adults. This value covers selenium intake from all sources of food, including supplements. UL values for several life stage groups are listed in Table 8.

To establish an UL for selenium, EVM (2003) selected a LOAEL of 0.91 mg/day. An UF of 2 was applied for the use of a LOAEL instead of a NOAEL. Hence, EVM (2003) derived an UL of 0.45 mg/day.

Table 8 Upper Intake Levels (UL) (µg/day) for selenium for several life stage groups

Live stage group	UL (SCF, 2000)
1 - 3 years	60
4 - 6 years	90
7 - 10 years	130
11 - 14 years	200
15 – 17 years	250
Adults	300
Pregnancy and lactation	300

23 Toxicological risks for user/workers

In humans the respiratory system is the primary site of injury after inhalation of elemental selenium or selenium compounds. Acute inhalation of selenium dioxide was reported to have provoked pulmonary edema as a result of the local irritant effect on alveoli. Acute inhalation exposure to elemental selenium dust has been shown to irritate mucous membranes in the nose and throat and to produce coughing, nosebleed, loss of olfaction, and in heavily exposed workers, dyspnea, bronchial spasms, bronchitis, and chemical pneumonia (ATSDR, 2003).

24 Toxicological risks for the environment

For selenised yeasts, the FEEDAP Panel reasoned that their use at recommended levels is unlikely to alter the concentration and distribution of selenium in the environment, as they will replace other selenium additives and do therefore not represent an additional selenium load to the environment (EFSA, 2006; EFSA 2006 b; EFSA, 2009). In addition, the implementation of the actual EU legislation, fixing maximum selenium contents in complete feedingstuffs, limits the contribution of selenium originating from animal excreta in the soil and the aquatic environment.

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26 Glossary

DMSe: dimethylselenide

GPX: gluthathione peroxidase

GSH-Px: gluthathione peroxidase

MMSe: monomethylselenol

SeCys: selenocysteine

SeMet: selenomethionine

Sodium selenite: Na_2SeO_3

Sodium selenate: Na_2SeO_4

T3: 3,5,3’-triiodothyronine

T4: 3,4,3’,5’-tetraiodothyronine

TMSe: trimethylselenonium

Annex 1 Selenium concentrations in edible tissues and products

Table 1 Selenium concentrations in edible tissues (mg/kg) of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Pork		Steak: 0.16 Chop: 0.17 Loin: 0.16			Gerber *et al*. (2009)
Pork		0.115	0.508	1.930	Larsen *et al*. (2002) [a]
Pigs (6 m)	62	0.656	1.17	2.51	López-Alonso *et al*. (2007)

[a]: Total diet study

Table 2 Selenium concentrations in edible tissues and products (mg/kg) of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Dairy cattle					0.23 - 0.35	Ayar *et al*. (2009)
Calves (6 - 12 m)	195		0.215	1.39		Blanco-Penedo *et al.* (2006)
Lamb		Chop: 0.11 Loin: 0.11				Gerber *et al*. (2009)
Beef cattle		Sirloin: 0.09 - 0.3 Rib-eye: 0.11 - 0.44 Steak: 0.10				
Cattle			0.26	0.77		Korsrud *et al*. (1985)
Beef		0.093	0.241	1.270		Larsen *et al*. (2002) [a]
Calves		0.084	0.224	1.370		
Lamb		0.061				
Dairy cattle	16				0.015	Leblanc *et al*. (2005)[a]
Dairy cattle	40				0.0132	Licata *et al*. (2004)
Cattle (free range)	100		0.432	1.02		Nriagu *et al*. (2009)
Dairy cattle					0.014	Ysart *et al*. (2000) [a]

[a]: Total diet study

Table 3 Selenium concentrations in edible tissues and products (mg/kg) of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken		Breast: 0.12 - 0.19 Leg: 0.28				Gerber *et al*. (2009)
Chicken		0.124	0.455		0.242	Larsen *et al*. (2002) [a]
Turkey		0.099	0.520			
Poultry		0.184 [b]			0.040 [c]	Leblanc *et al*. (2005)[a]
Hens, private owners	22				0.273	Van Overmeire *et al*. (2006)
Hens, commercial farms	19				0.197	
Poultry		0.19			0.19	Ysart *et al*. (2000) [a]

[a]: Total diet study; [b]: Poultry and game (n = 24); [c] : Eggs and egg products (n = 30)

Table 4 Selenium concentrations in edible tissues (mg/kg) of fish

Species - category	n	Muscle	Reference
Atlantic herring	3	0.31	Engman & Jorhem (1998)
Baltic herring	3	0.26	
Burbot	2	0.16	
Cod	4	0.26	
Eel	3	0.24	
Mackerel	4	0.37	
Perch	3	0.24	
Picked dogfish	2	0.27	
Pike	5	0.12	
Plaice	3	0.31	
Pollack	2	0.23	
Salmon	3	0.15	
Turbot	3	0.51	
Whitefish	3	0.24	
Cod	50	0.297	Larsen *et al* . (2002) [a]
Herring	30	0.294	
Mackerel	30	0.370	
Fish	62	0.170	Leblanc *et al* . (2005) [a]
Shellfish	18	0.011	

[a]: Total diet study

Table 5 Selenium concentrations in honey (mg/kg)

Description / origin	n	Honey	Reference
Turkey		0.038 - 0.113	Tuzen *et al* . (2007)

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Annex 2 Selenium concentrations in edible tissues and products linked with dietary intake of various selenium sources and doses

Table 1 Selenium concentrations in edible tissues and products of pigs and poultry (mg/kg)

Species / category	Source of Se supplemented	Dose of Se supplemented (mg Se/kg)	Se content of complete feed [1] (mg Se/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Growing-finishing pigs				84 d	0.397	1.664	0.154		Kim & Mahan (2001)
	Sodium selenite	5			3.089	3.108	0.333		
		10			6.399	6.664	0.277		
		15			7.122	8.776	0.323		
		20			8.405	8.567	0.322		
	Se enriched yeast	5			5.590	5.298	3.375		
		10			11.574	9.705	5.927		
		15			17.468	13.768	10.311		
		20			17.693	16.288	7.648		
Laying hens		0	0.150	28 d	0.582 [a]	0.551 [a]	0.135 [a]	0.192 [a]	Pan *et al*. (2007)
	Sodium selenite	0.2	0.347		0.612 [b]	0.763 [b]	0.137 [b]	0.337 [ef]	
	Sodium selenite	0.5	0.652		0.634 [c]	0.863 [c]	0.140 [ab]	0.354 [f]	
	Sodium selenite	1.0	1.157		0.690 [d]	0.826 [cd]	0.149 [b]	0.439 [g]	
	Se-enriched yeast	0.2	0.353		0.623 [bc]	0.700 [e]	0.149 [b]	0.358 [f]	
	Se-enriched yeast	0.5	0.648		0.661 [e]	0.782 [bdf]	0.161 [c]	0.445 [g]	
	Se-enriched yeast	1.0	1.145		0.722 [f]	0.775 [bf]	0.182 [d]	0.578 [h]	
Laying hens			0.10	28 d				0.249	Payne *et al*. (2005)
	Sodium selenite	0.15	0.24					0.284	
		0.30	0.39					0.299	
		0.60	0.57					0.327	
		3.00	2.60					0.641	
	Se-enriched yeast	0.15	0.29					0.366	
		0.30	0.46					0.495	
		0.60	0.79					0.670	
		3.00	2.94					2.207	

Se content of complete feed [1]: data from feed analysis

Statistics: Kim & Mahan (2001): kidney, liver and muscle concentrations: dietary Se source ($P < 0.01$), dietary Se linear response ($P < 0.01$);
Dietary Se level × Se source interaction ($P < 0.01$)
Pan *et al*. (2007): means within a column with different superscripts differ significantly ($P < 0.05$).
Payne *et al*. (2005): control vs. Se supplemented diets $P < 0.01$; sodium selenite linear $P < 0.01$; Se-enriched yeast linear $P < 0.01$.
Utterback *et al*. (2005): means with different superscript differ significantly;

Table 1 (continued) Selenium concentrations in edible tissues and products of poultry (mg/kg)

Species / category	Source of Se supplemented	Dose of Se supplemented (mg Se/kg)	Se content of complete feed [1] (mg Se/kg)	Duration of study	Liver	Kidney	Muscle	Eggs	Reference
Laying hens			0.1 DM	9 m	1.56 DM [a]	2.24 DM [a]	0.40 DM [a]		Petrovic *et al*. (2006)
	Sodium selenite	0.4 DM			2.56 DM [b]	3.93 DM [b]	0.53 DM [a]		
	Selenized yeast	0.4 DM			2.84 DM [b]	4.32 DM [bc]	1.34 DM [b]		
	Selenized yeast	0.9 DM			3.32 DM [c]	4.58 DM [c]	2.06 DM [c]		
Laying hens			0.11	56 d				0.065[c]	Utterback *et al*. (2005)
	Sodium selenite	0.3	0.38					0.182[b]	
	Se-enriched yeast	0.3	0.34					0.311[a]	
Broilers			0.14 - 0.18 [2]	49 d			0.472 DM [a]		Payne & Southern (2005)
	Sodium selenite	0.30	0.35 - 0.40				0.545 DM [a]		
	Se-enriched yeast	0.30	0.33 - 0.43				1.170 DM [b]		
Quail	Selenite (control)	0.2		182 d	0.327	0.664	breast: 0.133 leg: 0.130	yolk: 0.460 white: 0.042	Surai *et al*. (2006)
	Sel-Plex ™	0.5			0.821	1.257	breast: 0.438 leg: 0.357	yolk: 0.865 white: 0.368	

Se content of complete feed [1]: data from feed analysis; [2]: Starter diet: 0.18 mg/kg, grower diet: 0.14 mg/kg, finisher diet: 0.17 g/kg.
Surai *et al*. (2006): background level in the complete feedingstuff: 0.096 mg/kg
Statistics:
Utterback *et al*. (2005): means with different superscript differ significantly;
Payne & Southern (2005): means with different superscripts differ significantly ($P<0.05$);
Surai *et al*. (2006): Se concentrations differed significantly in liver, muscle and egg ($P < 0.001$) and in kidney ($P < 0.01$), Anova
Petrovic *et al*. (2006): specific superscripts within a column differ significantly at $P < 0.05$.

Table 1 (continued) Selenium concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Se supplemented	Dose of Se supplemented (mg Se/(head.day))	Se content of complete feed (mg Se/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Dairy goats			0.133 DM	112 d				0.0233 [a]	Petrera *et al*. (2009)
	Se-yeast	0.26	0.261 DM					0.0313 [b]	
	Sodium selenite	0.26	0.266 DM					0.0248 [a]	

Statistics:
Petrera *et al*. (2009): means with different superscripts differ significantly ($P < 0.001$)

Table 1 (continued) Selenium concentrations in edible tissues and products of ruminants (mg/kg)

Species / category	Source of Se supplemented	Dose of Se supplemented (mg Se/kg)	Se content of complete feed [1] (mg Se/kg)	Duration of study	Liver	Kidney	Muscle	Milk	Reference
Sheep (wethers)	Sodium selenite	0.2	0.48	420 d	2.66	8.43	0.71		Davis *et al*. (2008)
		20	20.48		31.72	19.94	3.13		
		30	30.86		41.42	27.93	4.41		
		40	38.10		78.18	27.89	5.13		
	Se-enriched yeast	0.2	0.54		15.67	22.26	5.73		
		20	20.26		23.42	33.96	14.69		
		30	30.71		132.73	77.61	23.51		
		40	37.65		41.24	36.28	26.87		
Lambs			milk replacer: 0.13 DM weaning pellets: 0.14 DM	91 d	1.35 DM	5.9 DM	*L d*: 0.30 DM *P m*: 0.29 DM		Juniper *et al*. (2009)
	Sel-Plex®		milk replacer: 5.94 DM weaning pellets: 6.63 DM		22.64 DM	18.96 DM	*L d*: 7.82 DM *P m*: 7.02 DM		
Dairy cattle			0.16 DM	112 d				0.024	Phipps *et al*. (2008)
	Sodium selenite		0.30 DM [3]					0.038	
	Sel-Plex®		0.30 DM [3]					0.057	
			0.45 DM [3]					0.072	
Beef steers			0.38 DM	126 d	2.33 DM [a]	8.40 DM [a]	1.33 DM		Lawler *et al*. (2004)
	Sodium selenate		2.84 DM		9.91 DM [b]	10.05 DM [b]	1.55 DM		
Calves			0.15	105 d	1.50	0.92	0.21 [a]		Skrivanova *et al*. (2007)
	Sel-Plex®		0.50 [3]		1.75	1.16	0.43 [b]		

Se content of complete feed [1]: data from feed analysis; [3]: Calculated values

L d: Longissimus dorsi, P m : Psoas major

Statistics:

Davis *et al*. (2008): Se kidney, liver and muscle concentrations: dietary Se level response ($P< 0.05$), Se kidney and muscle concentration: Se source response ($P< 0.05$);
Juniper *et al*. (2009): for all reported tissue concentrations control differs significantly from the treatment group ($P< 0.001$);
Lawler *et al*. (2004): means with different superscripts differ significantly;
Skrivanova *et al*. (2007): Values with different superscripts differ significantly ($P<0.05$) .

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Annex 3: Selenium Requirements

Pigs:

Category - Definition	Se Req. (NRC, 1998) (mg/kg) (a)	Category - Definition	Se Req. (GFE, 2008) (mg Se/kg DM)
Pigs: 3 - 5 kg	0.30	Piglets	0.20 - 0.25
Pigs: 5- 10 kg	0.30		
Pigs: 10 - 20 kg	0.25	Growing - fattening pigs	0.15 - 0.20
Pigs: 20 - 50 kg	0.15		
Pigs: 50 - 80 kg	0.15		
Pigs: 80 - 120 kg	0.15		
Sows: gestation	0.15	Breeding sows	0.15 - 0.20
Sows: lactation	0.15		
		Boars	0.15 - 0.20

Poultry:

Category - Definition	Se Req. (NRC, 1994) (mg/kg) (a)	Category - Definition	Se Req. (GfE, 1999) (mg/kg DM)
Broilers (0 - 8 weeks)	0.15	Broiler (Mast Broiler; Aufzucht Küken)	0.15
Immature leghorn- Type chickens (0-6 wk) white	0.15	Chickens reared for laying (Junghennen)	0.15
Immature leghorn- Type chickens (6 wk - first egg) white	0.10		
Immature leghorn- Type chickens (0-6 wk) brown	0.14		
Immature leghorn- Type chickens (6 wk - first egg) brown	0.10		
Leghorn-Type white egg layers (80 g $FI.day^{-1}$)	0.08	Layers (Eiproduction Legehennen)	0.15
Leghorn-Type white egg layers (100 g $FI.day^{-1}$)	0.06		
Leghorn-Type white egg layers (120 g $FI.day^{-1}$)	0.05		
		Female birds reared for breeding (Zuchthennen)	0.15
Growing turkeys (0 - 24 wk)	0.2		
Turkey holding hens	0.2		
Turkey laying hens	0.2		
White pekin ducks (0 - 2 wk)	0.2		

Bovines:

Category - Definition	Se Req. (Meschy, 2007) (mg/kg DM)
Bovines	0.1

Bovines: Beef Cattle

Category - Definition	Se Req. (NRC, 2000) (mg/kg DM)	Category - Definition	Se Req. (GfE, 1995) (mg/kg DM)
Growing and finishing	0.10	Growing and finishing from 175 kg on	0.1 - 0.15
Cows gestation	0.10		
Cows early lactation	0.10		

Bovines: Dairy Cattle

Category - Definition	Se Req. (NRC, 2001) (mg/kg DM)	Category - Definition	Se Req. (CVB, 2007) (mg/kg DM)
Lactating cow: Holstein - 90 days in milk	0.3	Lactating cows (FI: 20 kg.day^{-1})	0.15
Lactating cow: Jersey	0.3	Lactating cows (FI: 40 kg.day^{-1})	0.18
Dry cows: Holstein (240 d pregnant)	0.3	Dry cows. 8 -3 weeks before calving	0.13
Dry cows: Holstein (279 d pregnant)	0.3	Dry cows. 3 - 0 weeks before calving	0.13

Sheep

Category - Definition	Nutr. Req. (Meschy, 2007) (mg/kg DM)
Sheep	0.1

	Se Req. (NRC, 2007 (b)) concentrate diets - forage diets (mg/day)	Category - Definition	Se Req. (NRC, 2007 (b)) concentrate diets - forage diets (mg /day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	0.09 - 0.18		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	0.45 - 0.90		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	0.17 - 0.34	Mature ewes; breeding. DM intake: 0.85 kg/day	0.03 - 0.07
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	0.34 - 0.68	Mature ewes; breeding. DM intake: 2.18 kg/day	0.10 - 0.20
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	0.35 - 0.70	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	0.68 - 1.36	Mature ewes; early lact.; DM intake: 2.14 kg/day	0.59 - 1.18
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	0.08 - 0.16	Mature ewes; early lact.; DM intake: 5.29 kg/day	0.92 - 1.84
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	0.18 - 0.36	Mature ewes; late lact.; DM intake: 2.35 kg/day	0.26 - 0.53
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	0.20 - 0.41	Mature ewes; late lact.; DM intake: 4.05 kg/day	0.44 - 0.88
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	0.34 - 0.69		

Goats

Category - Definition	Se Req. (GfE, 2003) (mg/kg DM)	Category - Definition	Se Req. (Meschy, 2007) (mg/kg DM)
Goats	0.10 - 0.20	Goats	0.1

	Se Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Se Req. (NRC, 2007 (b)) (mg /day)
Kids; bw: 10 kg; DM intake: 0.35 kg/day	0.29	Mature does; breeding; DM intake: 0.60 kg/day	0.15
Kids; bw: 10 kg; DM intake: 0.39 kg/day	0.46	Mature does; breeding; DM intake: 1.86 kg/day	0.18
Kids; bw: 40 kg; DM intake: 1.10 kg/day	0.33		
Kids; bw: 40 kg; DM intake: 1.41 kg/day	0.85	***Milk yield: 4.65 - 6.43 kg/day***	
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	0.27	Dairy does; early lactation; DM intake: 2.81 kg/day	0.91
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	0.44	Dairy does; early lactation; DM intake: 4.83 kg/day	1.24
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	0.50	***Milk yield: 6.98 - 9.65 kg/day***	
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	0.84	Dairy does; early lactation; DM intake: 3.83 kg/day	1.40
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	0.20	Dairy does; early lactation; DM intake: 5.43 kg/day	1.88
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	0.30	***Milk yield: 1.99 - 2.76 kg/day***	
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	0.34	Dairy does; late lactation; DM intake: 2.48 kg/day	0.59
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	0.51	Dairy does; late lactation; DM intake: 3.64 kg/day	0.77
		Milk yield: 2.99 - 4.13 kg/day	
		Dairy does; late lactation; DM intake: 2.51 kg/day	0.78
		Dairy does; late lactation; DM intake: 4.53 kg/day	1.05

Horses

Category - Definition	Se Req. (NRC, 2007) (mg/day)	Category - Definition	Se Req. (NRC, 2007) (mg/day)
MBW 200 kg; Adult; no work	0.40	MBW 400 kg; Adult; no work	0.80
MBW 200 kg; Adult; working: light exercise	0.40	MBW 400 kg; Adult; working: light exercise	0.80
MBW 200 kg; Adult; working: moderate exercise	0.45	MBW 400 kg; Adult; working: moderate exercise	0.90
MBW 200 kg; Adult; working: (very) heavy exercise	0.50	MBW 400 kg; Adult; working: (very) heavy exercise	1.00
MBW 200 kg; Stallions nonbreeding; breeding	0.40	MBW 400 kg; Stallions nonbreeding; breeding	0.80
MBW 200 kg; Pregnant mares	0.40	MBW 400 kg; Pregnant mares	0.80
MBW 200 kg; Lactating mares	0.50	MBW 400 kg; Lactating mares	1.00
MBW 200 kg; Growing animals: 4 m	0.17	MBW 400 kg; Growing animals: 4 m	0.34
MBW 200 kg; Growing animals: 6 m	0.22	MBW 400 kg; Growing animals: 6 m	0.44
MBW 200 kg; Growing animals: 12 m	0.32	MBW 400 kg; Growing animals: 12 m	0.64
MBW 200 kg; Growing animals: 18 m	0.39	MBW 400 kg; Growing animals: 18 m	0.78
MBW 200 kg; Growing animals: 24 m	0.43	MBW 400 kg; Growing animals: 24 m	0.86

Horses

Category - Definition	Se Req. (NRC, 2007) (mg/day)	Category - Definition	Se Req. (NRC, 2007) (mg/day)
MBW 500 kg; Adult; no work	1.00	MBW 600 kg; Adult; no work	1.20
MBW 500 kg; Adult; working: light exercise	1.00	MBW 600 kg; Adult; working: light exercise	1.20
MBW 500 kg; Adult; working: moderate exercise	1.13	MBW 600 kg; Adult; working: moderate exercise	1.35
MBW 500 kg; Adult; working: (very) heavy exercise	1.25	MBW 600 kg; Adult; working: (very) heavy exercise	1.50
MBW 500 kg; Stallions nonbreeding; breeding	1.00	MBW 600 kg; Stallions nonbreeding; breeding	1.20
MBW 500 kg; Pregnant mares	1.00	MBW 600 kg; Pregnant mares	1.20
MBW 500 kg; Lactating mares	1.25	MBW 600 kg; Lactating mares	1.50
MBW 500 kg; Growing animals: 4 m	0.43	MBW 600 kg; Growing animals: 4 m	0.51
MBW 500 kg; Growing animals: 6 m	0.55	MBW 600 kg; Growing animals: 6 m	0.66
MBW 500 kg; Growing animals: 12 m	0.80	MBW 600 kg; Growing animals: 12 m	0.96
MBW 500 kg; Growing animals: 18 m	0.98	MBW 600 kg; Growing animals: 18 m	1.17
MBW 500 kg; Growing animals: 24 m	1.08	MBW 600 kg; Growing animals: 24 m	1.29
MBW 900 kg; Adult; no work	1.80		
MBW 900 kg; Adult; working: light exercise	1.80		
MBW 900 kg; Adult; working: moderate exercise	2.03		
MBW 900 kg; Adult; working: (very) heavy exercise	2.25		
MBW 900 kg; Stallions nonbreeding; breeding	1.80		
MBW 900 kg; Pregnant mares	1.80		
MBW 900 kg; Lactating mares	2.25		
MBW 900 kg; Growing animals: 4 m	0.77		
MBW 900 kg; Growing animals: 6 m	0.99		
MBW 900 kg; Growing animals: 12 m	1.44		
MBW 900 kg; Growing animals: 18 m	1.76		
MBW 900 kg; Growing animals: 24 m	1.94		

Salmonids

Category - Definition	Se Req. (NRC, 1993) (mg/kg)
Pacific salmon	required but not determined
Rainbow trout	0.3

Dogs

Category - Definition	Se Req. (NRC, 2006) (µg/kg DM)	Se Adequate intake (NRC, 2006) (µg/kg DM)	Se Rec. Allowance (NRC, 2006) (µg/kg DM)
Puppies after weaning	210		350
Adult dogs at maintenance		350	350
Bitches for late gestation and peak lactation		350	350

Cats

Category - Definition	Nut. Req. (NRC. 2006) (µg /kg DM)	Se Adequate intake (NRC. 2006) (µg/kg DM)	Se Rec. Allowance (NRC. 2006) (µg/kg DM)
Kittens after weaning	120		300
Adult cats		300	300
Queens in late gestation and peak lactation		300	300

Glossary

Req.: requirement
(a): 90 % dry matter
MBW: Mature body weight
FI: Feed Intake
lact.: lactation

Annex 3.2 Selenium Use Levels

Table 1 Supplementation recommendations, calculated background level ranges and calculated use levels for selenium (information acquired from the industry)

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg /kg)
Pigs (7 – 20 kg)	0.4	0.0 - 0.1	0.5	0.5
Pigs (20 – 30 kg)	0.4	0.0 -0.1	0.5	0.5
Pigs (30 – 100 kg)	0.4	0.0 - 0.1	0.5	0.5
Sows	0.4	0.0 - 0.1	0.5	0.5
Broilers	0.4	0.0 - 0.1	0.5	0.5
Hens	0.4	0.0 - 0.1	0.5	0.5
Veal	0.4	0.0 - 0.1	0.5	0.5
Cattle	0.4	0.0 - 0.1	0.5	0.5
Dairy Cattle	0.4	0.0 - 0.1	0.5	0.5
Sheep	0.4	0.0 - 0.1	0.5	0.5

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use level for selenium

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	0.2 - 0.3	0.1	0.3 - 0.4
Pigs (15 - 50 kg)	0.15 - 0.3	0.1	0.25 - 0.4
Pigs (50 - 150 kg)	0.2 - 0.3	0.1	0.3 - 0.4
Gestating sows	0.2 - 0.4	0.1	0.3 - 0.4
Lactating sows	0.2 - 0.4	0.1	0.3 - 0.4

Whittemore *et al.* (2002): Summary of supplementation levels found in Denmark, Germany, Netherlands, United Kingdom, United States, Spain and Australia

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Annex 4. Selenium concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	
Potato prot ASH>10	
Potato starch dried	
Se	
Potato pulp CP<95	
Potato pulp CP>95	
Potatoes sweet dried	
Bone meal	
Brewers' grains dr	
Brewers' yeast dried	
Sugarb pulp SUG<100	
Sugarb p SUG100-150	
Sugarb p SUG150-200	
Sugarb pulp SUG>200	
Biscuits CFAT<120	
Biscuits CFAT>120	
Blood meal spray dr	
Buckwheat	
Beans phas heat tr	
Bread meal	
Casein	
Chicory pulp dried	
Citrus pulp dried	
Meat meal Dutch	
Meat meal CFAT<100	
Meat meal CFAT>100	
Peas	
Barley	
Barley feed h grade	
Barley mill byprod	
Grass meal CP<140	
Grass meal CP140-160	
Grass meal CP160-200	
Grass meal CP>200	
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	
Peanut exp p with sh	
Peanut exp with sh	
Peanut extr wtht sh	
Peanut extr with sh	
Oats grain	
Oats grain peeled	
Oats husk meal	
Oats mill fd h grade	
Hempseed	
Carob	

INRA	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	0.11	
Maize	0.1	
Oats	0.19	
Oats groats	0.09	
Rice, brown	0.19	
Rye	0.07	
Sorghum	0.43	
Triticale		
Wheat, durum	0.06	
Wheat, soft	0.12	
WHEAT BY-PRODUCTS		
Wheat bran	0.47	0.13
Wheat middlings	0.62	
Wheat shorts	0.71	
Wheat feed flour		
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%		
Wheat gluten feed, starch 28%		
MAIZE BY-PRODUCTS		
Corn distillers	0.34	
Corn gluten feed	0.21	
Corn gluten meal	0.2	0.1
Maize bran	0.15	
Maize feed flour		
Maize germ meal, expeller		
Maize germ meal, solvent extracted	0.5	
Hominy feed	0.1	
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	0.59	
Brewers' dried grains	0.38	
Rice bran, extracted	0.15	
Rice bran, full fat	0.16	0.08
Rice, broken	0.09	
LEGUME AND OIL SEEDS		
Chickpea	0.09	
Cottonseed, full fat	0.13	
Faba bean, coloured flowers	0.02	
Faba bean, white flowers	0.02	
Linseed, full fat		
Lupin, blue	0.08	
Lupin, white	0.08	
Pea	0.15	
Rapeseed, full fat	0.77	
Soybean, full fat, extruded	0.28	
Soybean, full fat, toasted	0.28	
Sunflower seed, full fat	0.58	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	
Cottons exp p with h	
Cottons exp with h	
Cottons extr wtht h	
Cotts extr p with h	
Cottons extr with h	
Coconut exp CFAT<100	
Coconut exp CFAT>100	
Coconut extr	
Linseed	
Linseed exp	
Linseed extr	
Lentils	
Lupins CP<335	
Lupins CP>335	
Alf meal CP<140	
Alf meal CP140-160	
Alf meal CP160-180	
Alf meal CP>180	
Poppyseed	
Macoya fruit exp	
Maize	
Maize chem-h treated	
Maize gluten meal	
Maize glfeed CP<200	
Maize glfd CP200-230	
Maize glfeed CP>230	
Maize germ meal extr	
Maize germ m fd exp	
Maize germ m fd extr	
Dist grains and sol	
Maize feedflour	
Maize feed meal	
Maize feed meal extr	
Maize bran	
Maize starch	
Sugarbeet molasses	
Sugarc mol SUG<475	
Sugarc mol SUG>475	
Milk powder skimmed	
Milk powder whole	
Millet	

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller		
Cottonseed meal, crude fibre 7-14%	0.38	
Cottonseed meal, crude fibre 14-20%	0.54	
Grapeseed oil meal, solvent extracted	0.03	
Groundnut meal, detoxified, crude fibre < 9%	0.1	
Groundnut meal, detoxified, crude fibre > 9%	0.16	
Linseed meal, expeller	0.45	
Linseed meal, solvent extracted	0.66	
Palm kernel meal, expeller	0.12	
Rapeseed meal	1.1	0.3
Sesame meal, expeller	0.21	0.04
Soybean meal, 46		
Soybean meal, 48	0.2	
Soybean meal, 50	0.21	
Sunflower meal, partially decorticated	0.49	
Sunflower meal, undecorticated	0.51	
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	0.07	
Cassava, starch 72%	0.06	
Maize starch		
Potato tuber, dried	0.04	
Sweet potato, dried	0.02	
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	0.11	0.06
Beet pulp dried, molasses added	0.11	
Beet pulp, pressed	0.03	
Brewers' yeast, dried	0.82	
Buckwheat hulls		
Carob pod meal		
Citrus pulp, dried		
Cocoa hulls		
Grape marc, dried		
Grape seeds		
Liquid potato feed		
Molasses, beet		
Molasses, sugarcane		
Potato protein concentrate	1	
Potato pulp, dried		
Soybean hulls	0.21	
Vinasse, different origins	0	
Vinasse, from the production of glutamic acid	2	
Vinasse, from yeast production		
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	
Malt culms CP>200	
Nigerseed	
Horsebeans	
Horsebeans white	
Palm kernels	
Palm kern exp CF<180	
Palm kern exp CF>180	
Palm kernel extr	
Rapeseed	
Rapeseed exp	
Rapeseed extr CP<380	
Rapeseed extr CP>380	
Rapes meal Mervobest	
Rice wtht hulls	
Rice with hulls	
Rice husk meal	
Rice bran meal extr	
Rice feed m ASH<90	
Rice feed m ASH>90	
Rye	
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	
Semameseed meal extr	
Soybeans heat tr	
Soybeans not heat tr	
Soybean hulls CF<320	
Soyb hulls CF320-360	
Soybean hulls CF>360	
Soybean exp	
Soybm CF<45 CP<480	
Soybm CF<45 CP>480	
Soybm CF45-70 CP<450	
Soybm CF45-70 CP>450	
Soyb meal CF>70	
Soyb meal Mervobest	
Soyb meal Rumi S	
Sorghum	
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	
Tapioca STA 625-675	
Tapioca STA 675-725	
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	0.25	
Alfalfa, dehydrated, protein 17-18% dry matter	0.25	
Alfalfa, dehydrated, protein 18-19% dry matter	0.25	
Alfalfa, dehydrated, protein 22-25% dry matter	0.24	
Grass, dehydrated	0.2	0.08
Wheat straw		
DAIRY PRODUCTS		
Milk powder, skimmed	0.14	
Milk powder, whole	0.2	
Whey powder, acidic	0.2	
Whey powder, sweet	0.3	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	0.41	
Fish meal, protein 65%	0.4	
Fish meal, protein 70%	0.4	
Fish solubles, condensed, defatted	2	
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	0.58	0.08
Feather meal	0.7	0.05
Meat and bone meal, fat <7.5%	0.43	
Meat and bone meal, fat >7.5%	0.43	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	
Wheat gluten meal	
Wheat glutenfeed	
Wheat middlings	
Wheat germ	
Wheat germfeed	
Wheat feedfl CF<35	
Wheat feedfl CF35-55	
Wheat feed meal	
Wheat bran	
Triticale	
Feather meal hydr	
Fat from Animals	
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	
Vinasse Sugb CP>250	
Fish meal CP<580	
Fish meal CP580-630	
Fish meal CP630-680	
Fish meal CP>680	
Meat bone m CFAT<100	
Meat bone m CFAT>100	
Whey p l lac ASH<210	
Whey p l lac ASH>210	
Whey powder	
Sunflowers deh	
Sunflowers p deh	
Sunflowers w hulls	
Sunfls exp deh	
Sunfls exp p deh	
Sunfls exp w hulls	
Sunfmeal CF<160	
Sunfmeal CF 160-200	
Sunfmeal CF 200-240	
Sunfmeal CF>240	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	
Potato pulp pr NL	
Potato pulp pressed	
Potato cut raw	
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	
Pot sta STA 650-775	
Pot sta STA>750	

CVB

MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	
Pot s g STA 425-550	
Pot s g STA 550-675	
Pot sta gel STA>675	
Brewers gr 22% DM	
Brewers gr 27% DM	
Brewers yeast CP<400	
Brewers y CP400-500	
Brewers yeast CP>500	
Beetp pressed f+sil	
CCM CF<40	
CCM CF 40-60	
CCM CF>60	
Chicory pulp f+sil	
Distillers sol f	
Cheese whey CP<175	
Cheese w CP175-275	
Cheese whey CP>275	
Maize glutenf f+sil	
Maize solubles	
Wheat st FR STAt 300	
Wheat st STAtot 400	
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	**mg/kg DM**
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	
Beet rests siliâ€led	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	
Barley straw	
Grass fr April l y.	
Grass fr April n y.	
Grass fr April h y.	
Grass fr May l y.	
Grass fr May n y.	
Grass fr May h y.	
Grass fr June l y.	
Grass fr June n y.	
Grass fr June h y.	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	
Grass fr July n y.	
Grass fr July h y.	
Grass fr Aug l y.	
Grass fr Aug n y.	
Grass fr Aug h y.	
Grass fr Sept l y.	
Grass fr Sept n y.	
Grass fr Sept h y.	
Grass fr Oct l y.	
Grass fr Oct n y.	
Grass fr Oct h y.	
Grass average	
Grass horse gr past	
Grass horse same fld	
Grass sil May 2000	
Grass sil May 3500	
Grass sil May 5000	
Grass sil June 2000	
Grass sil June 3000	
Grass sil June 4000	
Grass sil Ju-Au 2000	
Grass sil Ju-Au 3000	
Grass sil Ju-Au 4000	
Grass sil Se-Oc 2000	
Grass sil Se-Oc 3000	
Grass sil average	
Grass sil horse fine	
Grass sil horse midd	
Grass sil horse crs	
Grass hay good qual	
Grass hay av qual	
Grass hay poor qual	
Grass hay horse fine	
Grass hay horse midd	
Grass hay horse crs	
Grass bales ad	
Grass seeds straw	
Oat straw	
Clover red fresh	
Clover red silage	
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	
Lucerne hay	
Lucerne (alfalfa) ad	
Maize Cob with leaves silage	
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	
Maize fod fr DM<240	
Maize f fr DM240-280	
Maize f fr DM280-320	
Maize fod fr DM 320	
Maize sil DM < 240	
Maize sil DM240-280	
Maize sil DM280-320	
Maize sil DM 320	
Maize (Fodder) ad	
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	
Chicory rts not frcd	
Chicory rts frcd cleaned	
Chicory rts frcd dirty	
Carrots	
Sunflower silage	

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	
Calcium carbonate	0.07
Diammonium phosphate	
Difluorinated phosphate	0.6
Dicalcium phosphate	0.6
Mono-dicalcium phosphate	0.6
Monoammonium phosphate	
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of selenium in a representative complete feedingstuff for a list of farm animal categories using INRA[1] trace element composition tables[2]

	# Feed materials	Mass with element concentration (%)	# Feed materials with element concentration	Element concentration (mg/kg)
Piglet Starter I (from weaning)	9	89.2	6	0.157
Piglet Starter II (complete feed)	20	78.2	10	0.123
Pig Grower (complete feed)	19	88.4	10	0.161
Pig Finisher (complete feed)	18	90.7	9	0.188
Sows, gestating (complete feed)	18	83.6	10	0.200
Sows, lactating (complete feed)	20	79.5	11	0.153
Starter Chicks (complete feed)	15	85.9	7	0.151
Chicken reared for laying (complete feed)	17	81.6	8	0.169
Layer Phase I (complete feed)	16	94.8	8	0.175
Layer Phase II (complete feed)	16	87.4	8	0.165
Broiler Starter (complete feed)	14	96.6	7	0.156
Broiler Grower (complete feed)	15	91.3	7	0.145
Broiler Finisher (complete feed)	15	89.8	6	0.143
Turkey Starter (complete feed)	14	96.7	6	0.172
Turkey Grower (complete feed)	13	93.5	6	0.161
Turkey Finisher (complete feed)	11	94.3	5	0.154
Turkey Breeder (complete feed)	8	91.4	5	0.119
Duck, grower/finisher (complete feed)	10	95.0	5	0.176
Geese, grower/finisher (complete feed)	8	98.7	6	0.142
Calf, milk replacer (complete feed)	10	30.7	1	0.061
Calf concentrate (complete feed)	17	79.9	9	0.220
Calf concentrate (complementary feed)	16	59.7	8	0.241
Cattle concentrate (complete feed)[3]	9	87.4	5	0.136
Cattle concentrate (complementary feed)	8	82.0	4	0.108
Dairy cows TMR (based on corn silage)[3]	15	98.6	10	0.204
Dairy cows TMR (based on grass silage)[3]	15	97.6	10	0.209
Dairy concentrate (complementary feed)	13	88.6	8	0.316
Dairy cows mineral feed (min. 40% crude ash)	8	39.3	2	0.074
Rabbit, breeder (complete feed)	8	99.1	5	0.335
Rabbit, grower/finisher (complete feed)	14	96.9	7	0.250
Salmon feed (wet)[3]	4	70.4	2	0.240
Salmon feed (dry)	6	79.4	3	0.259
Trout feed (dry)	12	78.2	4	0.177
Dog food (dry)	12	81.9	6	0.231
Cat food (dry)	16	65.1	6	0.297

[1] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [2] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [3] On DM basis

Selenium: Addendum to the monograph

Abstract

This addendum to the selenium monograph substantiates the data reported in Annex 5 of the selenium monograph in which selenium background levels are reported. The addendum provides the following information for each calculated background level: (1) the selenium concentration in each of the composing feed materials as reported by INRA (2004) and Batal & Dale (2008), feed materials for which no selenium concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated selenium content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	34.93	0.038	24.40
Maize	0.10	10.00	0.010	6.35
Wheat, soft	0.12	16.68	0.020	12.71
Wheat middlings	0.62	5.00	0.031	19.69
Soybean, full fat, extruded	0.28	15.10	0.042	26.85
Soybean meal, 50	0.21	7.50	0.016	10.00
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	0.157	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	15.00	0.017	13.43
Maize	0.10	15.81	0.016	12.87
Wheat, soft	0.12	27.50	0.033	26.87
Wheat middlings	0.62	2.00	0.012	10.10
Wheat gluten feed, starch 28%		10.00		
Corn distillers	0.34	3.00	0.010	8.30
Palm kernel meal, expeller	0.12	4.00	0.005	3.91
Rapeseed cake		6.00		
Soybean meal, 50	0.21	7.86	0.017	13.44
Sunflower meal, undecorticated	0.51	2.55	0.013	10.58
Tallow		3.00		
Phytase		1.50		
Calcium carbonate	0.07	0.45	<0.001	0.26
L-Lysine HCl		0.49		
Monocalciumphosphate	0.60	0.05	<0.001	0.24
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	0.123	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	20.00	0.022	13.63
Maize	0.10	9.42	0.009	5.83
Wheat, soft	0.12	35.00	0.042	26.01
Wheat middlings	0.62	7.27	0.045	27.92
Corn distillers	0.34	5.00	0.017	10.53
Palm kernel meal, expeller	0.12	4.00	0.005	2.97
Rapeseed cake		7.00		
Soybean meal, 50	0.21	3.40	0.007	4.42
Sunflower meal, undecorticated	0.51	2.32	0.012	7.31
Beet pulp, dried	0.11	2.00	0.002	1.36
Tallow		2.09		
Calcium carbonate	0.07	0.02	<0.001	0.01
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	0.161	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	20.00	0.022	11.69
Maize	0.10	6.93	0.007	3.68
Wheat, soft	0.12	35.00	0.042	22.31
Wheat middlings	0.62	10.00	0.062	32.94
Wheat gluten feed, starch 28%		3.04		
Corn distillers	0.34	6.21	0.021	11.22
Palm kernel meal, expeller	0.12	5.00	0.006	3.19
Rapeseed cake		1.35		
Sunflower meal, undecorticated	0.51	4.98	0.025	13.49
Beet pulp, dried	0.11	2.50	0.003	1.46
Tallow		2.00		
Calcium carbonate	0.07	0.04	<0.001	0.01
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	0.188	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	20.00	0.022	11.00
Maize	0.10	15.26	0.015	7.63
Wheat, soft	0.12	11.22	0.013	6.74
Wheat bran	0.47	12.50	0.059	29.38
Wheat middlings	0.62	7.50	0.047	23.26
Wheat gluten feed, starch 28%		5.00		
Maize germ meal, expeller		7.50		
Palm kernel meal, expeller	0.12	5.00	0.006	3.00
Sunflower meal, undecorticated	0.51	6.11	0.031	15.60
Beet pulp, dried	0.11	5.50	0.006	3.03
Molasses, sugarcane		0.10		
Tallow		1.91		
Phytase		1.50		
Calcium carbonate	0.07	0.48	<0.001	0.17
L-Lysine HCl		0.24		
Monocalciumphosphate	0.60	0.07	<0.001	0.20
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	0.200	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	20.00	0.022	14.33
Maize	0.10	10.00	0.010	6.52
Wheat, soft	0.12	23.43	0.028	18.32
Wheat middlings	0.62	7.50	0.047	30.30
Wheat gluten feed, starch 28%		10.00		
Soybean, full fat, extruded	0.28	1.39	0.004	2.54
Palm kernel meal, expeller	0.12	4.00	0.005	3.13
Rapeseed cake		6.00		
Soybean meal, 50	0.21	5.13	0.011	7.01
Sunflower meal, undecorticated	0.51	4.22	0.022	14.01
Beet pulp, dried	0.11	2.41	0.003	1.73
Tallow		2.16		
Phytase		1.50		
Calcium carbonate	0.07	1.02	0.001	0.47
L-Lysine HCl		0.34		
Monocalciumphosphate	0.60	0.42	0.003	1.66
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	0.153	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	20.00	0.020	13.24
Wheat, soft	0.12	35.62	0.043	28.30
Wheat gluten feed, starch 28%		5.75		
Soybean, full fat, extruded	0.28	0.69	0.002	1.28
Rapeseed cake		5.00		
Soybean meal, 50	0.21	19.79	0.042	27.52
Sunflower meal, undecorticated	0.51	7.94	0.041	26.82
Tallow		2.00		
Calcium carbonate	0.07	1.34	0.001	0.62
L-Lysine HCl		0.07		
Monocalciumphosphate	0.60	0.56	0.003	2.21
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.151	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	15.00	0.015	8.89
Wheat, soft	0.12	41.54	0.050	29.53
Wheat bran	0.47	7.50	0.035	20.88
Wheat gluten feed, starch 28%		10.00		
Corn distillers	0.34	2.50	0.009	5.04
Rapeseed cake		5.00		
Soybean meal, 50	0.21	2.95	0.006	3.67
Sunflower meal, undecorticated	0.51	10.00	0.051	30.21
Tallow		2.00		
Calcium carbonate	0.07	1.79	0.001	0.74
L-Lysine HCl		0.23		
Monocalciumphosphate	0.60	0.29	0.002	1.04
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	0.169	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	20.00	0.020	11.43
Wheat, soft	0.12	38.18	0.046	26.18
Wheat gluten feed, starch 28%		0.47		
Corn distillers	0.34	4.00	0.014	7.77
Soybean, full fat, extruded	0.28	8.36	0.023	13.38
Soybean meal, 50	0.21	5.93	0.012	7.12
Sunflower meal, undecorticated	0.51	10.00	0.051	29.14
Tallow		2.87		
Calcium carbonate	0.07	7.78	0.005	3.11
L-Lysine HCl		0.23		
Monocalciumphosphate	0.60	0.55	0.003	1.87
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.175	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	20.00	0.020	12.14
Wheat, soft	0.12	30.36	0.036	22.12
Wheat gluten feed, starch 28%		7.41		
Corn distillers	0.34	4.00	0.014	8.26
Soybean, full fat, extruded	0.28	7.80	0.022	13.27
Soybean meal, 50	0.21	6.34	0.013	8.09
Sunflower meal, undecorticated	0.51	10.00	0.051	30.97
Tallow		3.40		
Calcium carbonate	0.07	8.48	0.006	3.60
L-Lysine HCl		0.20		
Monocalciumphosphate	0.60	0.43	0.003	1.55
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	0.165	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	30.00	0.030	19.20
Wheat, soft	0.12	28.16	0.034	21.63
Corn gluten meal	0.20	2.50	0.005	3.20
Soybean, full fat, extruded	0.28	15.00	0.042	26.88
Soybean meal, 50	0.21	18.41	0.039	24.75
Tallow		1.50		
Calcium carbonate	0.07	1.62	0.001	0.73
L-Lysine HCl		0.44		
Monocalciumphosphate	0.60	0.94	0.006	3.62
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.156	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	15.00	0.015	10.34
Wheat, soft	0.12	42.41	0.051	35.08
Corn gluten meal	0.20	1.56	0.003	2.14
Soybean, full fat, extruded	0.28	10.00	0.028	19.30
Rapeseed cake		2.50		
Soybean meal, 50	0.21	20.22	0.042	29.26
Tallow		4.44		
Calcium carbonate	0.07	1.38	0.001	0.67
L-Lysine HCl		0.33		
Monocalciumphosphate	0.60	0.78	0.005	3.22
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	0.145	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat, soft	0.12	57.84	0.069	48.51
Corn gluten meal	0.20	0.68	0.001	0.95
Soybean, full fat, extruded	0.28	10.16	0.028	19.88
Rapeseed cake		2.50		
Soybean meal, 50	0.21	19.32	0.041	28.35
Tallow		6.00		
Calcium carbonate	0.07	1.38	0.001	0.68
L-Lysine HCl		0.28		
Monocalciumphosphate	0.60	0.39	0.002	1.63
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	0.143	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	20.00	0.020	11.60
Wheat, soft	0.12	25.35	0.030	17.65
Soybean meal, 50	0.21	42.45	0.089	51.72
Fish meal, protein 70%	0.40	5.00	0.020	11.60
Calcium carbonate	0.07	1.99	0.001	0.81
L-Lysine HCl		0.34		
Monocalciumphosphate	0.60	1.90	0.011	6.61
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.82	0.172	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	6.94	0.007	4.30
Wheat, soft	0.12	40.00	0.048	29.78
Soybean, full fat, extruded	0.28	2.00	0.006	3.47
Soybean meal, 50	0.21	41.24	0.087	53.72
Calcium carbonate	0.07	1.15	0.001	0.50
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	0.60	2.21	0.013	8.23
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	0.161	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	11.74	0.012	7.61
Wheat, soft	0.12	40.00	0.048	31.12
Soybean meal, 50	0.21	39.50	0.083	53.79
Calcium carbonate	0.07	1.30	0.001	0.59
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	0.60	1.77	0.011	6.89
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	0.154	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	69.44	0.069	58.50
Soybean meal, 50	0.21	11.40	0.024	20.17
Feather meal	0.70	2.00	0.014	11.79
Calcium carbonate	0.07	7.60	0.005	4.48
Dicalcium Phosphate	0.60	1.00	0.006	5.05
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	0.119	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat, soft	0.12	68.91	0.083	46.92
Wheat middlings	0.62	9.00	0.056	31.66
Soybean meal, 50	0.21	15.00	0.032	17.87
Calcium carbonate	0.07	1.20	0.001	0.48
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	0.60	0.90	0.005	3.06
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	0.176	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	10.00	0.011	7.74
Maize	0.10	34.00	0.034	23.92
Wheat, soft	0.12	20.00	0.024	16.88
Soybean meal, 50	0.21	33.00	0.069	48.75
Calcium carbonate	0.07	1.20	0.001	0.59
Dicalcium Phosphate	0.60	0.50	0.003	2.11
Premix		1.00		
Salt		0.30		
Total		100.00	0.142	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat gluten feed, starch 25%		5.00		
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	0.20	30.65	0.061	100.00
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	0.061	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	0.54	0.001	0.27
Wheat middlings	0.62	7.00	0.043	19.70
Wheat feed flour		8.00		
Linseed, full fat		1.25		
Rapeseed, full fat	0.77	3.50	0.027	12.23
Soybean, full fat, toasted	0.28	5.37	0.015	6.83
Palm kernel meal, expeller	0.12	5.50	0.007	3.00
Rapeseed meal	1.10	1.94	0.021	9.69
Beet pulp, dried	0.11	5.50	0.006	2.75
Citrus pulp, dried		8.00		
Molasses, beet		1.00		
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	0.20	50.00	0.100	45.38
Calcium carbonate	0.07	0.51	<0.001	0.16
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	0.220	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	1.08	0.001	0.49
Wheat middlings	0.62	14.00	0.087	36.07
Wheat feed flour		16.00		
Linseed, full fat		2.50		
Rapeseed, full fat	0.77	7.00	0.054	22.40
Soybean, full fat, toasted	0.28	10.74	0.030	12.50
Palm kernel meal, expeller	0.12	11.00	0.013	5.48
Rapeseed meal	1.10	3.88	0.043	17.74
Beet pulp, dried	0.11	11.00	0.012	5.03
Citrus pulp, dried		16.00		
Molasses, beet		2.00		
Vinasse, different origins		3.00		
Calcium carbonate	0.07	1.02	0.001	0.30
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	0.241	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	18.90	0.021	15.30
Wheat, soft	0.12	17.50	0.021	15.45
Linseed, full fat		7.51		
Soybean meal, 50	0.21	10.99	0.023	16.98
Beet pulp, dried	0.11	10.01	0.011	8.10
Molasses, beet		0.98		
Grass silage	0.20	30.00	0.060	44.16
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	0.136	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	27.00	0.030	27.40
Wheat, soft	0.12	25.00	0.030	27.68
Linseed, full fat		10.70		
Soybean meal, 50	0.21	15.70	0.033	30.42
Beet pulp, dried	0.11	14.30	0.016	14.51
Molasses, beet		1.40		
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	0.108	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat middlings	0.62	0.96	0.006	2.92
Corn gluten feed	0.21	0.95	0.002	0.98
Corn gluten meal	0.20	1.15	0.002	1.13
Palm kernel meal, expeller	0.12	1.78	0.002	1.05
Rapeseed meal	1.10	6.18	0.068	33.37
Rapeseed cake		0.59		
Soybean meal, 50	0.21	7.83	0.016	8.07
Beet pulp, dried	0.11	2.61	0.003	1.41
Molasses, beet		0.24		
Vinasse, different origins		0.36		
Grass silage	0.20	26.89	0.054	26.40
Corn silage	0.10	50.23	0.050	24.66
Calcium carbonate	0.07	0.06	<0.001	0.02
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	0.204	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat middlings	0.62	1.74	0.011	5.16
Corn gluten feed	0.21	1.72	0.004	1.73
Corn gluten meal	0.20	2.08	0.004	1.99
Palm kernel meal, expeller	0.12	3.22	0.004	1.85
Rapeseed meal	1.10	4.39	0.048	23.09
Rapeseed cake		1.07		
Soybean meal, 50	0.21	3.97	0.008	3.99
Beet pulp, dried	0.11	4.72	0.005	2.48
Molasses, beet		0.43		
Vinasse, different origins		0.64		
Grass silage	0.20	49.18	0.098	47.03
Corn silage	0.10	26.46	0.026	12.65
Calcium carbonate	0.07	0.11	<0.001	0.04
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	0.209	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat middlings	0.62	8.10	0.050	15.91
Corn gluten feed	0.21	8.00	0.017	5.32
Corn gluten meal	0.20	9.70	0.019	6.15
Palm kernel meal, expeller	0.12	15.00	0.018	5.70
Rapeseed meal	1.10	15.00	0.165	52.28
Rapeseed cake		5.00		
Soybean meal, 50	0.21	10.30	0.022	6.85
Beet pulp, dried	0.11	22.00	0.024	7.67
Molasses, beet		2.00		
Vinasse, different origins		3.00		
Calcium carbonate	0.07	0.50	<0.001	0.11
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	0.316	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)		Dairy cows mineral feed (min. 40% crude ash)		
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize starch		0.17		
Calcium carbonate	0.07	30.50	0.021	28.79
Dicalcium Phosphate	0.60	8.80	0.053	71.21
Salt		22.60		
Diammonium phosphate		6.40		
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	0.074	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	2.00	0.002	0.66
Wheat bran	0.47	46.00	0.216	64.58
Soybean meal, 50	0.21	9.00	0.019	5.65
Alfalfa, dehydrated	0.24	40.00	0.096	28.68
Calcium carbonate	0.07	2.10	0.001	0.44
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	0.335	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Barley	0.11	23.00	0.025	10.14
Wheat bran	0.47	12.00	0.056	22.60
Soybean meal, 50	0.21	5.00	0.011	4.21
Sunflower meal, undecorticated	0.51	10.00	0.051	20.43
Beet pulp, dried	0.11	10.00	0.011	4.41
Lard		2.00		
Alfalfa, dehydrated	0.24	35.00	0.084	33.65
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	0.60	1.90	0.011	4.57
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	0.250	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat, soft	0.12	14.90	0.018	7.45
Fish meal, protein 70%	0.40	55.53	0.222	92.55
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	0.240	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat, soft	0.12	7.42	0.009	3.44
Soybean meal, 50	0.21	20.00	0.042	16.22
Fish meal, protein 70%	0.40	52.00	0.208	80.34
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	0.259	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat, soft	0.12	2.87	0.003	1.95
Corn gluten meal	0.20	11.80	0.024	13.37
Soybean meal, 50	0.21	55.00	0.116	65.42
Maize starch		3.00		
Fish meal, protein 70%	0.40	8.50	0.034	19.26
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	0.177	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Maize	0.10	27.80	0.028	12.05
Rice, brown	0.19	7.30	0.014	6.01
Maize starch		2.78		
Beet pulp, dried	0.11	4.30	0.005	2.05
Brewers' yeast, dried	0.82	1.10	0.009	3.91
Lard		9.60		
Meat and bone meal, fat <7.5%	0.43	40.62	0.175	75.73
Calcium carbonate	0.07	0.80	0.001	0.24
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	0.231	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Se/kg feed material	% feed material	mg Se/kg complete feedingstuff	Se (% contribution)
Wheat, soft	0.12	12.21	0.015	4.93
Wheat feed flour		20.00		
Wheat gluten feed, starch 25%		2.06		
Linseed, full fat		3.00		
Brewers' yeast, dried	0.82	1.80	0.015	4.96
Fish meal, protein 70%	0.40	1.00	0.004	1.34
Feather meal	0.70	18.00	0.126	42.37
Meat and bone meal, fat <7.5%	0.43	29.76	0.128	43.03
Meat and bone meal, fat >7.5%	0.43	2.33	0.010	3.37
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	0.297	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Silicon

Executive summary of the monograph for silicon

Several silicon compounds are presently authorized as feed and food additives in the EU. Silicon is generally not accepted as an essential nutrient for higher animals and humans because it lacks a defined biochemical function. Silicon has been claimed to have a beneficial effect on several human disorders, e.g., osteoporosis, aging of the skin, hair and nails and atherosclerosis. Silicon deprivation was reported to lead to abnormally shaped bones and cartilage tissue in chicks, rats and calves. Silicon deprived rats showed decreased bone hydroxyproline and alkaline- and acid phosphatase activity. Furthermore, in rats decreases in collagen formation in wounds, and bone and liver ornithine transaminase activity were observed. Forages and cereal grains high in fiber are the major sources of silicon for animals. Soil type, plant species, transpiration rate, and nutrient supply affect the silica content of plants. Contamination of feeds, especially hay and pasture herbage, with soil elevates the silicon content. Extremely high intakes of silicon are required to induce only minor effects on growth and reproduction. The harmful effects of an excessive silicon intake in animals include a depression in roughage dry matter digestibility and formation of urinary calculi for ruminants, and depressed growth and abnormal reproduction for rats. Silicon is not considered as a problem for livestock except for a few areas in the world where the conditions are right for urolithiasis. The absorbability of silicon is considerably influenced by the amount ingested. Dietary silicon in low amounts is well absorbed based on human findings. Studies with ruminants indicate that generally less than 4% is absorbed when the diet contains high amounts of silicon as silica. Silicon is widely distributed in the body. Connective tissues contain the highest amounts. Silicon levels in foods from animal origin are lower compared to levels found in foods derived from plants.

Silicon is not considered to be genotoxic *in vitro* or *in vivo*. There are no reports on human toxicity following intake of silicon occurring naturally in food. Humans have for decades consumed amorphous silicates as food additives used for anti-foaming and anti-caking purposes without any reported deleterious effects. Silicon in the form of magnesium trisilicate has been used as an antacid for several decades. The only related adverse effect is the formation of renal silicate stones. EVM established an upper intake level (UL) for supplemental silicon of 700 mg/day for adults. EFSA and IOM considered the available data insufficient to establish an UL value. If inhaled at high concentrations over prolonged periods, certain forms of silica can cause silicosis. Inhaled silica particles can cause tissue damage that ultimately results in fibrosis which reduces the efficiency of the lungs and results in shortness of breath. Silicon is ubiquitously present in the environment. Hence, there were no indications that the presence of silicon in animal diets would have environmental consequences.

Silicon Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Silicon occurs naturally in foods as silicon dioxide (silica) and silicates. Orthosilicic acid ($Si(OH)_4$) is the major silicon species present in drinking water and other liquids e.g., beer (EFSA, 2004). Several silicon compounds are allowed as food and feed additives as anti-caking and anti-foaming agents (Chapter 2).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal nutrition

Silicon compounds presently authorized in the EU as feed additives (Council Directive 70/524/EEC[1]) and as feedingstuffs intended for the reduction of milk fever (Commission Directive 2008/4/EC[2]) are listed in Table 1.

Table 1 Silicon compounds authorized as feed additives (subclassification: binders, anticaking agents and coagulants) according to Council Directive 70/524/EEC[1] and Commission Directive 2008/4/EC[2]

EC No	Additive	Species or category of animal : Maximum content mg/kg of complete feedingstuff
E 551a	Silicic acid, precipitated and dried	All species or categories of animals
E 551b	Colloidal silica	All species or categories of animals
E 551c	Kieselgur, (diatomaceous earth, purified)	All species or categories of animals
E 552	Calcium silicate, synthetic	All species or categories of animals
E 554	Sodium aluminosilicate, synthetic	All species or categories of animals
E 558	Bentonite-montmorillonite	All species or categories of animals: 20000
E 559	Kaolinitic clays, free of asbestos	All species or categories of animals
E 560	Natural mixtures of steatites and chlorite	All species or categories of animals
E 561	Vermiculite	All species or categories of animals
E 562	Sepiolite	All species or categories of animals
E 563	Sepiolitic clay	
E 566	Natrolite-phonolite	All species or categories of animals : 25000
E 599	Perlite	All species or categories of animals
3	Clinoptilolite of volcanic origin	All species or categories of animals: 20000
4	Clinoptilolite of sedimentary origin	All species or categories of animals: 20000
	Zeolite (synthetic sodium aluminium silicate)	

[1] OJ C 50, 25.2.2004, p. 1

[2] OJ L 6, 10.1.2008, p. 4

In the US, the AAFCO adopted from the Code of Federal Regulations the following silicon compounds its Official Publication: Aluminium calcium silicate (582.2122), Magnesium silicate (582.2437), Hydrated sodium calcium aluminosilicate (582.2729), Tricalcium silicate (582.2906). These compounds are not specifically defined by AAFCO. They are listed in the Code of Federal Regulations as Substances Generally Recognized as Safe in Animal Feeds, Subpart C: Anticaking Agents (AAFCO, 2010).

2.2 Human nutrition

Silicon compounds are presently authorized in the EU as food additives other than colours and sweeteners (Council Directive 95/2/EC[3]). The authorized silicon compounds are: E 551 silicon dioxide, E 552 calcium silicate, E 553a magnesium silicate, magnesium trisilicate, E554 sodium aluminium silicate, E 555 Potassium aluminium silicate, E 556 Calcium aluminium silicate, E559 Aluminium silicate (Kaolin).

In the US the Code of Federal Regulations grants the generally recognized as safe status to various silicon compounds for their use as food additives, namely: General Purpose Food Additives: Bentonite (582.1155); Anticaking Agents: aluminium calcium silicate (582.2122), Calcium silicate (582.2227), magnesium silicate (582.2437), sodium aluminosilicate (582.2727), hydrated sodium calcium aluminosilicate (582.2729), Tricalcium silicate (582.2909).

3 Essential functions

NRC (2005) classified silicon as possibly essential. Silicon is generally not accepted as an essential nutrient for higher animals, apparently because of the lack of a clearly defined specific biochemical function (NRC, 2005). EFSA (2004) stated that the essentiality of silicon for man has not been established and a functional role for silicon in humans has not yet been identified. Both NRC and EFSA reported on observed deficiency symptoms in rats, chicks and calves. Additionally, it was shown *in vitro* that orthosilicic acid at physiological concentrations stimulated collagen type I synthesis, probably by modulating propyl hydroxylase activity, in human osteoblast like cells and to a lower degree in skin fibroblasts, and promoted osteoblastic differentiation (EFSA, 2004). Several lower forms of life, e.g., diatoms have an absolute requirement for silicon as monomeric silicic acid for normal cell growth (NRC, 2005).

[3] OJ L 61, 18.3.1995, p.1

4 Other functions

Silicon was reported to play a role in collagen and glycosaminoglycan formation or function, and thus influences bone formation, wound healing, and ectopic calcification (NRC, 2005; Uthus & Seaborn, 1996). Silicon has been claimed to have a beneficial effect on several human disorders e.g., osteoporosis, aging of the skin, hair and nails and atherosclerosis (Van Dyck *et al*., 1999). Silicate containing clay minerals and zeolite are added to livestock diets to increase animal welfare (EFSA, 2007).

5 Antimicrobial properties

No information was available on antimicrobial properties of silicon in principal literature sources.

6 Typical deficiency symptoms

In chicks, rats and calves, silicon deprivation was reported to lead to abnormally shaped bones and cartilagenous tissue. Silicon deprived rats showed decreased bone hydroxyproline and alkaline- and acid phosphatase activity. Furthermore, silicon deprivation in rats decreases collagen formation in wounds, and bone and liver ornithine transaminase activity (EFSA, 2004).

7 Animal requirements, allowances and use levels

No silicon requirements have been established by scientific bodies.

8 Concentration of the element in feed materials

Forages and cereal grains high in fiber, e.g., oats (4250 mg/kg) and barley (2420 mg/kg), are the major sources of silicon for animals (NRC, 2005; EVM, 2003). Silicon, present in plants as silica and soluble silicates, and in organic combinations, is bound to the cellulosic cell structure. Hydrated silica known as opaline silica or silica gel is commonly deposited in plants in the form of particles called phytoliths. Soil type, plant species, transpiration rate, and nutrient supply affect the silica content of plants. Contamination of feeds, especially hay and pasture herbage, with soil elevates the silicon content. In areas where urolithiasis is a problem for ruminants, the amount of silicon provided by the diet is extremely high. The gramineous species in these areas can contain up to 6% DM silicon (NRC, 2005).

9 Concentration of the element in complete feedingstuffs

There was no information available on silicon concentrations in complete feedingstuffs in principal literature sources.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Extremely high amounts of silicon are needed to induce just relatively minor effects on growth (NRC, 2005). The MTL values for silicon established by NRC (2005) are compiled in Table 2.

Table 2 Maximum Tolerable Levels (MTL) for silicon (mg/kg DM) (NRC, 2005)

Species	**MTL**	**Additional remarks**
Sheep	2000	
Cattle	2000	Value derived from interspecies extrapolation
Rodents, poultry, swine, horses, fish	-	Available data were considered insufficient to establish a MTL value

11 Typical symptoms of toxicosis

The most serious toxic effect of silicon is the formation of kidney stones in ruminants. Silicon urolithiasis is a concern in range animals in western Australia, western regions of Canada, and the arid northwestern United States. In other parts of the world, silicon toxicity is not a serious problem under practical farm and ranch conditions (EFSA, 2004; NRC, 2005). Although not a true toxicity action, silicon is reported to depress dry matter digestibility of forages. Renal tubular damage has been observed in guinea pigs and dogs following the oral administration of high doses of sodium silicate and magnesium trisilicate (EFSA, 2004).

12 Bioavailability

Early balance studies in animals indicated that the majority of the ingested silicon remains unabsorbed. In studies with ruminants, absorbabilities were estimated to be less than 4% when the diet contains high amounts of silicon as silica These low absorbabilities were likely the result of intakes of silicon that exceeded the amounts needed to achieve maximal absorption (NRC, 2005). Generally, the absorbability of silicon depends on the solubility of the silicon compound. It has been reported that the absorption of silicic acid from the gut varies between 20 – 75 % (EVM, 2003, IOM, 2001).

13 Metabolism

Silicon in blood exists almost entirely as silicic acid and is not bound to proteins. Silicon is widely distributed in the tissues. Absorbed silicon is predominantly excreted through urine (EFSA, 2004; EVM, 2003; IOM, 2001).

14 Distribution in the animal body

Various connective tissues including the aorta, trachea, bone, tendons, and skin contain most of the silicon present in the body (EFSA, 2004; IOM, 2001).

15 Deposition (typical concentration) in edible tissues and products

Silicon levels in foods from animal origin are lower compared to levels found in foods derived from plants (EVM, 2003). Silicon concentrations in beef, chicken and milk have been reported to be 1.21 mg/kg, 1.09 mg/kg and 0.76 mg/kg, respectively (Robberecht *et al*., 2008).
Silicon concentrations in edible tissues and products linked with dietary silicon intake are given in Annex 2.

16 Acute toxicity

EFSA (2004), EVM (2003) and IOM (2001) did not adopt any acute oral toxicity studies of silicon in humans in their assessments. Oral LD_{50}- values reported by NRC (2005) are given in Table 3.

Table 3 Oral LD_{50} values for silicon compounds (NRC, 2005)

Species	**Si compound**	**LD_{50}**
Rats	Silicon dioxide	> 22.5 g Si/kg bw
Mice	Silicon dioxide	> 15 g Si/kg bw
Rats	Sodium silicate	1.1 – 1.6 g Si/kg bw
Mice	Sodium silicate	1.1 g Si/kg bw
Rats	Sodium metasilicate	1.28 g Si/kg bw
Mice	Sodium metasilicate	2.4 g Si/kg bw
Rodents	Amorphous hydrophobic silica	> 7.9 g Si/kg bw
Humans	Oral silica / magnesium trisilicate	> 15 g Si/kg bw
Humans	Sodium silicate	0.5 – 5 g Si/kg bw

17 Genotoxicity and Mutagenicity

Silica is not considered to be genotoxic *in vitro* or *in vivo* (EFSA, 2004; EVM, 2003). Silicon was shown not to be carcinogenic in mice or rats at 5 % in the diet. Silica was negative in the *Bacillus subtilis rec* assay and was not mutagenic in the Ames test. Sister chromatid exchange was not induced in Chinese hamster V79 cells at a range of concentrations. Quarts has been reported to induce dose dependent increases in the number of morphologically transformed Syrian hamster cells (EVM, 2003).

18 Subchronic toxicity

EFSA (2009a), EFSA (2009b) adopted the results of subchronic toxicity trials with choline-stabilised orthosilicic acid and sodium metasilicate in their assessments. No observed side effects were reported. In Wistar rats given doses of sodium silicate up to 0.2% in drinking water, it was found that the anti-oxidant enzyme activity was reduced.

19 Chronic toxicity, including carcinogenicity

There are no reports on human toxicity following intake of silicon occurring naturally in food. Humans have for decades consumed low levels of amorphous silicates as food additives used for anti-foaming and anti-caking purposes without any reported deleterious effects. Silicon in the form of magnesium trisilicate has been used as an antacid for several decades. The only related adverse effect is the formation of renal silicate stones (EFSA, 2004; EVM, 2003; IOM, 2001). In chronic dialysis patients with high silicon plasma levels the following symptoms have been observed and might have been caused by silicon: painful skin eruptions, folliculitis, and disturbed hair growth (EFSA, 2004).

20 Reproduction and developmental toxicity

EFSA (2004) reported on one rat study that evaluated the oral reproductive and developmental toxicity of amorphous silica and which did not reveal any adverse effects.

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

IOM (2001) found no adequate data demonstrating a NOAEL for silicon and considered the available toxicity data insufficient to establish a UL. EVM (2003) identified a NOAEL for supplemental dietary silica of 50000 mg silica/kg, equivalent to 2500 mg silica/(kg bw.day) in rats and 7500 mg silica/(kg bw.day) in mice. A combined uncertainty factor of 100 was applied to account for interspecies variation (UF = 10) and interindividual variation (UF = 10). A UL value was calculated of 12 mg Si/(kg bw.day) or 700 mg Si/day for a 60 kg adult for supplemental silicon (EVM, 2003). EFSA (2004) considered the available data on toxicity of silicon insufficient to establish an UL value. It was stated that the dietary intake of silicon from food additives unlikely to cause adverse effects (EFSA, 2004).

23 Toxicological risks for user/workers

If inhaled at high concentrations over prolonged periods, certain forms of silica can cause silicosis. Silica particles are inhaled into the alveoli of the lung causing tissue damage that ultimately results in fibrosis, which reduces the efficiency of the lungs and results in shortness of breath. IARC has classified silica by inhalation as a Group I, known human carcinogen based on human epidemiological data with support from studies in both animals and biological systems (EVM, 2003). The carcinogenicity of inhaled silica particles is due to local tissue damage and inflammation with the production of reactive oxygen species, which overwhelm cellular defences and damage DNA. This process is considered not to be relevant to oral exposure to silica or silicon (EVM, 2003).

24 Toxicological risks for the environment

No relevant information was found in principal literature sources on environmental consequences of presence of silicon compounds in animal feed.

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Annex 2: Silicon concentrations in edible tissues and products linked with the dietary intake of silicon

Table 1 Silicon concentrations in edible tissues and products (mg/kg)

Species / category	Source of Si supplemented	Dose of Si supplemented (mg Si/kg)	Si content of complete feed (mg Si/kg)	Duration of study	Liver	Kidney	Muscle	Plasma (mg/L)	Reference
Chicks			1	4 w				0.14 [a]	Carlisle (1980)
	$Na_2SiO_3.9H_2O$	250						2.19	
Calves			479	39 d	1.43 DM	8.1 DM	4.85 DM	0.49	Turner *et al* . (2008)
	Sodium zeolite A		1632		2.08 DM	44.2 DM	7.63 DM	0.64	

Statistics

Carlisle (1980): [a]: Means differ significantly at P< 0.001

Table 1 Silicon concentrations in edible tissues and products (mg/kg)

Species / category	Source of Si supplemented	Dose of Si in complete feed (mg Si/day)	Duration of study	Liver	Kidney	Muscle	Milk (mg/L)	Plasma (mg/L)	Reference
Horses		10.79	45 d				0.265 [x]	1.263	Lang *et al* . (2001)
	Sodium Zeolite A	44.29					0.896 [y]	1.515	

Statistics :

Lang *et al* . (2001): [x,y]: Means with different superscripts differ significantly at P≤ 0.01

Annex 2: References

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Silver

Executive summary of the monograph for silver

Silver is considered a non-essential element as no essential functions have yet been identified. Silver compounds are used as water disinfection agents. Silver nanoparticles were shown to be beneficial for growth in weaned piglets which might be attributable to their antimicrobial properties. In poultry and rodents, excessive ingestion of silver induced signs associated with copper and selenium deficiency among which depressed growth was commonly observed. NRC concluded that silver is a relatively nontoxic element when ingested with a diet that contains rich amounts of copper, selenium and vitamin E. Contrarily, ionic silver in water is highly toxic to fish. Many silver compounds are known to be absorbed by humans across mucous membranes in the mouth and following ingestion. An average absorbability of 10 % for ingested silver has been reported. Following absorption silver undergoes a first pass effect through the liver resulting in silver being excreted into bile, thereby reducing systemic distribution to body tissues. Studies on rodents have indicated a high initial concentration of silver in the liver that decreases greatly within ten days, whereas silver concentrations in the spleen and brain are retained for longer periods.

Water soluble silver compounds have a local corrosive effect and may cause fatal poisoning if swallowed accidentally. Repeated dietary exposure to silver salts or colloidal silver brings about effects classically described as generalized argyria. This clinical entity is characterized by a grey-blue pigmentation of the skin and other body viscera. Inhaled silver compounds may be absorbed and the occupational exposure to silver dusts may lead to respiratory irritation. No relevant information was available in principal literature sources on environmental consequences related to the presence of silver in livestock diets.

Silver Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Silver may be ingested through consumption of marine organisms, through the release of small amounts from dental fillings and eating utensils and through drinking water which may be treated with silver for disinfection purposes (Holler *et al*., 2007).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorisation of use of silver and silver compounds in human and animal nutrition.

3 Essential functions

NRC (2005) classified silver as a non-essential element as no essential function for silver has been identified in animals.

4 Other functions or effects

No other functions or effects of silver have been reported in principal literature sources.

5 Antimicrobial properties

Silver is used as a drinking water disinfection agent (NRC, 2005). It was observed in weaned piglets that low doses of metallic silver nanoparticles given as dietary additive could improve feed intake and growth. It was suggested that this effect might be mediated through the antimicrobial properties of the product (Fondevila *et al*., 2009). RIVM assessed the potential risks of nanosilver particles and concluded that due to their nanosize these particles have specific properties. Additionally, it could not be determined to what extent the nanoform of a substance corresponds to the non-nanoform of the same substance. Furthermore, the adequacy of current risk assessment methods for these particles was questioned (RIVM, 2009).

6 Typical deficiency symptoms

No deficiency symptoms for silver have been reported in principal literature sources.

7 Animal requirements, allowances and use levels

No scientific bodies have established silver requirements.

8 Concentration of the element in feed materials

Accumulation of silver by terrestrial plants from soils is low, even if the soil is amended with silver containing sewage sludge. Generally, land plants have silver concentrations of 60 µg/kg. Hence, NRC concluded that diets are apparently not significant sources of silver for livestock (NRC, 2005; WHO, 2002). NRC (2005) did not locate any reports on silver concentrations in feed materials.

9 Concentration of the element in complete feedingstuffs

There were no data available on silver concentrations in complete feedingstuffs in principal literature sources.

10 Tolerance of animal species and Maximum Tolerable levels (MTL)

MTL values for silver established by NRC (2005) are compiled in Table 1.

Table 1 Maximum Tolerable Levels (MTL) (mg/kg DM) for silver (NRC, 2005)

Species	MTL	Additional remarks
Poultry	100	
Swine	100	Value derived from interspecies extrapolation
Fish	> 3	
Rodents, horses, cattle, sheep	-	Data were considered insufficient to set MTL values

11 Typical symptoms of toxicosis

In poultry, dietary silver concentrations above 100 mg/kg as silver sulphate have induced signs associated with copper and selenium deficiency including depressed growth, hemoglobin and aortic elastin, increased mortality and heart weight, and exudative diathesis. In turkeys, gizzard musculature dystrophy, enlarged hearts, and decreased packed red blood cells were observed in addition to depressed growth. In growing rats, signs of silver toxicity included depressed growth, increased mortality, liver necrosis, and a generalized deposition of silver in tissues (argyrosis). Ionic silver in water is highly toxic to fish. The manifestations of acute silver toxicity in fish are the result of the failure to maintain constant concentrations of sodium and chloride ions in blood plasma. Freshwater fish have a higher sensitivity to silver ions compared to marine fish (NRC, 2005). NRC (2005) concluded that silver is a relatively nontoxic element when ingested with a diet that contains rich amounts of copper, selenium and vitamin E.

12 Bioavailability

12.1 General

Many silver compounds, including silver salts and silver-protein colloids, are known to be absorbed by humans across mucous membranes in the mouth and following ingestion. The intestinal absorption of silver by mice, rats, monkeys, and dogs was reported to be approximately 10 % or less after ingestion of radioactive silver. A value of 18 % was estimated from a single human subject given silver acetate (ATSDR, 1999; Holler *et al*., 2007).

12.2 *Indicators of silver exposure*

Levels of silver in feces, blood, and urine have been associated with recent exposure via inhalation, oral and dermal routes. These biomarkers appear to be independent on the route of exposure, but have not been quantitatively correlated with the level and duration of exposure. Because silver is primarily excreted through the feces, recent exposure is most easily monitored through fecal analysis. Silver levels in biopsy specimens, e.g., of skin, may provide information concerning repeated exposure (ATSDR, 1990).

13 Metabolism

Following absorption, silver undergoes a first pass effect through the liver resulting in excretion into bile, thereby reducing systemic distribution to body tissues. Observations indicate that silver and copper share a common transport system for their hepatobiliary removal (ATSDR, 1990; NRC, 2005). The deposition of silver in tissues is the result of the precipitation of insoluble silver salts, such as silver chloride and silver phosphate. These insoluble silver salts appear to be transformed into soluble silver sulphide albumates, to bind to or form complexes with amino or carboxyl groups in RNA, DNA, and proteins, or to be reduced to metallic silver by ascorbic acid or catecholamines. Excretion of silver from the body is primarily biliary (ATSDR, 1990).

14 Distribution in the animal body

The distribution of ingested silver to various tissues depends upon quantity of silver administered and its chemical form (ATSDR, 1990). Studies on rodents have indicated a high initial concentration of silver in the liver that decreases greatly within 10 days, whereas silver concentrations in the spleen and brain are retained for longer periods. A study of the distribution of silver in mice that were provided drinking water containing 0.03 mg Ag/L as radiolabeled silver nitrate for one to two weeks found that the highest concentrations of the radiolabel occurred in musculus soleus, cerebellum, spleen, duodenum and myocardial muscle. In a human being exposed to radioactive silver, > 50 % of the body burden of silver was found in the liver 16 days and later after exposure (Holler *et al*., 2007; NRC, 2005).

15 Deposition (typical concentration) in edible tissues and products

ATSDR (1990) reported the following values on silver concentration in edible tissues and products: milk: 0.037 – 0.059 mg/kg, beef: 0.004 – 0.024 mg/kg, pork: 0.007 – 0.012 mg/kg, mutton and lamb: 0.006 – 0.011 mg/kg, fish (total fish): 0.004 – 1.900 mg/kg, molluscs: 0.1 – 10.0 mg/kg.

16 Acute toxicity

Water soluble silver compounds such as silver nitrate have a local corrosive effect and may cause fatal poisoning if swallowed accidentally (Holler *et al*., 2007). Autopsy findings in a case of a lethal intravenous injection of collargol, a silver salt, included pulmonary edema, hemorrhage, and necrosis of the bone marrow, liver and kidney (Holler *et al*., 2007).

17 Genotoxicity and Mutagenicity

ATSDR did not locate any studies regarding the genotoxic effects in humans or animals after oral exposure to silver or silver compounds. No *in vitro* studies regarding the genotoxic effects of silver or silver compounds were adopted in the Toxicological Profile (ATSDR, 1990).

18 Subchronic toxicity

No information on subchronic toxicity of silver or silver compounds was available in principal literature sources.

19 Chronic toxicity, including carcinogenicity

Repeated dietary exposure to silver salts or colloidal silver brings about effects classically described as generalized argyria. This clinical entity is characterized by a grey-blue discoloration of the skin, most pronounced in areas exposed to light. The discoloration is explained by deposits of microscopically detectable silver containing granules in the corium and particularly around the hair follicles and the sebaceous and sweat glands. The deposition of these silver compounds causing discoloration and sometimes also functional impairment may also occur in the basement membrane of the kidney, in the cornea and the anterior capsule of the lens, in the respiratory tract and gastrointestinal tract (Holler *et al*., 2007). Several reports describe the deposition of what are assumed to be silvercontaining granules in tissues of the central nervous system. There is however no evidence that clearly relates the existence or deposition of these granules to a neurotoxic effect of silver exposure (ATSDR, 1990).

20 Reproduction toxicity

ATSDR (1990) did not locate any studies in humans regarding reproductive and developmental effects after oral exposure to silver or silver compounds. No diminution of fertility was observed in male rats exposed for two years to 88.9 mg Ag/(kg bw.day) as silver nitrate or silver chloride in drinking water (ATSDR, 1990).

21 Non observed adverse effect level (NOAEL)

There were no NOAEL values identified for silver by scientific bodies to establish upper intake levels.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

No Upper Intake Levels for silver were established by scientific bodies.

23 Toxicological risks for user/workers

Silver compounds may be absorbed through inhalation, but there are no quantitative human data on the extent (Holler *et al*., 2007). Occupational exposure to silver dusts may lead to respiratory irritation. Abdominal pain has been reported in workers exposed to silver nitrate and silver oxide in the workplace at levels estimated to be between 0.039 – 0.378 mg/m^3 (ATSDR, 1999).

24 Toxicological risks for the environment

No relevant information was found in principal literature sources on environmental consequences related to the presence of silver in livestock diets.

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Strontium

Executive summary of the monograph for strontium

Strontium is considered a non-essential trace element. It can substitute for calcium in bone and was shown to increase bone formation and uncouple bone formation from bone resorption. In humans, strontium ranelate is a promising pharmaceutical for the treatment of postmenopausal osteoporosis. Extremely high oral doses of strontium relative to normal intakes are needed to elicit toxic effects in animals. Excessive strontium might disturb calcium metabolism. When young and growing animals are fed high dietary strontium in combination with low dietary calcium, they develop a condition known as strontium rickets. In humans, absorption of ingested strontium was for adults and children reported to be in the range of respectively, 11 – 28% and 15 – 30%. The distribution of strontium in the human body is similar to that of calcium, with approximately 99% of the total body burden in the skeleton. Absorbed strontium is primarily excreted via urine and feces.

Strontium caused death in laboratory animals only at doses that are very high compared to normal human exposure. There is little evidence for genotoxicity of stable strontium. Studies with young animals fed high dietary strontium and low or inadequate calcium levels showed significant adverse skeletal effects. ATSDR derived a minimal risk level for intermediate duration oral exposure to stable strontium of 2 mg/(kg bw.day). Case reports suggest that inhaled strontium compounds can be absorbed from the lungs without indications of linked adverse health effects. There were no indications that the presence of strontium in livestock diets would have environmental consequences.

Strontium Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Foods and feedstuffs of plant origin are richer sources of strontium than animal products, except for bone. Water may significantly add to the intake of strontium (NRC, 2005).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorization of use of strontium and strontium compounds in human and animal nutrition.

3 Essential functions

NRC (2005) classified strontium as a non essential trace element.

4 Other functions

Strontium can substitute for calcium in bone. Strontium was shown to increase bone formation and uncouple bone formation from bone resorption. In humans, strontium ranelate is considered a promising pharmaceutical for the treatment of postmenopausal osteoporosis (NRC, 2005).

5 Antimicrobial properties

There was no information available on antimicrobial properties of strontium in principal literature sources.

6 Typical deficiency symptoms

There was no information available on deficiency symptoms of strontium in principal literature sources.

7 Animal requirements, allowances and use levels

Established scientific bodies did not publish any strontium requirements for livestock species.

8 Concentration of the element in feed materials

Strontium tends to be concentrated in the bran rather than in the endosperm of grains. The strontium content is higher in leafy dicotyledons than in monocotyledons. Hence, strontium intakes are much higher from leguminous than from gramineous forages. Strontium concentrations in feed materials as reported by NRC (2005) are given in Table 1.

Table 1 Strontium concentrations in feed materials (mg/kg) (NRC, 2005)

Feed material	Sr concentration NRC (2005)	Feed material	Sr concentration Spiegel *et al*. (2009)
Red clover	53 – 115 DM	Spring durum, n= 30	1.14 DM
Ryegrass	5 – 18 DM	Winter durum, n = 15	1.28 DM
Wheat	3.46	Winter rye, n = 49	1.22 DM
Oats	3.01	Spring barley, n = 30	1.31 DM
Millet	1.29	Winter wheat, n = 136	1.31 DM
Buckwheat	3.48	Potatoes, n = 40	0.61 DM
Barley	0.98		
Hay	9.4		

9 Concentration of the element in complete feedingstuffs

There was no information available on strontium concentrations in complete feedingstuffs in principal literature sources.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

The MTL for strontium established by NRC (2005) are compiled in Table 2.

Table 2 Maximum Tolerable Levels (MTL) for strontium (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Poultry, swine, cattle	2000	
Horses, sheep	2000	Values derived from interspecies extrapolation
Rodents	1000	
Fish	-	Available data were considered insufficient to establish a MTL

11 Typical symptoms of toxicosis

Extremely high oral doses of strontium relative to normal intakes are needed to elicit toxic effects in animals. Excessive strontium might disturb calcium metabolism. The intake of strontium that induces signs of toxicity is dependent upon the calcium intake and when dietary calcium is adequate, animals have a high tolerance for strontium. When young and growing animals are fed high dietary strontium in combination with low dietary calcium, they develop a condition known as strontium rickets. In hens, reduced egg weight and production and feed consumption were observed when they were fed a dietary strontium level of 50000 mg/kg (NRC, 2005).

12 Bioavailability

In humans, absorption of ingested strontium from the gastrointestinal tract was reported to be within the range of 11 – 28 %. Studies conducted in infants and children indicate that approximately 15 – 30 % of dietary strontium is absorbed (ATSDR, 2004).

13 Metabolism

Strontium and calcium appeared to share common mechanisms of absorption. The exact site of absorption of strontium in the gastrointestinal tract is not known. Studies in hamsters suggest the possibility of absorption in both the stomach and small intestine. Strontium is primarily deposited in the skeleton. Absorbed strontium is mainly excreted via urine and feces with the urine:feces ratio estimated to be about 3 (ATSDR, 2004).

14 Distribution in the animal body

The distribution of absorbed strontium in the human body is similar to that of calcium, with approximately 99 % of the total body burden in the skeleton. The skeletal strontium burden, estimated from autopsies, was approximately 440 mg compared to 850 g of calcium ATSDR (ATSDR, 2004).

15 Deposition (typical concentration) in edible tissues and products

Strontium concentrations in animal tissues were reported to range between 0.01 and 0.10 mg/kg. Strontium accumulation in any particular species, soft organ or soft tissue was not observed (NRC, 2005).

16 Acute toxicity

Strontium caused death in laboratory animals only at doses that are very high compared to normal human exposure. Oral LD_{50}-values are given in Table 3 (ATSDR, 2004).

Table 3 Oral LD_{50} values for strontium (ATSDR, 2004).

Species	**Strontium compound**	**LD_{50}**
Mice, male	Strontium nitrate	2350 mg/kg bw
Albino mice, male	Strontium chloride, by gavage	2900 mg/kg bw
Albino mice, female	Strontium chloride, by gavage	2700 mg/kg bw

17 Genotoxicity and Mutagenicity

There is little evidence for genotoxicity of stable strontium. *In vitro* mutagenicity assays with strontium chloride using the Rec^- strains of *Bacillus subtilis* produced negative results. Strontium was found to have no adverse effect on the fidelity of DNA synthesis *in vitro* (ATSDR, 2004).

18 Subchronic toxicity

Acute and intermediate duration studies in animals showed significant adverse effects of strontium on bone that were especially severe in young animals. Among male weanling Wistar rats that ingested 3000 mg Sr/(kg bw.day) as strontium phosphate in the diet for two weeks, alkaline phosphatase activity was significantly increased in bone compared to controls. In young chickens fed 2300 – 2400 mg Sr/(kg bw.day) and an inadequate calcium level, severe defects in bone organization and decreased mineralization were observed within one or two weeks (ATSDR, 2004). More animal trials investigating the effect of strontium on bone are provided in the Toxicological Profile for Strontium (ATSDR, 2004).

In intermediate duration animal studies, ingestion of excess strontium was also reported to result in increased mortality. A premature death rate of 40 % was observed among weanling male Sprague-Dawley rats fed strontium at a dose level of 565 mg/(kg bw.day) for 43 days. Weanling male Wistar rats orally exposed to strontium phosphate at a dose level of 2820 mg Sr/(kg bw.day) for 4 – 6 weeks has a mortality rate of 30 % (ATSDR, 2004).

19 Chronic toxicity, including carcinogenicity

ATSDR (2004) located one epidemiological study which suggests that the skeletal toxicity observed at high oral strontium doses in juvenile animals may be relevant to humans. No studies were located regarding musculoskeletal effects in animals after chronic-duration oral exposure to strontium.

ATSDR (2004) did not locate any studies that demonstrated cancer effects of stable strontium following oral exposure in humans or animals.

20 Reproduction and developmental toxicity

ATSDR (2004) did not locate any studies regarding reproduction toxicity in humans or animals following oral exposure to stable strontium. In addition, no animal studies were located that examined the effect of exposure to stable strontium *in utero* following oral maternal exposure. Intermediate duration studies on rats demonstrated that ingestion of strontium resulted in more severe skeletal effects in young animals than in adults (ATSDR, 2004).

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

A NOAEL value of 140 mg Sr/(kg bw.day) for skeletal effects in weanling rats was identified by ATSDR as the most appropriate basis for calculating an intermediate duration exposure minimal risk level (MRL). A MRL of 2 mg/(kg bw.day) was calculated for intermediate duration (15-364 d) oral exposure to stable strontium. ATSDR considered the available data insufficient to establish a MRL for acute and chronic oral exposure to strontium (ATSDR, 2004).

23 Toxicological risks for user/workers

Several cases of accidental exposure of workers to airborne radiostrontium provide evidence that aerosols of strontium compounds e.g., $SrCl_2$, $SrTiO_3$, can be absorbed from the lungs. The absorption rate is dependent on the strontium compound. It was shown in animal experiments that $SrCl_2$ was relatively rapidly absorbed compared to strontium present in particles of fused clay. Reports of adverse health effects resulting from inhalation exposure to stable strontium are very limited (ATSDR, 2004).

24 Toxicological risks for the environment

There were no indications in principal literature sources that the presence of strontium in animal diets would have an environmental impact.

25 References

ATSDR (Agency for Toxic Substances and Disease Registry). 2004. Toxicological Profile for Strontium.

NRC (National Research Council of the National Academies). 2005. Mineral Tolerance of Animals, 2 nd Revised Edition. The National Academies Press, Washington D.C., USA.

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Tin

Executive summary of the monograph for tin

In the US, stannous chloride is an allowed feed ingredient and the GRAS status was granted to this tin compound. In the EU, legislation governs the maximum levels of inorganic tin in certain foodstuffs. In humans and animals tin has not been demonstrated to be an essential nutrient. Exposure of livestock to high levels of tin is unlikely. Signs of inorganic tin toxicosis include pancreatic athrophy, hyperthrophied gastrointestinal tracts, increased cell turnover in the small intestine, depressed growth, anaemia and reduced hematocrits. Organotin compounds are more toxic than inorganic tin compounds. In humans and animals the absorbability of inorganic tin compounds is low. Inorganic tin is mainly excreted in the feces with an additional slow urinary elimination of absorbed tin. In rats, the highest tin concentrations were reported in the skeleton, liver and kidney.

In humans, cases of acute tin toxicosis were observed as a result of the consumption of canned foods, especially acidic fruit products, packed in unlacquered tinplate cans. Symptoms include gastric irritation, vomiting, diarrhoea, fatigue and headache. There is limited evidence of genotoxicity for soluble tin salts. In subchronic duration oral exposure studies with inorganic tin compounds, the observed effects included reduced body weight gain, reduced haemoglobin concentration, pancreas athrophy, distended abdomens and reduced activity of serum lactate dehydrogenase. Based on the available studies in humans, there is no evidence that inorganic tin affects reproduction or development in humans or that it is a neurotoxin, immunotoxin, or a carcinogenic agent in humans. High intakes of tin may reduce the absorption of zinc. EFSA and EVM considered the available data insufficient to establish an UL for tin. EVM issued a guidance level for tin of 13 mg/day for adults. Stannic oxide dust or fumes were reported to produce a benign form of pneumoconiosis known as stannosis, in humans.

There are no indications that the presence of tin in animal diets would have an environmental impact.

Tin Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Tin occurs naturally in foods as stannous (Sn^{2+}) and stannic (Sn^{4+}) salts. Stannous chloride is a permitted food additive (E 512) in the EU and is GRAS-approved in the US. The major source of dietary tin for humans and for pets is canned foods (EFSA, 2005; NRC, 2005). WHO (2005) reported average tin concentration ranges for fresh foods, foods in lacquered cans and foods in unlacquered cans of respectively, < 0.003 – 0.2 mg/kg, 0.5 – 13.4 mg/kg and 24 – 156 mg/kg.

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal nutrition

In the US, stannous chloride is an allowed feed ingredient (chemical preservative), restricted to 0.0015% Sn (AAFCO, 2010).

2.2 Human nutrition

In the EU, Regulation EC 1881/2006[1] sets maximum levels (ML) for tin (inorganic) in certain foodstuffs, as summarized in Table 1. Stannous chloride (E 512) is an allowed additive in canned and bottled asparagus, with a maximum level of 25 mg Sn/kg (Directive 95/2/EC[2]).

Table 1 Maximum Levels (ML) for tin (inorganic) (mg/kg) in foodstuffs in the EU set by Regulations EC 1881/2006[1]

Foodstuffs	**ML**
Canned foods other than beverages	200
Canned beverages, including fruit juices and vegetable juices	100
Canned baby foods and processed cereal-based foods for infants and young children, excluding dried and powdered products	50
Canned infant formulae and follow-on formulae (including infant milk and follow-on milk), excluding dried and powdered products	50
Canned dietary foods for special medical purposes intended specifically for infants, excluding dried and powdered products	50

[1] OJ L 364, 20.12.2006, p. 19

[2] OJ L 61, 18.3.1995, p. 1

In the US, the Code of Federal Regulations grants a generally recognized as safe status to stannous chloride (582.3845) as a chemical preservative.

3 Essential functions

Tin has not been shown to be essential for humans or animals (NRC, 2005; EFSA, 2005).

4 Other functions

There was no information available on other function of tin in principal literature sources.

5 Antimicrobial properties

Limited data suggest that tin has cariostatic properties. Tin fluoride was found to have more antiplaque properties against *Streptococcus mutans* than other fluoride compounds (NRC, 2005).

6 Typical deficiency symptoms

There are no data on deficiency symptoms resulting from an inadequate intake of inorganic tin (EFSA, 2005).

7 Animal requirements, allowances and use levels

No tin requirements have been established by scientific bodies.

8 Concentration of the element in feed materials

Tin concentrations in pastures and cereals were reported to be in the range of 0.3 – 0.4 mg/kg DM and 5.6 – 7.9 mg/kg DM (Underwood & Suttle, 1999).

9 Concentration of the element in complete feedingstuffs

No information on tin concentrations in complete feedingstuffs was found in principal literature sources.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

The MTL values for tin established by NRC (2005) are compiled in Table 2.

Table 2 Maximum Tolerable Levels (MTL) for tin (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Rodents	100	
Poultry, Swine, Horses, Cattle, Sheep	100	Value derived from interspecies extrapolation
Fish	-	The data were considered insufficient to establish a MTL value

11 Typical symptoms of toxicosis

Exposure of livestock to high levels of inorganic tin is unlikely. Animals which are in a marginal nutritional status in regard to zinc or copper, are the most sensitive to chronic high doses of inorganic tin. Signs of inorganic tin toxicosis include pancreatic athrophy, hypertrophied gastrointestinal tracts, increased cell turnover in the small intestine, depressed growth due to the tin zinc antagonism, anaemia and reduced hematocrits (NRC, 2005). Organotin compounds are more toxic than inorganic tin. A summary of symptoms of toxicosis organized by type of organotin compound is reported in NRC (2005).

12 Bioavailability

The absorbability of inorganic tin compounds is low. In humans and animals 98 % of ingested tin was reported to be excreted in the feces (EFSA, 2005). The gastrointestinal absorption of tin, in humans, decreases with an increasing dose. Studies conducted in animals suggest that the fractional absorption of ingested inorganic tin(II) is higher, by a factor 4, than tin(IV) (ATSDR, 2005). ATSDR (2005) did not locate any studies that quantified the absorption of organotin compounds in humans.

13 Metabolism

In principal literature sources quantitative information on the bioavailability and distribution of tin ingested as inorganic tin compounds can be found (Chapters 12 and 14). Inorganic tin is mainly excreted in the feces with an additional slow urinary elimination of absorbed tin. Small fractions are secreted in bile (Ostrakhovitch & Cherian, 2007; WHO, 2005).

14 Distribution in the animal body

Inorganic tin distributes mainly to bone, but also to the lungs, liver, kidneys, spleen, lymph nodes, tongue, and skin. Certain data indicate that tin may have a higher affinity for the thymus than for other organs. Data from animal experiments suggest that tin does not readily cross the blood brain barrier. In rats, tissue distributions for tin(II) and tin(IV) were respectively, expressed as a percentage of the dose orally administered, reported to be 1.02% and 0.24 % in the skeleton, 0.08% and 0.02 % in the liver and 0.09% and 0.02 % in the kidneys (EFSA, 2005; WHO, 2005).

15 Deposition (typical concentration) in edible tissues and products

Tin concentrations in edible tissues and products are given Table 3 (EFSA, 2005). The organotin compounds, butyltin and phenyltin, accumulate within the marine food chain. The highest concentrations of triphenyltin, 1 µg/g muscle, have been measured in fish species obtained from bay or inshore areas (Ostrakhovitch & Cherian, 2007). NRC (2005) found no data on the accumulation of tin in tissues of livestock fed controlled levels of tin.

Table 3 Tin concentrations in edible tissues and products (mg/kg) (EFSA, 2005)

Edible tissues and products	Sn concentration
Carcass meat	0.007
Offal	0.014
Meat products	0.18
Poultry	0.006
Fish	0.032
Eggs	0.003
Milk	0.003
Dairy produce	0.297

16 Acute toxicity

Orally ingested inorganic tin was shown to cause a number of acute symptoms such as severe salivation and emesis, with vomiting in cats and dogs (EFSA, 2005). Case reports of humans consuming canned foods, especially acidic fruit products packed in unlacquered tinplate cans described symptoms including gastric irritation, vomiting, diarrhea, fatigue and headache. In general, the levels of tin in foods, which are responsible for these symptoms are between 250 and 2000 mg/L (EFSA, 2005; Ostrakhovitch & Cherian, 2007). Oral LD_{50} values are compiled in Tables 4 and 5.

Table 3 Oral LD_{50} values for inorganic tin compounds (EFSA, 2005)

Species, gender	Sn compound	Duration	LD_{50} (mg Sn/kg bw)
Rats, male	$SnCl_2$	21 d	700
Rats, male	$SnCl_2$	16 d	> 1500
Rats, female	$SnCl_2$	16 d	> 1500
Mice	$SnCl_2$	16 d	< 600
Rats, male	SnF_2	24 h	188.2
Mice, male	SnF_2	Fasted, 24 h	128.4
Mice, male	$NaSnF_5$	Fasted, 24 h	592.9
Rat, female	$NaSnF_5$	24 h	218.7
Rat, male	$NaSnF_5$	Fasted, 24 h	573.1
Rat, male	$NaSnF_5$	24 h	223.1

Table 4 Oral LD_{50} values for organic tin compounds (ATSDR, 2005)

Species, gender	Sn compound	Duration	LD_{50} (mg/kg bw)
Rats, male	Tributyltin, in corn oil		148
	Tributyltin, aqueous suspension		194
Hamsters, male	Tributyltin	2 w	150
Hamsters, female	Tributyltin	2 w	172
Rats	Trimethyltin	Single dose	12.6

17 Genotoxicity and Mutagenicity

Stannous chloride appears to be a genotoxic agent *in vitro*, able to induce gene mutations in bacterial cells, chromosome aberrations, sister chromatid exchanges and single strand breaks in mammalian cells. Stannous chloride as well as tin fluoride, were unable to induce micronuclei in bone marrow cells of mice treated *in vivo*. Overall, there is limited evidence of genotoxicity for soluble tin salts. An extensive compilation of genotoxicity studies with inorganic and organic tin compounds can be found in the Toxicological Profile for Tin and Tin compounds (ATSDR, 2005).

18 Subchronic toxicity

EFSA (2005) reported on several subchronic duration oral exposure studies with inorganic tin compounds. A concise summary is given in Table 6.

Table 6 Oral exposure subchronic toxicity studies with inorganic tin compounds (EFSA, 2005)

Species	Sn compound	Dose, duration	Effect
Rats	$SnCl_2$	0.886 - 8.86 mg Sn/(kg bw.day), 21 d	Reduced activity of serum lactate dehydrogenase
Rats	$SnCl_2$	1190 – 18782 mg Sn/(kg bw.day), 14 d	Decreased weight gain, roughened coats, distended abdomens
Rats	$SnCl_2.H_2O$	Dietary concentration: 0.8 %, 13 w	Reduced body weight gain, haemoglobin concentration and hematocrit, pancreas athrophy
Rats	SnO	Dietary concentration: 300 – 10000 mg/kg, 90d	No toxic effects

19 Chronic toxicity, including carcinogenicity

Based on the available studies in humans, there is no evidence that inorganic tin affects reproduction or development in humans or that it is a neurotoxin, immunotoxin, or a carcinogenic agent in humans. A relatively limited number of studies in animals have not clearly established potential target organs for inorganic tin toxicity. Of the effects described, hematological signs of anemia and gastrointestinal distension appear to be best identified as tin-related (ATSDR, 2005). Tin may affect the metabolism of other metals such as copper, zinc and iron. To what extent individuals with a marginal zinc status are at risk due to the ingestion of tin, remains unclear (ATSDR, 2005; WHO, 2005).
Available evidence indicates that orally ingested tin salts are not carcinogenic (EFSA, 2005; EVM, 2003).

20 Reproduction and developmental toxicity

ATSDR (2005) did not locate any studies regarding reproductive and developmental effects in humans after oral exposure to inorganic tin compounds. In a 13-week study in rats, dietary levels ranging from 1.5 to 9.2 mg Sn/(kg bw.day) as stannous chloride caused testicular degeneration. No adverse developmental effects were reported in studies with rats, mice and hamsters (ATSDR, 2005). Available evidence indicated that orally ingested tin salts are not teratogenic (EFSA, 2005).

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

EVM (2003) considered the available data insufficient to establish an UL value for tin. A NOAEL level of 22 – 33 mg Sn/(kg bw.day) was identified in a rat study for changes to liver cells and anaemia. A combined uncertainty factor of 100 was applied that accounts for interspecies variation and inter-individual variability. Thus, a guidance level, which is expected not to produce adverse effects, of 0.22 mg/(kg bw.day) or 13 mg/day for a 60 kg adult, was calculated (EVM, 2003). EFSA (2005) also considered the available data insufficient to derive an UL value for tin. Short-term human studies indicated that high intakes of tin may reduce the absorption of zinc. The current mean daily intake of tin in EU countries is well below the lowest intakes reported to cause adverse effects on zinc absorption (EFSA, 2005). ATSDR (2005) established an intermediate duration oral exposure (15 – 364 d) minimal risk level for inorganic tin of 0.3 mg/(kg bw.day).

23 Toxicological risks for user/workers

ATSDR (2005) found only limited information regarding the effects of inhaled inorganic or organotin compounds on human health. Stannic oxide dust or fumes produce a benign form of pneumoconiosis known as stannosis, in humans. No studies were located regarding respiratory effects in animals after inhalation exposure to inorganic tin compounds. In addition, ATSDR did not locate any studies regarding absorption in humans or animals after inhalation exposure to inorganic tin or organotin compounds (ATSDR, 2005).

24 Toxicological risks for the environment

There were no indications in principal literature sources that the presence of tin in animal diets would have an environmental impact.

25 References

AAFCO (Association of American Feed Control Officials). 2010. AAFCO 2010 Official Publication. AAFCO, Inc..

ATSDR (Agency for Toxic Substances and Disease Registry). 2005. Toxicological Profile for Tin and Tin Compounds.

EFSA. 2005. Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the Tolerable Upper Intake Level of Tin. The EFSA Journal 254: 1-25.

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Vanadium

Executive summary of the monograph for vanadium

Vanadium is not proven to be an essential nutrient for humans and animals as no defined biochemical function has yet been identified. It is an essential component in various enzymes in algae, bacteria, fungi, and lichens. Additionally, vanadium deficiency has been observed in goats and rats under experimental conditions. Vanadium compounds have shown to mimic the action of insulin in isolated cell systems, animal models and diabetic patients. The major clinical signs of vanadium toxicosis are a reduction in weight gain of growing animals, weight loss in adult animals, and death. In rats, toxic levels of vanadium ingestion led to reductions in reproduction, reduced fluid intake, diarrhea, and changes in behaviour and learning patterns. In laying hens, elevated vanadium intake reduced egg production, feed intake, feed conversion efficiency, and albumin quality. In humans, vanadium absorbability from soluble vanadium compounds was reported to vary between 0.1 – 1 %. In rats, vanadium was reported to be absorbed to a higher extent. Ingested vanadium is primarily excreted unabsorbed with feces, while absorbed vanadium is rapidly excreted with urine.

Acute vanadium poisoning in animals is characterized by marked nervous disturbance, haemorrhagic enteritis and a fall of temperature. Death is preceded by paralysis of hind legs, laboured respiration and convulsions. Test results suggest that vanadium compounds do not induce gene mutations in bacterial cells as well as, with the possible exception of ammonium metavanadate, in mammalian cells. There is clear evidence that pentavalent and tetravalent forms of vanadium produce aneuploidy *in vitro* and *in vivo*, very likely through interference with microtubule assembly and spindle formation. Subchronic oral exposure to vanadium compounds induced an increased systolic and diastolic blood pressure in several animal experiments. Other observed effects of subchronic vanadium toxicity in rats include lesions in the kidneys, spleen and lungs, reduced fluid and food intake, erythrocyte count and haemoglobin level. Decreased fertility, embryolethality, fetotoxicity, and teratogenicity were observed in rats, mice and hamsters after vanadium exposure. IARC classified vanadium pentoxide as possibly carcinogenic to humans (Group 2 B). IOM identified the renal toxicity of vanadium as a critical adverse effect and established an UL for vanadium of 1.8 mg/day for adults. EFSA and EVM considered the available dose-response data for vanadium to be too limited to derive an UL. The respiratory tract and the haematological system are sensitive targets of vanadium toxicity following inhalation exposure. There was no information available on the environmental consequences of the presence of vanadium in livestock diets.

Vanadium Monograph

Contents

Glossary

1 Forms/Sources of the element of importance in human and animal nutrition

Vanadium is widely distributed in the earth's crust. It occurs naturally in the form of about 70 minerals, but does not occur as metallic vanadium. In its compounds, it forms different oxidation states, the most common being +3, +4, and +5. Food is the major source of exposure to vanadium for the general population. Vanadium is usually present in food in the form of vanadyl and at concentrations of less than 1 µg/kg. Foods that are relatively high in vanadium (0.05 – 2 mg/kg) include black pepper, mushrooms, parsley, dill seed, shellfish, and some prepared foods. A concern in animal feed is the concentration of vanadium in rock phosphates used as phosphorus sources in diets (EFSA, 2004; NRC, 2005).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

There was no information available on the authorization of use of vanadium and vanadium compounds in human and animal nutrition.

3 Essential functions

NRC (2005) classified vanadium as a possibly essential element. Vanadium is an essential component in various enzymes in algae, bacteria, fungi, and lichens. The enzymes include haloperoxidases, which catalyse the oxidation of halide ions by hydrogen peroxide to facilitate the formation of a carbon-halide bond. Some bacteria require vanadium for the enzymatic reaction of reducing nitrogen gas to ammonia. Under experimental conditions vanadium deficiency signs have been observed in animals. However, a defined biochemical function has not been identified in higher animals (NRC, 2005). EFSA (2004) concluded that vanadium was not shown to be essential for humans. Nevertheless, it has been suggested that vanadium might play a role in the regulation of some enzymes, such as the Na^+/K^+-exchanging ATPase, phosphoryl-transfer enzymes, adenylate cyclase and protein kinases. This might imply a role of vanadium in hormone, glucose, lipid, bone and tooth metabolism (EFSA, 2004).

4 Other functions

Vanadium compounds have shown to mimic the action of insulin in isolated cell systems, animal models and diabetic patients. Therefore, their use in the therapy of diabetes mellitus has been considered (EFSA, 2004).

5 Antimicrobial properties

There was no information available on antimicrobial properties of vanadium in principal literature sources.

6 Typical deficiency symptoms

Although vanadium is not generally considered to be an essential nutrient, deficiency signs have been induced under experimental conditions. In goats, a depressed milk production and life span, an increased rate of spontaneous abortion, skeletal deformations in the forelegs and thickened forefoot tarsal joints have been reported. In rats, vanadium deprivation was shown to induce an increased thyroid weight, and thyroid weight:body weight ratio, a decreased erythrocyte glucose-6-phosphate dehydrogenase and cecal total carbonic anhydrase, and an altered response to high and low dietary iodine (Nielsen, 1996).

7 Animal requirements, allowances and use levels

Established scientific bodies did not publish any vanadium requirements for livestock species.

8 Concentration of the element in feed materials

NRC (2005) considered the vanadium content of rock phosphates used as phosphorus sources in diets, to be the major concern in animal nutrition related to vanadium. Some rock phosphates may contain vanadium up to 6000 mg/kg. Concentrations of vanadium in phosphorus sources vary by purity, with monocalcium phosphates ranging from 36 - 185 mg/kg, and thermochemically produced defluorinated phosphates ranging from 20 - 164 mg/kg. Grazing animals can be exposed to high vanadium levels through the ingestion of soil (NRC, 2005). There were no data on vanadium concentrations in other feed materials available in principal literature sources.

9 Concentration of the element in complete feedingstuffs

Hansard *et al*. (1978) measured a vanadium concentration of 2.2 mg/kg DM in a corn – cotton, seed hulls based diet for sheep. Gummow *et al*. (2005) reported daily vanadium intakes for cattle grazing adjacent to a vanadium mine and cattle grazing 2 – 3 km further from the mine to be respectively, 1229 mg/day and 532 mg/day.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

The MTL values established for vanadium by NRC (2005) are compiled in Table 1.

Table 1 Maximum Tolerable Levels (MTL) for vanadium (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Cattle, sheep	50	
Poultry, growing birds	25	
Poultry, laying hens	< 5	
Swine, horses	10	Values derived from interspecies extrapolation
Rodents, fish	-	

11 Typical symptoms of toxicosis

The major clinical signs of vanadium toxicosis are a reduction in weight gain of growing animals, weight loss in adult animals, and death. In rats, toxic levels of vanadium ingestion led to reductions in reproduction, reduced fluid intake, diarrhea, and changes in behavior and learning patterns. In laying hens, elevated vanadium intake has led to reduced egg production, feed intake, feed conversion efficiency, and albumin quality (NRC, 2005).

12 Bioavailability

12.1 *General*

The uptake of radioactive V_2O_5 given orally to rats was 2.6 %. Other studies in rats have indicated that amounts greater than 10% can be absorbed from the gastrointestinal tract. In humans, ingested vanadium compounds are poorly absorbed and absorbability values of 0.1 – 1% for the very soluble oxytartarovanadate were reported (EFSA, 2004; J-son Lagerkvist & Oskarsson, 2007).

12.2 *Vanadium status indicators*

Elevated levels of vanadium have been found in the serum and urine of vanadium exposed workers. However, relationships between exposure levels and serum and urine vanadium levels have not yet been established. Currently, no biomarker that can be used to quantify vanadium exposure levels has been identified (ATSDR, 2009).

13 Metabolism

Absorbed vanadium is transported in serum mainly bound to transferrin. Extracellular vanadium is present in the form of vanadate (VO_4^{3-}, V^{5+}) and intracellular vanadium most likely in the vanadyl (VO^{2+}, V^{4+}) form. Orally ingested vanadium was primarily excreted unabsorbed with feces. Parenterally administered vanadium compounds are rapidly excreted, mainly in urine. In a young man orally administered sodium metavanadate (12.5 mg/day for 12 days) was completely recovered, largely unabsorbed in the feces (87.6 %) and the remainder (12.4 %) in the urine (EFSA, 2004; J-son Lagerkvist & Oskarsson, 2007).

14 Distribution in the animal body

Acute studies with rats showed the highest vanadium concentrations to be located in the skeleton. Male rats had approximately 0.05 % of the administered ^{48}V in bones, 0.01 % in the liver, and < 0.01 % in the kidney, blood, testis, or spleen after 24 hours. Oral exposure for an intermediate duration produced the highest accumulation of vanadium in the kidney (ATSDR, 2009).

15 Deposition (typical concentration) in edible tissues and products

Vanadium concentrations in edible tissues and products are reported in Table 2.

Table 2 Vanadium concentrations in edible tissues and products

Edible tissue / product	**V concentration (mg/kg)**	**Reference**
Cattle, fillet	0.28	Gummow *et al*. (2005)
Cattle, triceps	0.25	
Cattle, liver	1.34	
Cattle, kidney	1.09	
Sea bass	0.19 DM – 0.24 DM	Alasalvar *et al*. (2002)
Hake (*Merluccius merluccius*), n = 3	0.82 DM	Lavilla *et al*. (2008)
Sole (*Solea solea*), n = 3	1.17 DM	

16 Acute toxicity

The oral acute toxicity of vanadium varies with the species and the nature of the compound. In general, vanadium is said to be better tolerated by the rat than the mouse than by larger animals including the rabbit and the horse. Acute vanadium poisoning in animals is characterized by marked nervous disturbance, haemorrhagic enteritis and a fall of temperature. Death is preceded by paralysis of hind legs, laboured respiration and convulsions (EFSA, 2004). Oral LD_{50} values for vanadium are compiled in Table 3.

Table 3 Oral LD_{50}- values for vanadium (mg/kg bw) (EFSA, 2004)

Species	Vanadium compound	LD_{50}
Rats	Vanadium pentoxide,	5.8
	Ammonium metavanadate	8.0
	Sodium metavanadate	41
	Vanadyl sulphate pentahydrate	90.3
Mice	Sodium metavanadate	31
	Vanadyl sulphate pentahydrate	94

17 Genotoxicity and Mutagenicity

EFSA (2004) made a comprehensive compilation of *in vitro* and *in vivo* genotoxicity test results of vanadium compounds. It was concluded that the test results suggest that vanadium compounds do not induce gene mutations in bacterial cells as well as, with the possible exception of ammonium metavanadate, in mammalian cells. There is clear evidence that pentavalent and tetravalent forms of vanadium produce aneuploidy *in vitro* and *in vivo*, very likely through interference with microtubule assembly and spindle formation (EFSA, 2004; WHO, 2001).

18 Subchronic toxicity

EFSA (2004) extensively reported on subchronic toxicity of vanadium compounds in animal experiments. A significantly increased systolic and diastolic blood pressure was observed in several experiments. A concise summary is given in Table 4.

Table 4 Subchronic toxicity of several vanadium compounds (EFSA, 2004)

Species	Vanadium compound	Dose, duration	Effects
Rats	Sodium metavanadate	0.8 – 7.7 mg/(kg bw.day), 3 m	Mild lesions in the kidneys, spleen and lungs, more evident with the highest dose
Rats, diabetic	Sodium vanadate, sodium orthovanadate, vanadyl sulphate pentahydrate	6.1 – 22.7 mg/(kg bw.day), 28 d	Reduced food and fluid intake, reduced blood glucose levels, sodium metavanadate was the most effective compound

Table 4 (continued) Subchronic toxicity of several vanadium compounds (EFSA, 2004)

Species	Vanadium compound	Dose, duration	Effects
Rats, male	Sodium metavanadate	100 mg/L drinking water, 7 m	Increased heart rate and systolic and diastolic blood pressure; increased urinary Na^+ and K^+ levels and affected kidneys
Rats	Ammonium metavanadate	0 – 6 mg/(kg bw.day), 4 w	Decreased erythrocyte count, decreased haemoglobin level, increased percentage of reticulocytes in the peripheral blood

19 Chronic toxicity, including carcinogenicity

The majority of the information available on the toxicity of vanadium is derived from subchronic exposure animal experiments (Chapter 18).

ATSDR (2009) did not locate any studies that specifically studied cancer in humans or animals after oral exposure to vanadium. IARC evaluated vanadium pentoxide and concluded that there is inadequate evidence in humans for the carcinogenicity of vanadium pentoxide and that there is sufficient evidence in experimental animals for the carcinogenicity of vanadium pentoxide. Hence, vanadium pentoxide was classified as possibly carcinogenic to humans (Group 2B) (IARC, 2003).

20 Reproduction and developmental toxicity

ATSDR (2009) did not locate any studies regarding reproductive and developmental effects in humans after oral exposure to vanadium. The lowest observed effect level values for decreased fertility in rats for vanadium are 12 and 10 mg/(kg bw.day) for females and males, respectively. Decreased fertility, embryolethality, fetotoxicity, and teratogenicity have been demonstrated in rats, mice, and hamsters after vanadium exposure, but it is not certainly established whether vanadate (V^{5+}) and vanadyl (V^{4+}) compounds are reproductive and developmental toxicants (Apostoli *et al*., 2007). WHO (2001) concluded that skeletal abnormalities were consistent observations in a number of developmental studies on pentavalent and tetravalent vanadium compounds.

21 Non Observed Adverse Effect Level (NOAEL) and LOAEL (Lowest Observed Adverse Effect Level)

NOAEL and LOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake (ADI) and Upper Intake Level (UL)

IOM (2001) selected the renal toxicity of vanadium as a critical adverse effect on which to base an UL. A LOAEL value was identified of 7.7 mg/(kg bw.day) in a study with rats. At this dose, there were evident lesions of the kidneys and small but significant, increases in plasma urea and uric acid. A combined uncertainty factor (UF) of 300 was applied which accounts for the extrapolation from a LOAEL to a NOAEL (UF = 3), for the extrapolation from laboratory animals to humans (UF = 10) and for intraspecies variability (UF = 10). Consecutively, an UL for vanadium of 1.8 mg/day was calculated for adults. It was reasoned that given the severity of the critical effect of vanadium in adults, the lack of data on vanadium toxicity in other more sensitive live stage groups is of particular concern. Hence, it was considered not possible to determine UL values for vanadium for pregnant and lactating women, children and infants. The advice was given that these individuals should be particularly cautious about consuming vanadium supplements (IOM, 2001). EVM considered the available data from human or animal studies insufficient to establish an UL. Additionally, the available studies were judged inadequate to support the safe use of vanadium in supplements (EVM, 2003). EFSA (2004) also concluded in its assessment that the available dose-response data for vanadium are too limited to derive an UL. ATSDR (2009) established a minimal risk level for intermediate duration (15 – 364 days) oral exposure to vanadium of 0.01 mg/(kg bw.day).

23 Toxicological risks for user/workers

Several occupational studies indicate that absorption of vanadium can occur in humans following inhalation exposure. The extent of absorption of different vanadium compounds in the lungs has not been determined adequately, although it was estimated that approximately 25 % of soluble vanadium compounds is absorbed (ATSDR, 2009; J-son Lagerkvist & Oskarsson, 2007). Studies in laboratory animals provide strong support that the respiratory tract is the most sensitive target following inhalation exposure to vanadium. A variety of lung lesions including alveolar/bronchiolar hyperplasia, inflammation, and fibrosis have been observed in rats and mice exposed to vanadium pentoxide. The severity of the lesions was related to the concentration and the duration of the inhalation exposure. The hematological system is also a known sensitive target of vanadium toxicity following inhalation exposure. ATSDR established minimal risk levels for respectively, acute duration and chronic duration inhalation exposure to vanadium pentoxide dust of 0.0008 mg vanadium/m^3 and 0.0001 mg vanadium/m^3 (ATSDR, 2009).

24 Toxicological risks for the environment

There was no information available in principal literature sources on the environmental consequences of the presence of vanadium in livestock diets.

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Glossary

Vanadate ion: VO_3^-, in which vanadium is in the +5 oxidation state (V^{5+})
Vanadyl ion: VO^{2+}, in which vanadium is in the +4 oxidation state (V^{4+})

Zinc

Executive summary of the monograph for zinc

Several zinc compounds are presently authorized as feed and food additives in the EU. Zinc exerts the large majority of its biochemical functions in association with proteins. It is an integral part of 300 known enzymes and more than 2000 transcription factors require zinc to maintain structural integrity and bind to DNA. In livestock, reduced feed intake and growth retardation or cessation are the first effects of zinc deprivation. Zinc deficiency is further characterized by lesions of the integument and its outgrowths, hair, wool, and feathers. Impaired immunity is also a generally observed characteristic. Livestock species exhibit considerable tolerance to high intakes of zinc. Generally, signs of toxicosis develop when dietary concentrations exceed 1000 mg/kg DM. Signs of zinc toxicosis usually consist of reduced feed intake, growth rate, and other signs of secondary deficiencies of other minerals such as copper. The bioavailability of zinc from foods varies widely. There is a consensus that phytic acid is the most potent inhibitor of zinc absorption in monogastric livestock and humans. In monogastric livestock, tibia, toe and metatarsal zinc concentrations are considered the most adequate response criteria for the assessment of the relative biological value of zinc compounds. In humans and monogastric species, zinc is absorbed in the small intestine. In ruminants the larger part of the ingested zinc is absorbed in the rumen. Zinc is transported in plasma bound principally to albumin. Zinc is loosely bound to albumin and albumin can donate zinc to tissues. Humans and animals have a limited capacity for storing zinc in a rapidly mobilizable form and there are no conventional tissue reserves that can be released or sequestered quickly in response to variations in dietary supply. An inadequate intake rapidly leads to an onset of biochemical signs of zinc depletion. Zinc homeostasis is primarily maintained by adjustments in zinc absorption and endogenous intestinal secretions. Muscle and bone are estimated to contain 60% and 30 % of the total zinc body content, respectively. Zinc concentrations in skeletal muscle and milk are well conserved.

Oral exposure to high doses of zinc generally results in gastrointestinal distress with clinical signs of nausea, vomiting, abdominal cramps and diarrhoea. Genotoxicity studies in a variety of test systems have failed to provide evidence for the mutagenicity of zinc. A excessive dietary zinc intake will interfere with copper absorption and are a conditioning factor for copper deficiency. WHO, IOM and SCF established upper intake levels for zinc for adults of 45 mg/day, 40 mg/day and 25 mg/day, respectively. Inhalation exposure to zinc compounds might affect various organ systems. According to SCAN there is no particular risk for the environment consecutive to the use of zinc in animal diets. The implementation of the actual EU legislation, fixing maximum zinc contents in complete feedingstuffs, limits the contribution of zinc originating from animal excreta in the soil and the aquatic environment.

Zinc Monograph

Contents

1 Forms/Sources of the element of importance in human and animal nutrition

Several zinc compounds are authorized as feed and food additives. These zinc compounds are considered of importance in human and animal nutrition (Chapter 2).

2 Information on the authorisation of use of the element –and which specific form or source– in human/animal nutrition

2.1 Animal Nutrition

Zinc compounds presently authorized in the EU as additives (EC 1334/2003[1], EC 479/2006[2], and EC 888/2009[3]) are listed in Table 1.

Table 1 Conditions of use of zinc compounds as additives in feedingstuffs according to the Commission Regulations EC 1334/2003[1], EC 479/2006[2] and EC 888/2009[3]

Additive	**Chemical formula**	**Maximum content of the element in the complete feedingstuff (mg/kg)**
Zinc lactate, trihydrate	$Zn(C_3H_5O_3)_2.3H_2O$	Pet animals: 250 (Total) Fish: 200 (Total) Milk replacers: 200 (Total) Other species: 150 (Total)
Zinc acetate, dihydrate	$Zn(CH_3COO)_2.2\ H_2O$	
Zinc carbonate	$ZnCO_3$	
Zinc chloride, monohydrate	$ZnCl_2.\ H_2O$	
Zinc oxide	ZnO	
Zinc sulfate, heptahydrate	$ZnSO_4.5\ H_2O$	
Zinc sulfate, monohydrate	$ZnSO_4.H_2O$	
Zinc chelate of amino acids hydrate	$Zn(X)_{1-3}.n\ H_2O$ X: anion of any amino acid derived from hydrolysed soya protein. Molecular weight not exceeding 1500 g/mol	
Zinc chelate of glycine hydrate	$Zn(X)_{1-3}.n\ H_2O$ (X: anion of synthetic glycine)	
Zinc chelate of hydroxyl analogue of methionine	Characterization: min 16% zinc, min 80 % (2-hydroxy-4-methylthio) butanoic acid	Chickens for fattening: 150

[1] OJ L 187, 26.7.2003, p.11

[2] OJ L 86, 24.3.2006, p.4

[3] OJ L 254, 26.9.2009, p. 72

In the US, the following zinc compounds are allowed in animal feeds: zinc acetate, zinc carbonate, zinc chloride, zinc chloride diammine complex, zinc oxide, zinc sulphate, zinc amino acid complex, zinc lysine complex, zinc methionine complex, zinc amino acid chelate, zinc polysaccharide complex, zinc proteinate (AAFCO Official Publication §57: Mineral Products). Zinc gluconate and zinc stearate are not specifically defined by AAFCO, but were adopted in its publication from the Federal Code of Regulations. They are listed as generally recognised as safe in animal feeds (AAFCO, 2010).

Canadian legislation lays down a range of nutrient guarantees for complete feeds for use in the exemption of feeds from registration (Feeds Regulations, 1983; http://laws-lois.justice.gc.ca; Current to June 17 th 2009) (Table 2).

Table 2 Range of zinc guarantees for complete feeds for use in the exemption of feeds from registration according to Canadian legislation

Species / category	**Range (mg/kg)**
Chickens	65 - 500
Turkeys	75 - 500
Swine	100 - 500
Dairy cattle	40 - 500
Beef cattle	20 - 250
Sheep	35 - 150
Horses	40 - 500
Goats	50 - 250
Ducks and geese	70 - 500
Salmonid fish	75 - 300
Mink, breeding	66 - 500
Mink others	60 - 500
Rabbits, lactating, breeding	70 - 500
Rabbits, other	50 - 500

2.2 Human nutrition

Zinc compounds are presently authorized in the EU:

- As substances that may be added for specific nutritional purposes in foods for particular nutritional uses under Regulation EC 953/2009[4]. The authorized zinc compounds are: zinc acetate, zinc chloride, zinc citrate, zinc gluconate, zinc lactate, zinc oxide, zinc carbonate, zinc sulphate, zinc bisglycinate.

- As food supplements under Regulation EC 1170/2009[5]. The authorized zinc compounds are zinc acetate, zinc L-ascorbate, zinc L-aspartate, zinc bisglycinate, zinc chloride, zinc citrate, zinc gluconate, zinc lactate, zinc L-lysinate, zinc malate, zinc mono-L-methionine sulphate, zinc oxide, zinc carbonate, zinc L-pidolate, zinc picolinate, zinc sulphate.

- As substances which may be added to foods under Regulation EC 1925/2006[6] as amended by Regulation EC 1170/2009[5]. The authorized zinc compounds are: zinc acetate, zinc bisglycinate, zinc chloride, zinc citrate, zinc gluconate, zinc lactate, zinc oxide, zinc carbonate, zinc sulphate.

- Directive 2008/100/EC[7] lays down a Recommended Daily Allowance (RDA) for zinc of 10 mg.

In the US the Code of Federal Regulations grants the generally recognized as safe status (Part 582) to various zinc compounds for their use as food additives, namely: Nutrients and / or Dietary supplements (Subpart F): zinc chloride (582.5985), zinc gluconate (582.5988), zinc oxide (582.5991), zinc stearate (582.5994), zinc sulphate (582.5997). (July 28 th 2009, www.access.gpo.gov/nara/cfr/waisidx_04/21cfr582_04.html).

3 Essential functions

Zinc is an essential element that exerts the large majority of its biochemical functions in association with proteins (O'Dell, 1998; McCall *et al*., 2000; NRC, 2005). The stability of zinc-protein complexes is highly variable, giving rise to what are termed zinc metalloproteins, highly stable complexes that do not lose zinc during their isolation, and zinc-protein complexes, which dissociate more readily (O'Dell, 1998). The zinc ion sometimes plays a catalytic role and sometimes a structural role. In its structural role, Zn usually stabilizes the quaternary structure of the enzymes, i.e. protein conformation (McDowell, 2003). Zinc is an integral part of 300 known enzymes which catalyse more than 50 different biochemical reactions (McDowell, 2003; O'Dell, 1998). The most studied Zn metalloenzymes are carbonic anhydrase,

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[4] OJ L 269, 14.10.2009, p. 9

[5] OJ L 314, 1.12.2009, p. 36

[6] OJ L 404, 30.12.2006, p. 26

[7] OJ L 285, 29.10.2008, p. 9

carboxypeptidase A and related peptidases, alkaline phosphatase, alcohol dehydrogenase, and cytosolic superoxide dismutase (McDowell, 2003).

Substantial quantities of firmly bound zinc stabilize the structures of RNA, DNA, and ribosomes. Zinc proteins have been shown to be involved in the transcription and translation of the genetic material, perhaps accounting for its essentiality to all forms of life. More than 2000 transcription factors that regulate gene expression require zinc to maintain structural integrity and bind to DNA. Evidently, therefore the intracellular zinc concentration is tightly controlled by zinc transporters, zinc binding molecules and zinc sensors (Murakami & Hirano, 2008). Although gene transcription is a highly important function in biology and zinc plays a critical role in the process, there is no evidence that transcription factor function is impaired by dietary zinc deficiency (O'Dell, 1998). The vital roles zinc plays in digestion, glycolysis, DNA synthesis, nucleic acid and protein metabolism may mostly derive from primary effects on gene expression; effects which are most marked when cells are rapidly dividing, growing or synthesizing. Evidently, this can be linked to the observation zinc is essential for highly proliferating cells, especially in the immune system. It influences both innate and acquired immune functions (Wintergerst *et al.*, 2007). Zinc exerts a protective role in the plasma membrane by preventing reversible oxidation of protein sulfhydryl groups. Sulfhydryl groups are important to the function of calcium channels. Because the predominant role of calcium as a second messenger in cell signal transduction, impairment of calcium-channel function could explain most, if not all, of the pathology associated with zinc deficiency (O'Dell, 1998). Sulfhydryl stabilization can be classified as an antioxidant property of zinc. The ability of zinc to retard oxidative processes has been extensively reviewed by Powell (2000).

4 Other functions

A growth promoting effect of zinc supplementation at high levels, 2000 – 6000 mg/kg, has been observed in piglets after weaning. These supplementation levels should be considered as prophylactic or therapeutical and are intended to prevent or overcome diarrhea of young animals (SCAN, 2003). SCAN (2003) concluded that the effect of zinc on growth performance remains questionable.

5 Antimicrobial properties

High dietary zinc concentrations have a preventive effect on diarrhea in piglets. It has been observed that these high supplementation levels support a large diversity of coliforms in weaned piglets and that they reduced the pigs' susceptibility to *E. coli* infections. These observations may contribute to the growth promoting effect of high dietary zinc in weaned piglets (Poulsen & Carlson, 2008).

6 Typical deficiency symptoms

In livestock reduced feed intake and growth retardation or cessation are the first effects of zinc deprivation. Appetite for solid foods is extremely sensitive to zinc. This is expressed in all species and may reflect the pivotal role of zinc in cell replication. Deficiency is further characterized by lesions of the integument and its outgrowths, hair, wool, and feathers. More explicitly it leads to skin lesions in pigs, scaled skin, and poor feathering in chicks. In swine and poultry bone growth is affected which is also the case in calves but to a lesser extent. Impaired immunity is a generally observed characteristic. Many of the adverse effects of severe zinc deficiency are secondary to a loss of appetite (McDowell, 2003; Underwood & Suttle, 1999). Although severe clinical deficiencies are described, marginal zinc deficiency is of much higher economic importance.

Zinc has a fundamental importance in cellular growth and differentiation and a dietary zinc restriction rapidly affects growth and differentiation. Hence, growing embryos, foetuses, infants, young children or patients mounting an immune response or requiring tissue repair are specially vulnerable to an inadequate supply of zinc (Hambidge, 2000). Cells that are rapidly turning over, notably those of the immune system, are specially sensitive to zinc deficiency (Hambidge, 2000; Ibs & Rink, 2003; Rink & Gabriel, 2000). The main clinical manifestations of zinc deficiency are growth retardation, delay of sexual maturation, diarrhoea, increased susceptibility to infections, dermatitis, the appearance of behavioural change, and alopecia. Symptoms of mild to marginal zinc deficiency include delayed wound healing, impaired resistance to infection and reduced growth rate. This reveals that even mild zinc deficiency depresses immunity of humans (Ibs & Rink, 2003). Diarrhea, the prevalence of pneumonia and malaria appear to be reduced by zinc supplementation (Bhaskaram, 2002; SCF, 2003; Hambidge, 2000; Prasad, 2004, Walsh *et al*., 1994; WHO, 2004). Zinc deficiency may lead to delays in cognitive development. In humans severe zinc deficiency can cause abnormal cerebellar function and impair behavioural and emotional responses (Black *et al*., 1998). The influence of zinc on brain function is reviewed by Sandstead *et al*. (2000) and Sandstead (2003). Mild to moderate zinc deficiency is largely related to inadequate intake or absorption of zinc from the diet, although excess losses of zinc during diarrhoea may also contribute. A sufficient intake may result in an inadequate supply caused by the presence of high levels of inhibitors such as phytates (WHO, 2002). Mild to moderate zinc deficiency is prevalent and considered a worldwide problem (Walsh *et al*., 1994). The WHO (2002) estimated that zinc deficiency effects about one third of the world's population. It was calculated that zinc deficiency is responsible for approximately 16 % of lower respiratory tract infections, 18 % of malaria, 10 % of diarrhoeal disease, 1,4 % (0,8 million) of deaths and 0,45 million of deaths in children < 5 years worldwide (WHO, 2002; Black *et al*., 2008). Severe or clinically relevant zinc deficiency is rare and observed in conjunction with malabsorption syndrome, parenteral nutrition, treatment with chelating agents, e.g. penicillamine, acrodermatitis enteropathica and excessive use of alcohol (SCF, 2003; Prasad, 2004).

7 Animal requirements, allowances and use levels

Zinc requirements for livestock established by scientific bodies are compiled in Annex 3.1, use levels are compiled in Annex 3.2.

8 Concentration of the element in feed materials

Zinc concentrations in feed materials are compiled in Annex 4.

9 Concentration of the element in complete feedingstuffs

Zinc concentrations in complete feedingstuffs are compiled in Annex 5.

10 Tolerance of animal species and Maximum Tolerable Levels (MTL)

Livestock exhibits considerable tolerance to high intakes of zinc. Signs of toxicosis generally develop when dietary concentrations exceed 1000 mg/kg DM. Swine are more tolerant to high zinc levels than most other species. Dietary zinc intakes as high as 3000 mg/kg for periods of 3 or 4 weeks promote growth and feed efficiency of young pigs. Ruminants are more susceptible to zinc toxicity compared to rats, pigs and poultry. High levels of zinc affect rumen metabolism, probable by a toxic effect on ruminal microorganisms (NRC, 2005). MTL values for zinc established by NRC (2005) are compiled in Table 3.

Table 3 Maximum Tolerable Levels (MTL) for zinc (mg/kg DM) (NRC, 2005)

Species	MTL	Additional remarks
Swine	1000	Higher levels of zinc as zinc oxide (2000 – 3000 mg/kg DM) are tolerated for several weeks and may provide growth promotion in weanling piglets
Poultry, cattle	500	
Rodents, horses	500	Values derived from interspecies extrapolation
Sheep	300	
Fish	250	

11 Typical symptoms of toxicosis

Initial signs of zinc toxicosis in animals usually consist of reduced feed intake, growth rate, and other measures of performance or signs of secondary deficiencies of other minerals, such as copper (NRC, 2005).

12 Bioavailability

12.1 *General*

The bioavailability of zinc from foods varies widely. Dietary factors can alter the proportion of zinc that is available for absorption in the small intestine by as much as tenfold. For humans and monogastric livestock there is a consensus that phytic acid is the most potent inhibitor and it is together with the total quantity of dietary zinc the principal determinant of zinc absorption. The inhibitory effect of phytic acid on zinc absorption follows a dose-dependent response (Ammerman *et al*., 1995, IZiNCG, 2004; McDowell, 2003). The effect of phytic acid on absorbability is further increased by the presence of excess calcium. Calcium ions present in high concentrations bind to the phytic acid molecules and further decrease their solubility (Fairweather-Tait, 1988; Oberleas, 1996). Molar ratios of [phytate]:[zinc] or [phytate × Ca]:[zinc] are commonly used to predict zinc bioavailability in human nutrition. Assessment of the impact of phytic acid on zinc bioavailability led to the strategy of the WHO and IZiNCG to use [phytate]: [zinc] molar ratios to predict zinc absorption and dietary zinc requirements (IZiNCG, 2004; WHO, 2002). Values of the [phytate]:[zinc] molar ratio of > 10:1 to > 20:1 were reported to be indicative of an increased risk of zinc deficiency (Sandstead & Smith, 1996; Solomons, 2001). A recently developed model predicted that adding 1000 mg/day dietary phytate doubles and adding 2000 mg/day triples the Estimated Average Requirement (EAR). Furthermore, the EAR for men and women could not be attained with [phytate]: [zinc] molar ratios > 11:1 and 15:1, respectively (Hambidge *et al*., 2008; Miller *et al*., 2007). An overview of dietary factors that may affect zinc bioavailability is given in Table 4.

Table 4 Dietary factors influencing zinc bioavailability adapted from Ammerman *et al*. (1995); Couzy *et al*. (1993); Fairweather-Tait & Hurrell (1996) and Lönnerdal (2000)

Chelating agents	Inhibitors	Phytate; hemicelluloses, oxalate
	Promotors	Animal protein, e.g. whey; amino acids, e.g. histidine, methionine; organic acids, e.g., citrate, picolinate
Metal ion interactions	Inhibitors	Calcium (phytate intermediated effect); copper; iron; manganese

In ruminants phytate is degraded by microbial phytase in the rumen. Dietary factors that determine zinc bioavailability in ruminants are not clearly defined. A relatively large portion of zinc in forages is associated with the plant cell wall which might reduce absorption (Spears, 2003).

Phytase supplementation and organic zinc forms are put forward as options to enhance zinc bioavailability. For pigs and poultry phytase addition was proven to be a successful strategy (Jondreville *et al*., 2007; Jondreville *et al*., 2005; Martinez *et al*., 2004; Revy *et al*., 2006; Shelton & Southern, 2006). The effect of phytase has been quantified by generating equivalency equations. Revy *et al*. (2004, 2006) estimated that

1200 and 700 U of 3-phytase are equivalent to 31 – 39 and 32 – 43 ppm of zinc as sulphate in a pig diet based on maize, and soybean meal, respectively. Jondreville *et al*. (2005) calculated that 250, 500, and 750 U of 3-phytase are equivalent to 17, 32 and 40 mg zinc as sulphate in a maize soybean meal diet for piglets.

The influence of the chemical compound on zinc bioavailability has been intensively investigated. Jongbloed *et al*. (2002) selected relative bioavailability studies based on the appropriateness of the used bioavailability response criterions. The relative bioavailabilty values for several inorganic and organic zinc compounds per species category are summarized in Table 5.

Table 5 Relative bioavailability assessments of zinc compounds compared to zinc sulphate (Jongbloed *et al*., 2002)

	Pigs	**Ruminants**	**Poultry**
Zinc sulphate	100	100	100
Zinc carbonate	98	58	93
Zinc chloride		42	107
Zinc oxide	92	95	67
Zinc amino acid chelate	102	102	131

12.2 *Indicators of zinc status*

Delves (1985) summarized possible indicators for the assessment of zinc status. Plasma zinc, plasma albumin bound zinc, plasma alkaline phosphatase and leukocyte zinc were considered valid parameters, whereas erythrocyte zinc, urinary zinc and hair zinc were classified as inadequate. The measurement of plasma zinc concentration is the only biochemical indicator recommended by the IZiNCG (2004) to assess the zinc status of populations. In accordance with the magnitude of the occurrence of zinc deficiency a sensitive parameter is sought to determine suboptimal zinc status. Plasma zinc concentrations only drop when the dietary intake is so inadequate that homeostasis, including reduction in zinc excretion and reduction of growth rate, cannot be established without use of zinc from the exchangeable pool of which plasma zinc is a component. Erythrocyt metallothionein concentration was suggested to sensitively reflect changes in available dietary zinc. More recently mRNA of proteins involved in zinc regulation have been quantified in different tissues e.g., metallothionein mRNA in lymphocytes (King, 1990; Gibson *et al*., 2008).

Jongbloed *et al*. (2002) ranked response criterions for assessing the relative biological value of zinc compounds in livestock (Table 6).

Table 6 Ranking of adequacy of response criterions for assessing the relative biological value of zinc compounds [1] (Jongbloed *et al*., 2002)

	Pigs		Poultry		Ruminants	
Supplementation level →	Suboptimal	Above requirement	Suboptimal	Above requirement	Suboptimal	Above requirement
Criterion						
Tibia/ toe /metatarsal Zn	5	5	5	5		
Serum/ plasma Zn	4	3	4	-	2	1
Zn absorption (true)	3	3	3	3		
Zn absorption (apparent)	3	3	3	1	2	1
Animal performance	3	-	3	-		
Pancreatic zinc	3	3	3	3		
Zn liver accumulation					4	2
Zn kidney accumulation					3	1

[1]: the highest values correspond to the best adequacy

As part of the assessment of a zinc chelate of hydroxy analogue of methionine, EFSA, included a trial with chickens where the zinc concentration in tibia bone was chosen as a parameter to determine the relative bioavailability of this chelate compared to zinc sulphate (EFSA, 2008).

13 Metabolism

In humans and monogastric species zinc absorption is limited to the small intestine (Krebs, 2000; McDowell, 2003). In ruminants the larger part of ingested zinc is absorbed in the rumen (McDowell, 2003). It has been shown that zinc is absorbed either carrier mediated or diffusion mediated, which are specific saturable and nonspecific unsaturable processes respectively. Zinc is transported in the plasma bound principally to albumin (70%). The reminder is bound tightly to α-2-macroglobulin (18%), and other proteins such as transferrin and caeruloplasmin (Gibson *et al*., 2008, McDowell, 2003). Zinc is loosely bound to albumin and albumin can donate zinc to tissues (Cousins, 1985). Induction of liver metallothionein synthesis by zinc plays a key role in removing zinc from the plasma and partitioning it between various pathways (McDowell, 2003). The zinc fraction in the nervous system and in bones is firmly bound. A more rapid accumulation and turnover of retained zinc occurs in the pancreas, liver, kidney and spleen. These are supplies of zinc for metabolic use (McDowell, 2003). However, humans and animals have a limited capacity for storing zinc in a rapidly mobilizable form and there are no conventional tissue reserves that can be released or sequestered quickly in response to variations in dietary supply (Hess *et al*., 2007; IZiBCG, 2004; McDowell, 2003). Consequently, an inadequate intake rapidly leads to an onset of biochemical signs of zinc depletion. The major route of excretion is via the gastrointestinal tract (70 – 80

%) (Barceloux, 1999). The pancreas secretes two to five times the amount of zinc consumed on average per day. Hence, it is essential that a major fraction of the endogenous secreted zinc is reabsorbed to maintain homeostasis (Oberleas, 1996).

In humans and animals zinc homeostasis is primarily maintained by adjustments in zinc absorption and endogenous intestinal secretions. Shifts in endogenous secretions appear rapidly as a response to an altered intake. These endogenous secretions are partially metabolically inevitable i.e. obligatory. Thus, they cannot be fully reduced confronted with an inadequate zinc intake or when the individual is already in a zinc deficient state (King *et al*., 2000; Oberleas, 1996). A modification of zinc absorption occurs later but this mechanism has a higher capacity to cope with fluctuations of intake. Homeostatic compensatory mechanisms are effective in regulating the whole body zinc content over a tenfold change in intake (King *et al*., 2000; Krebs, 2000). When an inadequate intake is consumed over a long period of time, homeostatic mechanisms are insufficient and a negative zinc balance occurs. When the total body zinc content is depleted, plasma, liver, bone and testes concentrations drop whereas the zinc content of skeletal muscle, skin, and heart is better preserved and remains constant (Hess *et al*., 2007; IZiNCG, 2004; King *et al*., 2000).

14 Distribution in the animal body

Approximately 85 % of the total body zinc is in skeletal muscle and bone. About 95 % of body zinc is intracellular, with 40% of the cellular zinc found in the nucleus (NRC, 2005). In humans the total zinc content of the body is distributed among tissues as follows: approximately 60 % in muscle, 30 % in bone, 8 % in skin and hair, 5% in liver, 3% in the gastrointestinal tract and pancreas and other organs contain < 1% (Sandstead & Au, 2007).

15 Deposition (typical concentration) in edible tissues and products

Excess intake of zinc leads to an increased deposition in the liver, pancreas, kidney, and bone. Concentrations in milk and skeletal muscle of various species are more conserved (NRC, 2005).
Zinc concentrations in edible tissues and products are reported in Annex 1 and zinc concentrations in edible tissues and products linked with dietary intake of various zinc compounds and doses are reported in Annex 2.

16 Acute toxicity

Oral exposure to a high dose of zinc compounds generally results in gastrointestinal distress with clinical signs of nausea, vomiting, abdominal cramps and diarrhea. Commonly, exposure levels resulting in these effects in several different species range from 2 – 8 mg Zn/(kg bw.day). In humans it was observed that the ingestion of 1 – 2 g of zinc sulphate produced emesis. Severe nausea and vomiting occurred within 30 min of the ingestion of 4 g zinc gluconate.

Ingestion of 3 ounce of 11 % $ZnCl_2$ resulted in lethargy and mucus membrane irritation, but no serious systemic effects. The ingestion of a 35 % $ZnCl_2$ solution produced severe upper pharyngeal corrosion, subcutaneous emphysema of the upper chest, and severe corrosion of the stomach with gastric obstruction (Barceloux, 1999; NRC, 2005).

17 Genotoxicity and Mutagenicity

Genotoxicity studies in a variety of test systems have failed to provide evidence for mutagenicity of zinc (ATSDR, 2005; Sandstead & Au, 2007). Desoize (2003) reported the effectiveness of zinc in the prevention of oxidative stress in relation to carcinogenesis. Zinc stabilizes cell membranes and inhibits the oxidation of sulfhydryl groups. The zinc ion is able to displace redox active metal ions from site specific loci where damage occurs, as has been shown with copper and iron ions.

18 Subchronic toxicity

The ATSDR Toxicological profile of zinc includes information on the subchronic toxicity of several zinc compounds on several organ systems and by several exposure routes ATSDR (2005).

19 Chronic toxicity, including carcinogenicity

A chronic over dosage of zinc will interfere with copper absorption. High ingested zinc levels induce metallothionein (MT) synthesis in the enterocytes. Copper has a higher affinity for the MT protein and thus replaces zinc. Metallothionein bound copper is relatively unavailable for transfer to plasma and is consequently excreted into faeces when the mucosal cells are sloughed off. Therefore, disproportionately high oral intakes of zinc relative to copper are a conditioning factor for copper deficiency (ATSDR, 2005; Barceloux, 1999, Maret & Sandstead, 2006). Excess zinc may alter the levels or activity of copper dependent enzymes, which include cytochrome c oxidase, superoxide dismutase, ferroxidase, monoamine oxidase, and dopamine-β-monooxygenase. Additionally, changes in immunological parameters, cholesterol and lipoprotein distribution have been documented. Maret & Sandstead (2006) summarized studies evaluating the effect of zinc on copper status for Zn:Cu molar ratios ranging from 18.6 to 53. It was concluded from the existing studies that no Zn:Cu molar ratio threshold value could be determined for the onset of the observed copper deficiency symptoms. Previously, Sandstead & Au (2007) put forward that a dietary Zn:Cu molar ratio > 18 poses a potential risk for copper deficiency.

Leitzmann *et al*. (2003) reported on the occurrence of prostate cancer within a cohort of 46974 men. Zinc supplementation did not have an effect on the frequency of developing prostate cancer. However, men within the cohort who had taken supplements of 100 mg Zn/day had a greater probability of developing advanced cancer, if a tumor occurred.

20 Reproduction toxicity

Pregnant women receiving capsules containing 0.3 mg Zn/(kg bw.day) as zinc sulphate during the last two trimesters did not exhibit any reproductive effects (ATSDR, 2005). Taking the results of six studies into account, SCF (2003) concluded that supplementation doses of 20 – 90 mg/day produce no adverse effects on pregnancy outcome.

21 Non Observed Adverse Effect Level (NOAEL)

NOAEL values identified by scientific bodies to establish upper intake levels are reported in Chapter 22.

22 Acceptable Daily Intake and Upper Intake Level (UL)

SCF (2003) and IOM (2001) identified NOAEL/LOAEL values and established UL values for zinc based on data of studies that evaluated the impact of zinc supplementation on copper status (Table 7). EVM (2003) derived a safe upper level for supplemental zinc of 25 mg/day. IZiNCG (2004) revised the values published by IOM and the studies on which the calculations were based. IZiNCG concurs with the IOM (2001) UL value of 40 mg Zn/day but expressed concerns on the values for children < 3 years of age. These IOM values were argued to be inappropriately low taking into account the recommended dietary allowance (RDA) values of the same age groups. It was further reasoned that a too narrow margin between UL and RDA may hamper the development of interventions to improve zinc intakes. BfR (2006) took UL values of the above mentioned bodies under consideration and resolved on adopting the value published by SCF (2003) of 25 mg Zn/day for adults. Recently, Hambidge *et al*. (2008) estimated the effect of phytate on upper limits using a mathematical model. It was simulated that with a dietary phytate intake of 900 mg/day a zinc intake of 100 mg results in an equivalent absorbed amount of zinc as a dietary zinc intake of 40 mg with no phytate present in the diet.

Table 7 Non Observed Adverse Effect Levels (NOAEL), Lowest Observed Adverse Effect Levels, Uncertainty Factors (UF) and Upper Intake Levels (UL) for zinc

SCF (2003)		IOM (2001)		WHO (2004)	
NOAEL (mg/day)	50	**LOAEL (mg/day)**	60		
UF	2	**UF**	1.5		
UL (mg/day):		**UL (mg/day):**		**UL (mg/day):**	
		0 - 6 months	4		
1 - 3 years	7	7 - 12 months	5		
4 - 6 years	10	1 - 3 years	7		
7 - 10 years	13	4 - 8 years	12	Children	23 - 82
11 - 14 years	18	9 - 13 years	23		
15 - 17 years	22				
		14 - 18 years	34		
Adults	25	≥ 19 years	40	Adult man	45
Pregnancy: any age	25	Pregnancy: 14 - 18 years	34		
		Pregnancy: 19 - 50 years	40		
Lactation: any age	25	Lactation: 14 - 18 years	34		
		Lactation: 19 - 50 years	40		

23 Toxicological risks for user/workers

An overview of pathologies and symptoms caused by inhalation exposure to zinc is given in Table 8.

Table 8 Effects of inhalation exposure to various zinc compounds (ATSDR, 2005)

Zn compound	Organ system	Symptoms and signs
Zinc oxide	Respiratory	Metal fume fever: impairs pulmonary function but does not progress to chronic lung disease
	Gastrointestinal	Nausea and irritation of stomach and intestines
	Neurological	Non specific neurological effects such as headaches
Zinc chloride	Respiratory	Corrosive salt which is more damaging to mucous membranes of the respiratory tract compared to zinc oxide. Severe effects include ulcerative and edematous changes in mucous membranes, pulmonary fibrosis, subpleural hemorrhage, fatal respiratory stress syndrome

ATSDR (2005) reported on two epidemiological studies where workers did not have an increased incidence of cancers associated with occupational exposure (primarily inhalation exposure) to zinc.

24 Toxicological risks for the environment

SCAN concluded in their opinion on the use of zinc in feedstuffs that no particular risk for the environment has been identified consecutive to the use of zinc in animal diets (SCAN, 2003). Zinc concentrations in manure from multiple monitoring studies are compiled in Table 9.

Table 9 Zinc content of manure from various species

Species, category	**Zn content (mg/kg DM)**	**Reference**
Dairy cattle FYM	153	Nicholson *et al*. (1999)
Dairy cattle slurry	209	
Beef cattle FYM	81	
Beef cattle slurry	133	
Pig FYM	431	
Pig slurry	575	
Broiler / turkey	378	
Layer	459	
Cattle, FYM, Se	174	Öborn *et al*. (2008)
Cattle, FYM, RF	152	
Broiler	254	van Ryssen (2008)
Layer	372	
	(g/m^3)	
Pig, gestating	89	Moral *et al*. (2008)
Pig, farrowing	75	
Pig, weaner	533	
Pig, finisher	108	

FYM: Farm yard manure; Se: Sweden; RF: Research facility

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Zinc Annex 1

Table 1.1 Zinc concentrations (mg/kg) in edible tissues of pigs

Species - category	n	Muscle	Liver	Kidney	Reference
Hogs	324	24.0	66.9	25.0	Coleman *et al*. (1992)
Boar / sow	281	33.8	63.7	24.7	
Pork		Neck steak: 33 Chop: 15 Loin: 15			Gerber *et al*. (2009)
Pigs (6 m)	63	42.5	81.3	28.9	López-Alonso *et al*. (2007)
Pigs (pork)	3	Saddle: 9.8 Loin: 15.5 Chop: 22.8			Lombardi-Boccia *et al*. (2005)

Table 1.2 Zinc concentrations (mg/kg) in edible tissues of ruminants

Species - category	n	Muscle	Liver	Kidney	Milk	Reference
Calves (6 – 12 m)	195		53.9	25.9		Blanco-Penedo *et al*. (2006)
Calves	327	32.8	103.0	27.4		Coleman *et al*. (1992)
Heifers / Steers	289	41.7	38.2	20.1		
Bulls / Cows	95	49.0	53.4	21.0		
Lambs	165	34.1	39.2	24.5		
Mature sheep	34	33.0	47.8	22.2		
Lambs		Chop: 23 Loin: 24				Gerber *et al*. (2009)
Beef cattle		Sirloin : 37 - 38 Rib-eye : 42 - 51 Steak: 32				
Dairy Cattle [(a)]	16				5.06	Leblanc *et al*. (2005)
Dairy cattle	40 [(b)]				2.016	Licata *et al*. (2004)
Calves	438	47.8				Alonso *et al*. (2002)
Cows	56	52.7				
Beef cattle	3	Sirloin: 40.9 Fillet: 40.1				Lombardi-Boccia *et al*. (2005)
Calves (veal)	3	Fillet: 50.1				
Cattle (free range)	100		92.2 DM	84.8 DM		Nriagu *et al*. (2009)
Dairy cows - conventional	38	57	38	20		Olsson *et al*. (2001)
Dairy cows - organic	29	67	36	19		
Beef cattle	97	43.3	40.3	18.3		Waegeneers *et al*. (2009)

(a) total diet study; (b): number of dairy farms;

Table 4.3 Zinc concentrations (mg/kg) in edible tissues of poultry

Species - category	n	Muscle	Liver	Kidney	Eggs	Reference
Chicken (young)	312	9.21	30.6	21.3		Coleman *et al*. (1992)
Chicken (mature)	308	11.0	50.5	26.2		
Turkey (young)	61	21.9	32.2	19.7		
Duck	99	21.3	58.0	22.2		
Hens	108	Femoral: 17.7 Pectoral: 4.5	34.3	22.2	Yolk: 7.84 White: 0.28	Doganoc (1996)
Chickens	51	Femoral: 15.9 Pectoral: 4.2	28.5	19.8		
Chickens		Breast: 7 Leg + skin: 14				Gerber *et al*. (2009
Hens [(a)]	30				10.07	Leblanc *et al*. (2005)
Chickens	32	Breast: 6.5				Lombardi-Boccia *et al*. (2005)
	16	Lower leg:14.7 Thigh: 17.1 Wing: 12.9				
Turkeys	3	Breast: 10.8 Lower leg: 25.7 Thigh: 24.7				
Hens, private owners	22				11.54	Van Overmeiren *et al*. (2006)
Hens, commercial farms	19				9.74	
Hens, private owners	40				20.3	Waegeneers *et al*. (2008)
	58				19.2	

[(a)] total diet study;

Table 4.4 Zinc concentrations (mg/kg) in edible tissues of rabbits and ostrich

Species - category	n	Muscle	Liver	Kidney	Reference
Ostriches	3	Fillet: 19.6 Sirloin: 25 Leg: 31			Lombardi-Boccia *et al*. (2005)
Rabbits	3	5.5			Lombardi-Boccia *et al*. (2005)
Rabbits	10	Hind leg: 27.12 DM Loin: 20.96 DM	14.35		Fébel *et al*. (2009)

Table 1.5 Zinc concentrations (mg/kg) in edible tissues of fish

Species - category	n	Muscle	Reference
Sea bass – cultured (*Dicentrarchus labrax*)	3	45.1 DM	Alasalvar *et al*. (2002)
Sea bass – wild (*Dicentrarchus labrax*)	3	43.6 DM	
Atlantic herring	3	8.6	Engman & Jorhem (1998)
Baltic herring	3	20	
Burbot	2	6.8	
Cod	4	4.3	
Eel	3	28	
Mackerel	4	5.9	
Perch	3	5.7	
Picked dogfish	2	3.1	
Pike	5	9.9	
Plaice	4	5.8	
Pollack	2	4.4	
Salmon	3	3.9	
Turbot	3	8.3	
Whitefish	3	5.7	
Tilapia (*Tilapia nilotica*)	18	14.77 DM	Kargin & Çogun (1999)

Table 1.6 Zinc concentrations (mg/kg) in honey

Description	**n**	**Concentration**	**Reference**
Origin: Holzing (AU)	23	0.53	Pechhacker *et al*. (2009)
Origin: Neustadt (AU)	25	0.44	
Origin: Hollabrunn (AU)	19	1.19	

Annex 1: References

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Annex 2: Zinc concentrations in edible tissues and products linked with the dietary intake of various zinc compounds and doses

Table 2.1 Zinc concentrations (mg/kg DM) in edible tissues of pigs

Species / category	DT	F matrix	Source of Zn	Zn background conc. (mg/kg)	Supplemented Zn dose (mg/kg)	Total Zn conc. [c] (mg/kg)	Liver	Reference
Weanling pigs	35 d	Corn – soybean meal – whey.	$ZnSO_4$	24	80	NQ	160.9	van Heugten *et al.* (2003)
			$ZnSO_4$		160		156.5	
			$ZnSO_4$ / ZnMet		80 / 80		162.6	
			$ZnSO_4$ / ZnLys		80 / 80		141.3	
			$ZnSO_4$ / ZnMet / ZnLys		80 / 40 / 40		158.1	
			$ZnSO_4$		240		155.8	

Statistics: van Heugten *et al.* (2003): liver zinc concentrations did not differ significantly between treatments.

Table 2.1 (continued) Zinc concentrations (mg/kg) in edible tissues of pigs

Species / category	DT	Source of Zn	Zn background conc. (mg/kg)	Supplemented Zn dose (mg/kg)	Total Zn conc. [c] (mg/kg)	Liver	Kidney	Muscle	Reference
Weanling pigs	42 d	ZnSO4 [b]		100 / 80	194 / 119	46.8	20.6	11.8	EFSA (2009)
		ZnSO4 [b]		150 / 150	195 / 180	53.1	19.7	12.1	
		ZnChel [a,b]		150 / 150	192 / 184	58.0	18.8	12.4	

[a]: Zinc chelate of hydroxy analogue of methionine; [b]: Prestarter /starter feed; [c]: data from zinc analysis
Statistics: EFSA (2009): Zn concentrations in liver, kidney and muscle did not differ significantly between treatments with supplemented $ZnSO_4$ and ZnChel at the same supplementation level (150 mg/kg).

Table 2.2 Zinc concentrations (mg/kg DM) in edible tissues of poultry

Species / category	DT	F matrix	Source of Zn	Zn background conc. (mg/kg)	Supplemented Zn dose (mg/kg)	Total Zn conc. (mg/kg)	Liver	Kidney	Reference
Broiler chicks	20 d	Corn – soybean meal	+ premix	63 DM	-	NQ	75.6	75.5	Sandoval *et al*. (1997)
			$ZnSO_4$		400		79.8	77.3	
			$ZnSO_4$		800		79.2	75.7	
			$ZnSO_4$		1200		82.0	98.6	
			$3Zn(OH)_2.2ZnCO_3$		400		74.8	83.4	
			$3Zn(OH)_2.2ZnCO_3$		800		82.8	80.6	
			$3Zn(OH)_2.2ZnCO_3$		1200		91.0	90.3	
			ZnO		400		79.6	79.5	
			ZnO		800		78.9	78.9	
			ZnO		1200		90.6	86.0	
			Zn metal		400		75.6	84.3	
			Zn metal		800		82.8	80.6	
			Zn metal		1200		91.0	82.6	

Statistics: Sandoval *et al*. (1997): Liver Zn and kidney Zn increased significantly as dietary Zn increased at respectively ($P < 0.0001$) and ($P < 0.001$). A source level interaction was observed for kidney Zn ($P < 0.05$).

Table 2.2 Zinc concentrations in edible tissues (mg/kg DM) of poultry

Species / category	DT	F matrix	Source of Zn	Background Zn conc. (mg/kg)	Supplemented Zn dose (mg/kg)	Total Zn conc. (mg/kg)	Liver	Kidney	Reference
Broiler chicks	20 d	Corn – soybean meal		35 DM		NQ	71.4	72.3	Sandoval *et al*. (1997)
			$ZnSO_4$		40		75.5	74.1	
			$ZnSO_4$		80		79.7	75.3	
			$ZnSO_4$		120		79.1	74.6	
			ZnO		40		76.3	75.7	
			ZnO		80		80.3	77.0	
			ZnO		120		78.8	79.5	
Chicks	14 d	Corn – soybean meal	$ZnCO_3$	45	72	NQ	164	140	Wedekind *et al*. (1992)
			$ZnSO_4$ / $ZnCO_3$		250 / 72		136	130	
			$ZnSO_4$ / $ZnCO_3$		500 / 72		166	142	
			$ZnSO_4$ / $ZnCO_3$		750 / 72		160	132	
			ZnO / $ZnCO_3$		250 / 72		149	117	
			ZnO / $ZnCO_3$		500 / 72		173	156	
			ZnO / $ZnCO_3$		750 / 72		154	175	
			ZnMet / $ZnCO_3$		250 / 72		183	135	
			ZnMet / $ZnCO_3$		500 / 72		126	149	
			ZnMet / $ZnCO_3$		750 / 72		205	132	

Statistics: Sandoval *et al*. (1997): Liver Zn concentration was not affected by dietary Zn source ($P > 0.10$) or dietary Zn concentration ($P > 0.05$). Kidney Zn concentrations were significantly higher when given ZnO ($P < 0.05$), no effect was observed of dietary Zn concentration ($P > 0.10$), ANOVA.
Wedekind *et al*. (1992): No linear responses in liver and kidney Zn for any of the dietary Zn sources tested.

Table 2.3 Zinc concentrations in edible tissues (mg/kg DM) in ruminants

Species / category	DT	F matrix	Source of Zn	Background Zn conc. (mg/kg)	Supplemented Zn dose (mg/kg)	Total Zn conc. (mg/kg)	Liver	Kidney	Reference
Lambs	21 d	Corn – soybean meal – cottonseed hulls	-	58 DM	-	NQ	113	108	Cao *et al*. (2000)
			$ZnSO_4$		700		255	528	
			$ZnSO_4$		1400		374	1164	
			$ZnSO_4$		2100		436	1519	
			ZnProt		1400		415	1394	
			ZnAAchel		1400		324	1114	
			ZnMet		1400		342	980	
Angus steers	42 d	Citrus pulp – cottonseed hulls	-	20.9 DM	-	20.9	90.5 [a]		Spears *et al*. (2004)
			$ZnSO_4$		20	43.1	89.7 [a]		
			ZnMet		20	41.0	92.2 [a]		
			ZnGly		20	44.8	114.0 [b]		

Statistics: Cao *et al*. (2000): liver and kidney Zn increased linearly with additions of dietary Zn ($P < 0.0001$).
Spears *et al*. (2004): [a, b]: Means within a column with different superscripts differ significantly ($P < 0.05$);

Table 2.3 (continued) Zinc concentrations in edible tissues (mg/kg DM) in ruminants

Species / category	DT	F matrix	Source of Zn	Background Zn conc. (mg/kg)	Supplemented Zn dose (mg/kg)	Total Zn conc. (mg/kg)	Liver	Kidney	Reference
Holstein calves	14 d	Cracked corn – cottonseed hulls – soybean meal	-	28 DM	-		133.2	95.8	Wright & Spears (2004)
			$ZnSO_4$		20 DM		127.9	97.2	
			ZnProt.		20 DM		146.1	89.7	
			$ZnSO_4$ / ZnProt		10/10 DM		175.9	114.3	
			$ZnSO_4$		500 DM		231.0	183.1	
			ZnProt		500 DM		331.0	356.7	
			$ZnSO_4$ / ZnProt		250/250 DM		286.8	299.5	

Statistics: Wright & Spears (2004): Liver Zn: low dietary Zn (20 ppm/kg DM) vs. high dietary Zn (500 mg/kg DM) differ significantly at $P < 0.01$; high dietary $ZnSO_4$ vs. high dietary ZnProt differ significantly at $P < 0.1$. Kidney Zn: low dietary Zn vs. high dietary Zn and high dietary $ZnSO_4$ vs. high dietary ZnProt differ significantly at $P < 0.01$; high dietary $ZnSO_4$ vs. high dietary Zn mixed from both sources differ significantly at $P < 0.05$.

Table 2.4 Zinc tissue concentrations (mg/kg DM) in fish

Species / category	DT	Source of Zn	Added Zn concentration in the water (mg/L)	Muscle	Liver	Gill	Reference
Tilapia nilotica	10 d	-	NQ	14.77^{a}	23.33^{a}	43.77^{a}	Kargin & Çogun (1999)
		$ZnCl_2$	1	23.60^{b}	32.94^{b}	74.62^{b}	
			10	28.52^{b}	46.48^{b}	79.48^{b}	

Statistics: Kargin & Çogun (1999): Means within each column with different superscripts differ significantly ($P < 0.01$)

Table 2.4 (continued) Zinc tissue concentrations (mg/kg DM) in fish

Species / category	DT	F matrix	Source of Zn	Background conc. (mg/kg)	Supplemented dose (mg/kg)	Total conc. (mg/kg)	Muscle	Liver	Reference
Atlantic salmon (*Salmo salar*)	56 d	Greater silver smelt – coal fish	-		-		22.0	112	Vangen & Hemre (2003)
			$ZnSO_4$		34	146	22.0	165	
			$ZnSO_4$		6.8	55	20.3	156	
			$ZnSO_4$		39	136	23.5	164	
			$ZnSO_4$		6.8	48	20.4	168	

Statistics: Vangen & Hemre (2003): Muscle and liver Zn concentrations do not differ significantly.

Glossary: NQ: not quantified; DT: duration the experimental feed was fed; F matrix: principal components of the feed matrix; ZnAA chel: zinc amino acid chelate; ZnGlyc: zinc glycine complex; ZnLys: zinc lysine complex; ZnMet: zinc methionine complex; ZnProt: zinc proteinate

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Annex 3.1: Zinc Requirements

Pigs:

Category - Definition	**Zn Req. (NRC, 1998) (mg /kg)**	**Category - Definition**	**Zn Req. (GFE , 2008) (mg /kg DM)**
Pigs: 3 - 5 kg	100	Piglets	80 - 100
Pigs: 5- 10 kg	100		
Pigs: 10 - 20 kg	80	Growing - fattening pigs	50 - 60
Pigs: 20 - 50 kg	60		
Pigs: 50 - 80 kg	50		
Pigs: 80 - 120 kg	50		
Sows: gestation	50	Breeding sows	50
Sows: lactation	50		
		Boars	50

Poultry:

Category - Definition	**Zn Req. (NRC, 1994) (mg /kg)**	**Category - Definition**	**Zn Req. (GfE, 1999) (mg/kg DM)**
Broilers (0 - 8 weeks)	40	Broiler (Mast Broiler; Aufzucht Küken)	50
Immature leghorn- Type chickens (0-6 wk) white	40.0	Chickens reared for laying (Junghennen)	40
Immature leghorn- Type chickens (6 wk - first egg) white	35.0		
Immature leghorn- Type chickens (0-6 wk) brown	38.0		
Immature leghorn- Type chickens (6 wk - first egg) brown	33.0		
Leghorn-Type White Egg Layers (80 g FI.day^{-1})	44	Layers (Eiproduction Legehennen)	50
Leghorn-Type White Egg Layers (100 g FI.day^{-1})	35		
Leghorn-Type White Egg Layers (120 g FI.day^{-1})	29		
Growing Turkeys (0 - 4 wk)	70	Female birds reared for breeding (Zuchthennen)	50
Growing Turkeys (4 - 8 wk)	65		
Growing Turkeys (8 - 12 wk)	50		
Growing Turkeys (12 - 24 wk)	40		
Turkey Holding Hens	40		
Turkey Laying Hens	65		
White Pekin Ducks (0 - 2 wk)	60		

Bovines:

Category - Definition	Zn Req. (Meschy, 2007) (mg /kg DM)
Bovines	45

Bovines: Beef Cattle

Category - Definition	Zn Req. (NRC, 2000) (mg /kg DM)	Category - Definition	Zn Req. (GfE, 1995) (mg/kg DM)
Growing and finishing	30.00	Growing and finishing from 175 kg on	40
Cows gestation	30.00		
Cows early lactation	30.00		

Bovines: Dairy Cattle

Category - Definition	Zn Req. (NRC, 2001) (mg /kg DM)	Category - Definition	Zn Req. (CVB, 2007) (mg/kg DM)
Lactating cow: Holstein - 90 days in milk	43 - 55	Lactating cows (FI: 20 $kg.day^{-1}$)	26.5
Lactating cow: Jersey	45 - 54	Lactating cows (FI: 40 $kg.day^{-1}$)	32.5
Dry cows: Holstein (240 d pregnant)	21	Dry cows, 8 -3 weeks before calving	21.4
Dry cows: Holstein (279 d pregnant)	30	Dry cows, 3 - 0 weeks before calving	22.4

Sheep

Category - Definition	Zn Req. (Meschy, 2007) (mg /kg DM)
Sheep	45

Sheep

Category - Definition	Zn Req. (NRC, 2007 (b)) (mg /day)	Category - Definition	Zn Req. (NRC, 2007 (b)) (mg /day)
Lambs; bw: 20 kg; DM intake: 0.63 kg/day	13		
Lambs; bw: 80 kg; DM intake: 2.87 kg/day	90		
Mature ewes; early lact.; single lamb; DM intake: 1.09 kg/day	44	Mature ewes; breeding. DM intake: 0.85 kg/day	23.0
Mature ewes; early lact.; single lamb; DM intake: 3.8 kg/day	115	Mature ewes; breeding. DM intake: 2.18 kg/day	79
Mature ewes; early lact.; three lambs; DM intake: 1.36 kg/day	72	***Parlor production***	
Mature ewes; early lact.; three lambs; DM intake: 4.37 kg/day	167	Mature ewes; early lact.; DM intake: 2.14 kg/day	117
Mature ewes; late lact.; single lamb; DM intake: 1.09 kg/day	30	Mature ewes; early lact.; DM intake: 5.29 kg/day	204
Mature ewes; late lact.; single lamb; DM intake: 2.60 kg/day	91	Mature ewes; late lact.; DM intake: 2.35 kg/day	69
Mature ewes; late lact.; three lambs; DM intake: 2.06 kg/day	60	Mature ewes; late lact.; DM intake: 4.05 kg/day	133
Mature ewes; late lact.; three lambs; DM intake: 3.59 kg/day	118		

Goats

Category - Definition	Zn Req. (GfE, 2003) (mg/kg DM)	Category - Definition	Zn Req. (Meschy, 2007) (mg/kg DM)
Goats	50 - 80	Goats	45
	Zn Req. (NRC, 2007 (b)) (mg /day)	**Category - Definition**	**Zn Req. (NRC, 2007 (b)) (mg /day)**
Kids; bw: 10 kg; DM intake: 0.35 kg/day	2	Mature does; breeding; DM intake: 0.60 kg/day	6
Kids; bw: 10 kg; DM intake: 0.39 kg/day	10	Mature does; breeding; DM intake: 1.86 kg/day	27
Kids; bw: 40 kg; DM intake: 1.10 kg/day	6		
Kids; bw: 40 kg; DM intake: 1.41 kg/day	31	***Milk yield: 4.65 - 6.43 kg/day***	
Mature does; early lact.; single kid; DM intake: 0.96 kg/day	29	Dairy does; early lactation; DM intake: 2.81 kg/day	171
Mature does; early lact.; single kid; DM intake: 2.62 kg/day	79	Dairy does; early lactation; DM intake: 4.83 kg/day	245
Mature does; early lact.; three kids; DM intake: 1.54 kg/day	32	***Milk yield: 6.98 - 9.65 kg/day***	
Mature does; early lact.; three kids; DM intake: 4.15 kg/day	158	Dairy does; early lactation; DM intake: 3.83 kg/day	271
Mature does; late lact.; single kid; DM intake: 0.70 kg/day	16	Dairy does; early lactation; DM intake: 5.43 kg/day	381
Mature does; late lact.; single kid; DM intake: 2.05 kg/day	51	***Milk yield: 1.99 - 2.76 kg/day***	
Mature does; late lact.; three kids; DM intake: 1.25 kg/day	46	Dairy does; late lactation; DM intake: 2.48 kg/day	99
Mature does; late lact.; three kids; DM intake: 2.66 kg/day	94	Dairy does; late lactation; DM intake: 3.64 kg/day	144
		Milk yield: 2.99 - 4.13 kg/day	
		Dairy does; late lactation; DM intake: 2.51 kg/day	141
		Dairy does; late lactation; DM intake: 4.53 kg/day	201

Horses

Category - Definition	Zn Req. (NRC, 2007) (mg /day)	Category - Definition	Zn Req. (NRC, 2007) (mg /day)
MBW 200 kg; Adult; no work	160.0	MBW 400 kg; Adult; no work	320.0
MBW 200 kg; Adult; working: light exercise	160.0	MBW 400 kg; Adult; working: light exercise	320.0
MBW 200 kg; Adult; working: moderate exercise	180.0	MBW 400 kg; Adult; working: moderate exercise	360.0
MBW 200 kg; Adult; working: (very) heavy exercise	200.0	MBW 400 kg; Adult; working: (very) heavy exercise	400.0
MBW 200 kg; Stallions nonbreeding; breeding	160.0	MBW 400 kg; Stallions nonbreeding; breeding	320.0
MBW 200 kg; Pregnant mares	160.0	MBW 400 kg; Pregnant mares	320.0
MBW 200 kg; Lactating mares	200.0	MBW 400 kg; Lactating mares	400.0
MBW 200 kg; growing animals: 4 m	67.4	MBW 400 kg; growing animals: 4 m	134.8
MBW 200 kg; growing animals: 6 m	86.4	MBW 400 kg; growing animals: 6 m	172.7
MBW 200 kg; growing animals: 12 m	128.5	MBW 400 kg; growing animals: 12 m	257.0
MBW 200 kg; growing animals: 18 m	155.0	MBW 400 kg; growing animals: 18 m	310.0
MBW 200 kg; growing animals: 24 m	171.7	MBW 400 kg; growing animals: 24 m	343.4

Category - Definition	Zn Req. (NRC, 2007) (mg /day)	Category - Definition	Zn Req. (NRC, 2007) (mg /day)
MBW 600 kg; Adult; no work	480.0	MBW 900 kg; Adult; no work	720.0
MBW 600 kg; Adult; working: light exercise	480.0	MBW 900 kg; Adult; working: light exercise	720.0
MBW 600 kg; Adult; working: moderate exercise	540.0	MBW 900 kg; Adult; working: moderate exercise	810.0
MBW 600 kg; Adult; working: (very) heavy exercise	600.0	MBW 900 kg; Adult; working: (very) heavy exercise	900.0
MBW 600 kg; Stallions nonbreeding; breeding	480.0	MBW 900 kg; Stallions nonbreeding; breeding	720.0
MBW 600 kg; Pregnant mares	480.0	MBW 900 kg; Pregnant mares	720.0
MBW 600 kg; Lactating mares	600.0	MBW 900 kg; Lactating mares	900.0
MBW 600 kg; growing animals: 4 m	202.1	MBW 900 kg; growing animals: 4 m	303.2
MBW 600 kg; growing animals: 6 m	259.1	MBW 900 kg; growing animals: 6 m	388.6
MBW 600 kg; growing animals: 12 m	385.5	MBW 900 kg; growing animals: 12 m	578.2
MBW 600 kg; growing animals: 18 m	465.0	MBW 900 kg; growing animals: 18 m	697.5
MBW 600 kg; growing animals: 24 m	515.0	MBW 900 kg; growing animals: 24 m	772.6

Salmonids

Category - Definition	Zn Req. (NRC, 1993) (mg /kg)
Pacific Salmon	required in diet but quantity not determined
Rainbow Trout	30

Dogs

Category - Definition	Zn. Req. (NRC, 2006) (mg/kg DM)	Adequate intake (NRC, 2006) (mg /kg DM)	Rec. Allowance (NRC, 2006) (mg /kg DM)
Puppies after weaning	40		100
Adult dogs at maintenance		60	60
Bitches for late gestation and peak lactation		96	96

Cats

Category - Definition	Zn. Req. (NRC, 2006) (mg /kg DM)	Adequate intake (NRC, 2006) (mg/kg DM)	Rec. Allowance (NRC, 2006) (mg/kg DM)
Kittens after weaning	50		75
Adult Cats		74	74
Queens in late gestation and peak lactation	42		60

Glossary:

Req.: requirement

(a): 90 % dry matter

MBW: Mature body weight

FI: Feed Intake

lact.: lactation

Annex 3.2 Zinc Use Levels

Table 1 Supplementation recommendations, calculated background level ranges (information acquired from the industry) and calculated use levels for zinc

Species category	Supplementation recommendation (mg/kg)	Background level range (mg/kg)	Calculated Use Level (mg/kg)	Max. legally allowed amount (mg/kg)
Pigs (7 – 20 kg)	100	30 – 40	140	150
Pigs (20 – 30 kg)	100	30 – 40	140	150
Pigs (30 – 100 kg)	100	30 - 40	140	150
Sows	100	40 – 50	150	150
Broilers	70	30 – 40	110	150
Hens	70	35 – 40	110	150
Veal	100	40 – 50	150	200
Cattle	100	45 – 60	160	150
Sheep	100	50 - 60	160	150

Table 2 Supplementation levels (Whittemore *et al* ., 2002), maximum background levels (information acquired from the industry) and calculated use levels for zinc

Species category	Supplementation level (mg/kg)	Background level max (mg/kg)	Calculated Use Level (mg/kg)
Weaned pigs (< 15 kg)	100 - 200	40	240
Pigs (15 - 50 kg)	100 - 200	40	240
Pigs (50 - 150 kg)	70 - 150	40	190
Gestating sows	80 - 125	50	175
Lactating sows	80 - 120	50	170

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Annex 4. Zinc concentration in feed materials according to CVB[1] and INRA[2] feed composition tables[3]

CVB

COMPOUND FEED INGREDIENTS	mg/kg
Potatoes dried	
Potato crisps	
Potato prot ASH<10	3
Potato prot ASH>10	29
Potato starch dried	3
Potato sta heat tr	2
Potato pulp CP<95	35
Potato pulp CP>95	35
Potatoes sweet dried	6
Bone meal	118
Brewers' grains dr	65
Brewers' yeast dried	49
Sugarb pulp SUG<100	16
Sugarb p SUG100-150	24
Sugarb p SUG150-200	30
Sugarb pulp SUG>200	25
Biscuits CFAT<120	8
Biscuits CFAT>120	11
Blood meal spray dr	37
Buckwheat	9
Beans phas heat tr	32
Bread meal	16
Casein	36
Chicory pulp dried	31
Citrus pulp dried	9
Meat meal Dutch	114
Meat meal CFAT<100	156
Meat meal CFAT>100	122
Peas	31
Barley	23
Barley feed h grade	67
Barley mill byprod	35
Grass meal CP<140	34
Grass meal CP140-160	41
Grass meal CP160-200	39
Grass meal CP>200	47
Grass seeds	
Peanuts wtht shell	
Peanuts with shell	
Peanut exp wtht sh	65
Peanut exp p with sh	64
Peanut exp with sh	65
Peanut extr wtht sh	51
Peanut extr with sh	50
Oats grain	25
Oats grain peeled	28
Oats husk meal	21
Oats mill fd h grade	
Hempseed	
Carob	6

INRA

	Mean	St. Dev.
	mg/kg	
CEREALS		
Barley	30	8
Maize	19	6
Oats	23	4
Oats groats	26	
Rice, brown	17	
Rye	22	
Sorghum	19	7
Triticale	20	9
Wheat, durum	15	
Wheat, soft	27	8
WHEAT BY-PRODUCTS		
Wheat bran	74	25
Wheat middlings	91	20
Wheat shorts	81	
Wheat feed flour	40	
Wheat bran, durum		
Wheat middlings, durum		
Wheat distillers' grains, starch <7%		
Wheat distillers' grains, starch >7%		
Wheat gluten feed, starch 25%	62	
Wheat gluten feed, starch 28%	61	
MAIZE BY-PRODUCTS		
Corn distillers	65	
Corn gluten feed	53	15
Corn gluten meal	33	16
Maize bran	2	
Maize feed flour		
Maize germ meal, expeller		
Maize germ meal, solvent extracted	131	
Hominy feed	45	
OTHER CEREAL BY-PRODUCTS		
Barley rootlets, dried	78	
Brewers' dried grains	82	28
Rice bran, extracted	73	
Rice bran, full fat	60	22
Rice, broken	16	
LEGUME AND OIL SEEDS		
Chickpea	22	
Cottonseed, full fat	34	3
Faba bean, coloured flowers	31	6
Faba bean, white flowers	31	
Linseed, full fat	45	
Lupin, blue	31	
Lupin, white	27	
Pea	32	7
Rapeseed, full fat	40	
Soybean, full fat, extruded	40	
Soybean, full fat, toasted	40	
Sunflower seed, full fat	51	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Canaryseed	31
Greaves	
Cottonseed wtht husk	
Cottonseed with husk	
Cottons exp wtht h	71
Cottons exp p with h	72
Cottons exp with h	71
Cottons extr wtht h	68
Cotts extr p with h	68
Cottons extr with h	68
Coconut exp CFAT<100	46
Coconut exp CFAT>100	46
Coconut extr	53
Linseed	50
Linseed exp	69
Linseed extr	52
Lentils	33
Lupins CP<335	37
Lupins CP>335	52
Alf meal CP<140	27
Alf meal CP140-160	24
Alf meal CP160-180	22
Alf meal CP>180	21
Poppyseed	
Macoya fruit exp	
Maize	21
Maize chem-h treated	18
Maize gluten meal	19
Maize glfeed CP<200	57
Maize glfd CP200-230	68
Maize glfeed CP>230	63
Maize germ meal extr	63
Maize germ m fd exp	62
Maize germ m fd extr	62
Dist grains and sol	61
Maize feedflour	4
Maize feed meal	
Maize feed meal extr	46
Maize bran	
Maize starch	
Sugarbeet molasses	9
Sugarc mol SUG<475	9
Sugarc mol SUG>475	9
Milk powder skimmed	45
Milk powder whole	50
Millet	25

INRA	Mean	St. Dev.
	mg/kg	
OIL SEED MEALS		
Cocoa meal, extracted		
Copra meal, expeller	49	
Cottonseed meal, crude fibre 7-14%	72	
Cottonseed meal, crude fibre 14-20%	58	
Grapeseed oil meal, solvent extracted	15	
Groundnut meal, detoxified, crude fibre < 9%	58	
Groundnut meal, detoxified, crude fibre > 9%	57	11
Linseed meal, expeller	66	
Linseed meal, solvent extracted	60	
Palm kernel meal, expeller	32	20
Rapeseed meal	65	17
Sesame meal, expeller	125	
Soybean meal, 46		
Soybean meal, 48	47	8
Soybean meal, 50	47	
Sunflower meal, partially decorticated	69	
Sunflower meal, undecorticated	92	11
STARCH, ROOTS AND TUBERS		
Cassava, starch 67%	15	
Cassava, starch 72%	19	
Maize starch		
Potato tuber, dried	25	
Sweet potato, dried	17	
OTHER PLANT BY-PRODUCTS		
Alfalfa protein concentrate		
Beet pulp, dried	19	9
Beet pulp dried, molasses added	13	
Beet pulp, pressed	4	1
Brewers' yeast, dried	64	
Buckwheat hulls		
Carob pod meal	7	
Citrus pulp, dried	12	13
Cocoa hulls		
Grape marc, dried	25	
Grape seeds		
Liquid potato feed	7	
Molasses, beet	17	
Molasses, sugarcane	13	15
Potato protein concentrate	21	
Potato pulp, dried	40	
Soybean hulls	40	11
Vinasse, different origins		
Vinasse, from the production of glutamic acid		
Vinasse, from yeast production	97	
Wheat distillers' grains		

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Millet pearlmillet	
Malt culms CP<200	39
Malt culms CP>200	39
Nigerseed	42
Horsebeans	41
Horsebeans white	40
Palm kernels	20
Palm kern exp CF<180	44
Palm kern exp CF>180	42
Palm kernel extr	
Rapeseed	40
Rapeseed exp	62
Rapeseed extr CP<380	60
Rapeseed extr CP>380	60
Rapes meal Mervobest	60
Rice wtht hulls	16
Rice with hulls	
Rice husk meal	
Rice bran meal extr	93
Rice feed m ASH<90	56
Rice feed m ASH>90	73
Rye	29
Rye middlings	
Safflowerseed	
Safflower meal extr	
Sesameseed	
Sesameseed exp	126
Semameseed meal extr	91
Soybeans heat tr	38
Soybeans not heat tr	38
Soybean hulls CF<320	50
Soyb hulls CF320-360	50
Soybean hulls CF>360	50
Soybean exp	46
Soybm CF<45 CP<480	48
Soybm CF<45 CP>480	48
Soybm CF45-70 CP<450	48
Soybm CF45-70 CP>450	48
Soyb meal CF>70	48
Soyb meal Mervobest	51
Soyb meal Rumi S	47
Sorghum	19
Sorghum gluten meal	
Sugar	
Tapioca STA 575-625	10
Tapioca STA 625-675	8
Tapioca STA 675-725	8
Tapioca starch	

INRA	Mean	St. Dev.
	mg/kg	
DEHYDRATED FORAGES		
Alfalfa, dehydrated, protein < 16% dry matter	21	
Alfalfa, dehydrated, protein 17-18% dry matter	19	5
Alfalfa, dehydrated, protein 18-19% dry matter	19	7
Alfalfa, dehydrated, protein 22-25% dry matter	26	8
Grass, dehydrated	32	7
Wheat straw	19	
DAIRY PRODUCTS		
Milk powder, skimmed	43	
Milk powder, whole	33	
Whey powder, acidic	64	
Whey powder, sweet	20	
FISH MEALS AND SOLUBLES		
Fish meal, protein 62%	89	5
Fish meal, protein 65%	85	14
Fish meal, protein 70%	88	
Fish solubles, condensed, defatted	78	
Fish solubles, condensed, fat		
OTHER ANIMAL BY-PRODUCTS		
Blood meal	23	2
Feather meal	130	18
Meat and bone meal, fat <7.5%	109	
Meat and bone meal, fat >7.5%	110	

CVB	
COMPOUND FEED INGREDIENTS	mg/kg
Wheat	23
Wheat gluten meal	36
Wheat glutenfeed	47
Wheat middlings	85
Wheat germ	169
Wheat germfeed	86
Wheat feedfl CF<35	54
Wheat feedfl CF35-55	54
Wheat feed meal	74
Wheat bran	99
Triticale	34
Feather meal hydr	140
Fat from Animals	9
Fats/oils veg h %d	
Fats/oils vegetable	
Vinasse Sugb CP<250	40
Vinasse Sugb CP>250	15
Fish meal CP<580	83
Fish meal CP580-630	81
Fish meal CP630-680	84
Fish meal CP>680	83
Meat bone m CFAT<100	99
Meat bone m CFAT>100	104
Whey p l lac ASH<210	10
Whey p l lac ASH>210	32
Whey powder	13
Sunflowers deh	
Sunflowers p deh	42
Sunflowers w hulls	42
Sunfls exp deh	70
Sunfls exp p deh	71
Sunfls exp w hulls	71
Sunfmeal CF<160	91
Sunfmeal CF 160-200	91
Sunfmeal CF 200-240	100
Sunfmeal CF>240	79
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Potato juice conc	111
Potato pulp pr NL	11
Potato pulp pressed	18
Potato cut raw	15
Potato c CFAT 40-120	
Potato c CFAT120-180	
Potato cut CFAT>180	
Potato p st STA<350	
Pot p st STA350-475	29
Pot p st STA475-600	
Potato p st STA>600	
Potato starch solid	
Pot sta STA 500-650	19
Pot sta STA 650-775	19
Pot sta STA>750	

CVB	
MOISTURE RICH FEED INGREDIENTS	mg/kg DM
Pot s g STA 300-425	32
Pot s g STA 425-550	32
Pot s g STA 550-675	32
Pot sta gel STA>675	32
Brewers gr 22% DM	99
Brewers gr 27% DM	98
Brewers yeast CP<400	65
Brewers y CP400-500	65
Brewers yeast CP>500	65
Beetp pressed f+sil	34
CCM CF<40	29
CCM CF 40-60	28
CCM CF>60	30
Chicory pulp f+sil	41
Distillers sol f	
Cheese whey CP<175	37
Cheese w CP175-275	29
Cheese whey CP>275	37
Maize glutenf f+sil	45
Maize solubles	226
Wheat st FR STAt 300	27
Wheat st STAtot 400	33
Wheat st STAtot 600	
Carrot peelings st p	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Potatoes fresh	
Potatoes sil	
Potato-peelings sil	
Endive fresh	
Apples fresh	
Gherkin fresh	
Beet leaves fresh	
Beet leaves w p beet	
Beet leaves sil	189
Beet rests sililed	
Bean straw (Phas)	
Bean straw (Vicia)	
Chicory leaves fresh	
Chicory leaves sil	
Pea haulm fresh	
Pea haulm sil	
Pea straw	
Whole crop sil(Cer)	48
Barley straw	
Grass fr April l y.	43
Grass fr April n y.	43
Grass fr April h y.	43
Grass fr May l y.	43
Grass fr May n y.	43
Grass fr May h y.	43
Grass fr June l y.	43
Grass fr June n y.	43
Grass fr June h y.	43

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Grass fr July l y.	43
Grass fr July n y.	43
Grass fr July h y.	43
Grass fr Aug l y.	43
Grass fr Aug n y.	43
Grass fr Aug h y.	43
Grass fr Sept l y.	43
Grass fr Sept n y.	43
Grass fr Sept h y.	43
Grass fr Oct l y.	43
Grass fr Oct n y.	43
Grass fr Oct h y.	43
Grass average	43
Grass horse gr past	43
Grass horse same fld	43
Grass sil May 2000	42
Grass sil May 3500	42
Grass sil May 5000	42
Grass sil June 2000	42
Grass sil June 3000	42
Grass sil June 4000	42
Grass sil Ju-Au 2000	42
Grass sil Ju-Au 3000	42
Grass sil Ju-Au 4000	42
Grass sil Se-Oc 2000	42
Grass sil Se-Oc 3000	42
Grass sil average	42
Grass sil horse fine	42
Grass sil horse midd	42
Grass sil horse crs	42
Grass hay good qual	42
Grass hay av qual	42
Grass hay poor qual	42
Grass hay horse fine	42
Grass hay horse midd	42
Grass hay horse crs	42
Grass bales ad	42
Grass seeds straw	16
Oat straw	
Clover red fresh	
Clover red silage	24
Clover red hay	
Clover red ad	
Clover red straw	
Cucumber fresh	65
Winterrape	
Marrowstem	
Cauliflower	
Kale (white-red)	
Brussels sprouts l&s	
Brussels sprouts	
Turnip cabbage	
Beetroot	

CVB	
ROUGHAGES AND COMPARABLE PRODUCTS	mg/kg DM
Lucerne fresh	
Lucerne silage	45
Lucerne hay	14
Lucerne (alfalfa) ad	28
Maize Cob with leaves silage	31
Sweet pepper fresh	
Pears fresh	
Leeks fresh	
Rye straw	
Lettuce fresh	
Green cereals fresh	
Green cereals silage	41
Maize fod fr DM<240	38
Maize f fr DM240-280	38
Maize f fr DM280-320	38
Maize fod fr DM 320	38
Maize sil DM < 240	38
Maize sil DM240-280	38
Maize sil DM280-320	38
Maize sil DM 320	38
Maize (Fodder) ad	38
Spinach fresh	
Sugar beets fresh	
Wheat straw	
Tomatoes fresh	
Onions	
Field beans silage	
Fodderbeets dirty	
Fodderbeets cleaned	100
Chicory rts not frcd	
Chicory rts frcd cleaned	14
Chicory rts frcd dirty	
Carrots	
Sunflower silage	57

MINERAL FEEDS[3]	mg/kg
Bone meal (steamed)	424
Calcium carbonate	
Diammonium phosphate	300
Difluorinated phosphate	44
Dicalcium phosphate	220
Mono-dicalcium phosphate	210
Monoammonium phosphate	300
Sodium tripolyphosphate	
Phosphoric acid (75%)	

[1] CVB. 2007. Feed Tables. Produktschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral feeds element concentrations are from Batal and Dale. 2008. Feedstuffs September 10, p. 16

Annex 5. Background concentration of zinc in a representative complete feedingstuff for a list of farm animal categories using CVB[1] and INRA[2] trace element composition tables[3]

	# Feed materials	Mass with element concentration (%)		# Feed materials with element concentration		Element concentration (mg/kg)	
		CVB	INRA	CVB	INRA	CVB	INRA
Piglet Starter I (from weaning)	9	90.0	89.2	7	6	27.63	31.00
Piglet Starter II (complete feed)	20	96.8	87.8	12	10	32.17	32.22
Pig Grower (complete feed)	19	97.5	88.4	11	9	34.48	32.49
Pig Finisher (complete feed)	18	97.0	93.7	11	9	35.98	38.41
Sows, gestating (complete feed)	18	97.7	88.3	13	11	45.94	39.48
Sows, lactating (complete feed)	20	96.7	88.5	13	11	37.39	36.62
Starter Chicks (complete feed)	15	97.4	90.4	9	7	35.90	34.98
Chicken reared for laying (complete feed)	17	96.8	89.8	10	8	39.67	38.55
Layer Phase I (complete feed)	16	90.4	87.5	9	8	32.12	33.48
Layer Phase II (complete feed)	16	89.7	86.3	9	8	33.22	35.31
Broiler Starter (complete feed)	14	96.5	95.0	7	6	29.90	30.76
Broiler Grower (complete feed)	15	96.9	90.0	8	6	30.29	29.95
Broiler Finisher (complete feed)	15	96.9	88.4	7	5	29.47	29.80
Turkey Starter (complete feed)	14	94.7	94.7	5	5	38.60	38.99
Turkey Grower (complete feed)	13	92.4	92.4	5	5	35.85	36.94
Turkey Finisher (complete feed)	11	93.0	93.0	4	4	34.34	35.31
Turkey Breeder (complete feed)	8	83.8	83.8	4	4	25.05	23.35
Duck, grower/finisher (complete feed)	10	93.8	93.8	4	4	32.68	35.83
Geese, grower/finisher (complete feed)	8	97.5	97.5	5	5	30.98	31.47
Calf, milk replacer (complete feed)	10	77.9	35.7	6	2	16.72	22.72
Calf concentrate (complete feed)	17	99.1	97.6	13	12	41.73	35.04
Calf concentrate (complementary feed)	16	98.2	95.2	12	11	41.46	38.08
Cattle concentrate (complete feed)[4]	9	95.9	95.9	7	7	33.09	30.61
Cattle concentrate (complementary feed)	8	94.1	94.1	6	6	29.26	30.00
Dairy cows TMR (based on corn silage)[4]	15	98.6	98.8	11	10	41.32	28.71
Dairy cows TMR (based on grass silage)[4]	15	97.5	97.9	11	10	41.53	30.67
Dairy concentrate (complementary feed)	13	88.4	90.1	9	8	43.20	38.72
Dairy cows mineral feed (min. 40% crude ash)	8	15.2	15.2	2	2	38.56	38.56
Rabbit, breeder (complete feed)	8	97.0	97.0	4	4	53.14	49.27
Rabbit, grower/finisher (complete feed)	14	98.9	96.9	8	7	44.63	42.51
Salmon feed (wet)[4]	4	70.4	70.4	2	2	50.07	52.89
Salmon feed (dry)	6	79.4	79.4	3	3	54.95	57.16
Trout feed (dry)	12	94.2	78.2	5	4	39.89	38.00
Dog food (dry)	12	90.7	81.1	6	5	72.98	52.32
Cat food (dry)	16	68.4	90.2	10	9	46.27	74.36

[1] CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; [2] INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; [3] For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16; [4] On DM basis

Zinc: Addendum to the monograph

Abstract

This addendum to the zinc monograph substantiates the data reported in Annex 5 of the zinc monograph in which zinc background levels are reported. The addendum provides the following information for each calculated background level: (1) the zinc concentration in each of the composing feed materials as reported by CVB (2007) or INRA (2004) and Batal & Dale (2008), feed materials for which no zinc concentration was available in the trace element composition table were left blank; (2) the feed material composition of the complete feedingstuff; (3) the contribution of each of the composing feed materials to the total calculated zinc content of the complete feedingstuff. The latter value is also reported in Annex 5. Hence, this addendum to the monograph contains one sheet for each calculated background level reported in Annex 5.

The background levels are defined as the trace element concentrations in the complete feedingstuffs delivered by the feed materials. It is hereby stressed that element contributions by premixes are not included in these calculations of the total element content. It has also to be mentioned that INRA (2004) does not provide trace element concentrations for silages, in contrast to CVB (2007). For the complete feedingstuffs containing grass or maize silage (cattle concentrate complete feed; dairy cows TMR based on grass silage; dairy cows TMR based on maize silage) the trace element concentration of 'dehydrated grassland, rich in grass' was used for grass silage and the trace element concentration of 'maize (cereals)' was used for maize silage.

CVB (2007)	Piglet Starter I (from weaning)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	23	34.93	8.03	29.08
Maize	21	10.00	2.10	7.60
Soybeans heat tr	38	15.10	5.74	20.76
Soybm CF<45 CP>480	48	7.50	3.60	13.03
Wheat	23	16.68	3.84	13.89
Wheat middlings	85	5.00	4.25	15.38
Fat from Animals	9	0.80	0.07	0.26
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	27.63	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Piglet Starter II (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	23	15.00	3.45	10.72
Maize	21	15.81	3.32	10.32
Dist grains and sol	61	3.00	1.83	5.69
Palm kern exp CF<180	44	4.00	1.76	5.47
Rapeseed exp	62	6.00	3.72	11.56
Soybm CF<45 CP>480	48	7.86	3.77	11.73
Wheat	23	27.50	6.33	19.66
Wheat gluten meal	36	10.00	3.60	11.19
Wheat middlings	85	2.00	1.70	5.28
Fat from Animals	9	3.00	0.27	0.84
Sunfmeal CF<160	91	2.55	2.32	7.21
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate	210	0.05	0.10	0.32
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	32.17	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Grower (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	2.00	0.60	1.74
Barley	23	20.00	4.60	13.34
Maize	21	9.42	1.98	5.73
Dist grains and sol	61	5.00	3.05	8.85
Palm kern exp CF<180	44	4.00	1.76	5.10
Rapeseed exp	62	7.00	4.34	12.59
Soybm CF<45 CP>480	48	3.40	1.63	4.73
Wheat	23	35.00	8.05	23.35
Wheat middlings	85	7.27	6.18	17.92
Fat from Animals	9	2.09	0.19	0.55
Sunfmeal CF<160	91	2.32	2.11	6.11
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	34.48	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Pig Finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	2.50	0.75	2.08
Barley	23	20.00	4.60	12.78
Maize	21	6.93	1.45	4.04
Dist grains and sol	61	6.21	3.79	10.53
Palm kern exp CF<180	44	5.00	2.20	6.11
Rapeseed exp	62	1.35	0.84	2.32
Wheat	23	35.00	8.05	22.37
Wheat gluten meal	36	3.04	1.09	3.04
Wheat middlings	85	10.00	8.50	23.62
Fat from Animals	9	2.00	0.18	0.50
Sunfmeal CF<160	91	4.98	4.53	12.59
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	35.98	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, gestating (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	5.50	1.65	3.59
Barley	23	20.00	4.60	10.01
Maize	21	15.26	3.20	6.97
Maize germ meal extr	63	7.50	4.73	10.28
Sugarc mol SUG<475	9	0.10	0.01	0.02
Palm kern exp CF<180	44	5.00	2.20	4.79
Wheat	23	11.22	2.58	5.62
Wheat glutenfeed	47	5.00	2.35	5.12
Wheat middlings	85	7.50	6.38	13.88
Wheat bran	99	12.50	12.38	26.94
Fat from Animals	9	1.91	0.17	0.37
Sunfmeal CF<160	91	6.11	5.56	12.11
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate	210	0.07	0.14	0.30
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	45.94	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Sows, lactating (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	2.41	0.72	1.94
Barley	23	20.00	4.60	12.30
Maize	21	10.00	2.10	5.62
Palm kern exp CF<180	44	4.00	1.76	4.71
Rapeseed exp	62	6.00	3.72	9.95
Soybean exp	46	1.39	0.64	1.71
Soybm CF<45 CP>480	48	5.13	2.46	6.58
Wheat	23	23.43	5.39	14.41
Wheat glutenfeed	47	10.00	4.70	12.57
Wheat middlings	85	7.50	6.38	17.05
Fat from Animals	9	2.16	0.19	0.52
Sunfmeal CF<160	91	4.22	3.84	10.26
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate	210	0.42	0.89	2.38
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	37.39	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Starter Chicks (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	20.00	4.20	11.70
Rapeseed exp	62	5.00	3.10	8.63
Soybeans not heat tr	38	0.69	0.26	0.73
Soybm CF<45 CP>480	48	19.79	9.50	26.46
Wheat	23	35.62	8.19	22.82
Wheat gluten meal	36	5.75	2.07	5.76
Fat from Animals	9	2.00	0.18	0.50
Sunfmeal CF<160	91	7.94	7.23	20.13
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate	210	0.56	1.17	3.25
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	35.90	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Chicken reared for laying (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	15.00	3.15	7.94
Dist grains and sol	61	2.50	1.53	3.84
Rapeseed exp	62	5.00	3.10	7.81
Soybm CF<45 CP>480	48	2.95	1.42	3.57
Wheat	23	41.54	9.55	24.08
Wheat gluten meal	36	10.00	3.60	9.08
Wheat bran	99	7.50	7.43	18.72
Fat from Animals	9	2.00	0.18	0.45
Sunfmeal CF<160	91	10.00	9.10	22.94
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate	210	0.29	0.62	1.56
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	39.67	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase I (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	20.00	4.20	13.08
Dist grains and sol	61	4.00	2.44	7.60
Soybeans not heat tr	38	8.36	3.18	9.89
Soybm CF<45 CP>480	48	5.93	2.85	8.87
Wheat	23	38.18	8.78	27.34
Wheat gluten meal	36	0.47	0.17	0.53
Fat from Animals	9	2.87	0.26	0.80
Sunfmeal CF<160	91	10.00	9.10	28.33
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate	210	0.55	1.14	3.56
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	32.12	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Layer Phase II (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	20.00	4.20	12.64
Dist grains and sol	61	4.00	2.44	7.34
Soybean exp	46	7.80	3.59	10.80
Soybm CF<45 CP>480	48	6.34	3.04	9.16
Wheat	23	30.36	6.98	21.02
Wheat gluten meal	36	7.41	2.67	8.03
Fat from Animals	9	3.40	0.31	0.92
Sunfmeal CF<160	91	10.00	9.10	27.39
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate	210	0.43	0.89	2.69
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	33.22	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Starter (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	30.00	6.30	21.07
Maize gluten meal	19	2.50	0.48	1.59
Soybeans not heat tr	38	15.00	5.70	19.06
Soybm CF<45 CP>480	48	18.41	8.84	29.56
Wheat	23	28.16	6.48	21.66
Fat from Animals	9	1.50	0.14	0.45
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate	210	0.94	1.98	6.62
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	29.90	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Grower (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	15.00	3.15	10.40
Maize gluten meal	19	1.56	0.30	0.98
Rapeseed exp	62	2.50	1.55	5.12
Soybeans not heat tr	38	10.00	3.80	12.55
Soybm CF<45 CP>480	48	20.22	9.70	32.04
Wheat	23	42.41	9.75	32.21
Fat from Animals	9	4.44	0.40	1.32
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate	210	0.78	1.63	5.39
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	30.29	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Broiler Finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize gluten meal	19	0.68	0.13	0.44
Rapeseed exp	62	2.50	1.55	5.26
Soybeans not heat tr	38	10.16	3.86	13.10
Soybm CF<45 CP>480	48	19.32	9.27	31.46
Wheat	23	57.84	13.30	45.14
Fat from Animals	9	6.00	0.54	1.83
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate	210	0.39	0.81	2.76
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	29.47	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Starter (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	20.00	4.20	10.88
Soybm CF<45 CP>480	48	42.45	20.38	52.80
Wheat	23	25.35	5.83	15.10
Fats/oils vegetable		1.83		
Fish meal CP630-680	84	5.00	4.20	10.88
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate	210	1.90	3.99	10.34
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Other		0.15		
Total		99.82	38.60	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Grower (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	6.94	1.46	4.06
Soybeans not heat tr	38	2.00	0.76	2.12
Soybm CF<45 CP>480	48	41.24	19.80	55.21
Wheat	23	40.00	9.20	25.66
Fats/oils vegetable		5.00		
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	210	2.21	4.64	12.94
Salt		0.30		
Total		100.00	35.85	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	11.74	2.47	7.18
Soybm CF<45 CP>480	48	39.50	18.96	55.21
Wheat	23	40.00	9.20	26.79
Fats/oils vegetable		4.60		
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	210	1.77	3.72	10.82
Salt		0.30		
Total		100.00	34.34	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Turkey Breeder (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	21	69.44	14.58	58.20
Soybm CF<45 CP>480	48	11.40	5.47	21.84
Feather meal hydr	140	2.00	2.80	11.18
Calcium carbonate		7.60		
Dicalcium Phosphate	220	1.00	2.20	8.78
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	25.05	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Duck, grower/finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Soybm CF<45 CP>480	48	15.00	7.20	22.03
Wheat	23	68.91	15.85	48.50
Wheat middlings	85	9.00	7.65	23.41
Fats/oils veg h %d		3.87		
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	220	0.90	1.98	6.06
Premix		0.50		
Salt		0.37		
Total		100.02	32.68	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Geese, grower/finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	23	10.00	2.30	7.42
Maize	21	34.00	7.14	23.05
Soybm CF<45 CP>480	48	33.00	15.84	51.13
Wheat	23	20.00	4.60	14.85
Calcium carbonate		1.20		
Dicalcium Phosphate	220	0.50	1.10	3.55
Premix		1.00		
Salt		0.30		
Total		100.00	30.98	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf, milk replacer (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize starch		5.00		
Soybm CF<45 CP>480	48	10.00	4.80	28.71
Wheat gluten meal	36	5.00	1.80	10.77
Fat from Animals	9	6.25	0.56	3.36
Whey p l lac ASH<210	10	15.00	1.50	8.97
Whey powder	13	30.65	3.98	23.84
Cheese whey CP>275	37	11.00	4.07	24.35
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	16.72	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	5.50	1.65	3.95
Citrus pulp, dried	9	8.00	0.72	1.73
Barley	23	0.54	0.12	0.30
Linseed	50	1.25	0.63	1.50
Sugarbeet molasses	9	1.00	0.09	0.22
Palm kern exp CF<180	44	5.50	2.42	5.80
Rapeseed	40	3.50	1.40	3.35
Rapeseed extr CP>380	60	1.94	1.16	2.79
Soybeans heat tr	38	5.37	2.04	4.89
Wheat middlings	85	7.00	5.95	14.26
Wheat feedfl CF<35	54	8.00	4.32	10.35
Vinasse Sugb CP>250	15	1.50	0.23	0.54
Grass hay good qual	42	50.00	21.00	50.32
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	41.73	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Calf concentrate (complementary feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	11.00	3.30	7.96
Citrus pulp, dried	9	16.00	1.44	3.47
Barley	23	1.08	0.25	0.60
Linseed	50	2.50	1.25	3.02
Sugarbeet molasses	9	2.00	0.18	0.43
Palm kern exp CF<180	44	11.00	4.84	11.67
Rapeseed	40	7.00	2.80	6.75
Rapeseed extr CP>380	60	3.88	2.33	5.62
Soybeans heat tr	38	10.74	4.08	9.85
Wheat middlings	85	14.00	11.90	28.70
Wheat feedfl CF<35	54	16.00	8.64	20.84
Vinasse Sugb CP>250	15	3.00	0.45	1.09
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	41.46	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	10.01	3.00	9.07
Barley	23	18.90	4.35	13.14
Linseed	50	7.51	3.76	11.35
Sugarbeet molasses	9	0.98	0.09	0.27
Soybm CF<45 CP>480	48	10.99	5.28	15.94
Wheat	23	17.50	4.03	12.16
Fats/oils veg h %d		1.60		
Grass sil average	42	30.00	12.60	38.07
Premix		2.50		
Total		99.99	33.09	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cattle concentrate (complementary feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	14.30	4.29	14.66
Barley	23	27.00	6.21	21.22
Linseed	50	10.70	5.35	18.28
Sugarbeet molasses	9	1.40	0.13	0.43
Soybm CF<45 CP>480	48	15.70	7.54	25.75
Wheat	23	25.00	5.75	19.65
Fats/oils veg h %d		2.30		
Premix		3.60		
Total		100.00	29.26	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on corn silage)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	2.61	0.78	1.90
Maize glfd CP200-230	68	0.95	0.65	1.56
Maize feed meal		1.15		
Sugarbeet molasses	9	0.24	0.02	0.05
Palm kern exp CF<180	44	1.78	0.78	1.90
Rapeseed exp	62	0.59	0.37	0.89
Rapeseed extr CP>380	60	6.18	3.71	8.97
Soybm CF<45 CP>480	48	7.83	3.76	9.10
Wheat middlings	85	0.96	0.82	1.97
Vinasse Sugb CP>250	15	0.36	0.05	0.13
Grass sil average	42	26.89	11.29	27.33
Maize sil DM280-320	38	50.23	19.09	46.20
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.95	41.32	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows TMR (based on grass silage)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	4.72	1.42	3.41
Maize glfd CP200-230	68	1.72	1.17	2.82
Maize feed meal		2.08		
Sugarbeet molasses	9	0.43	0.04	0.09
Palm kern exp CF<180	44	3.22	1.42	3.41
Rapeseed exp	62	1.07	0.66	1.60
Rapeseed extr CP>380	60	4.39	2.63	6.34
Soybm CF<45 CP>480	48	3.97	1.91	4.59
Wheat middlings	85	1.74	1.48	3.56
Vinasse Sugb CP>250	15	0.64	0.10	0.23
Grass sil average	42	49.18	20.66	49.74
Maize sil DM280-320	38	26.46	10.05	24.21
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		99.94	41.53	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy concentrate (complementary feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	22.00	6.60	15.28
Maize glfd CP200-230	68	8.00	5.44	12.59
Maize feed meal		9.70		
Sugarbeet molasses	9	2.00	0.18	0.42
Palm kern exp CF<180	44	15.00	6.60	15.28
Rapeseed exp	62	5.00	3.10	7.18
Rapeseed extr CP>380	60	15.00	9.00	20.83
Soybm CF<45 CP>480	48	10.30	4.94	11.44
Wheat middlings	85	8.10	6.89	15.94
Vinasse Sugb CP>250	15	3.00	0.45	1.04
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	43.20	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dairy cows mineral feed (min. 40% crude ash)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate	220	8.80	19.36	50.21
Salt		22.60		
Diammonium phosphate	300	6.40	19.20	49.79
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	38.56	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, breeder (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	23	2.00	0.46	0.87
Alf meal CP160-180	22	40.00	8.80	16.56
Soybm CF<45 CP>480	48	9.00	4.32	8.13
Wheat germfeed	86	46.00	39.56	74.44
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	53.14	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG150-200	30	10.00	3.00	6.72
Barley	23	23.00	5.29	11.85
Alf meal CP160-180	22	35.00	7.70	17.25
Soybm CF<45 CP>480	48	5.00	2.40	5.38
Wheat bran	99	12.00	11.88	26.62
Fat from Animals	9	2.00	0.18	0.40
Sunfmeal CF 200-240	100	10.00	10.00	22.41
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	220	1.90	4.18	9.37
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	44.63	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Salmon feed (wet)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat	23	14.90	3.43	6.84
Fish meal CP630-680	84	55.53	46.65	93.16
Fish oil		18.92		
Magnesiumoxide		10.64		
Total		99.99	50.07	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)		Salmon feed (dry)		
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Soybm CF<45 CP>480	48	20.00	9.60	17.47
Wheat	23	7.42	1.71	3.11
Fish meal CP630-680	84	51.96	43.65	79.42
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.00	54.95	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Trout feed (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize starch		3.00		
Soybm CF<45 CP>480	48	55.00	26.40	66.19
Wheat	23	2.87	0.66	1.65
Wheat gluten meal	36	11.80	4.25	10.65
Fat from Animals	9	16.00	1.44	3.61
Fish meal CP630-680	84	8.50	7.14	17.90
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Total		100.00	39.89	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Dog food (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Sugarb p SUG100-150	24	4.30	1.03	1.41
Meat meal CFAT<100	156	40.62	63.37	86.82
Maize	21	27.80	5.84	8.00
Maize starch		2.78		
Rice wtht hulls	16	7.30	1.17	1.60
Fat from Animals	9	9.60	0.86	1.18
Brewers y CP400-500	65	1.10	0.72	0.98
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	72.98	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

CVB (2007)	Cat food (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Brewers' yeast dried	49	1.80	0.88	1.91
Meat meal Dutch	114	1.33	1.52	3.28
Greaves		29.76		
Linseed	50	3.00	1.50	3.24
Wheat	23	12.21	2.81	6.07
Wheat glutenfeed	47	2.06	0.97	2.09
Wheat feedfl CF<35	54	20.00	10.80	23.34
Feather meal hydr	140	18.00	25.20	54.46
Fat from Animals	9	7.97	0.72	1.55
Fish meal CP630-680	84	1.00	0.84	1.82
Meat bone m CFAT>100	104	1.00	1.04	2.25
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	46.27	100.00

CVB. 2007. Feed Tables. Productschap Diervoeding, The Netherlands; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter I (from weaning)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	34.93	10.48	33.81
Maize	19	10.00	1.90	6.13
Wheat, soft	27	16.68	4.50	14.53
Wheat middlings	91	5.00	4.55	14.68
Soybean, full fat, extruded	40	15.10	6.04	19.48
Soybean meal, 50	47	7.50	3.53	11.37
Tallow		0.80		
Phytase		<0.01		
Premix and others		10.00		
Total		100.00	31.00	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Piglet Starter II (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	15.00	4.50	13.97
Maize	19	15.81	3.00	9.32
Wheat, soft	27	27.50	7.43	23.04
Wheat middlings	91	2.00	1.82	5.65
Wheat gluten feed, starch 28%	61	10.00	6.10	18.93
Corn distillers	65	3.00	1.95	6.05
Palm kernel meal, expeller	32	4.00	1.28	3.97
Rapeseed cake		6.00		
Soybean meal, 50	47	7.86	3.70	11.47
Sunflower meal, undecorticated	92	2.55	2.34	7.28
Tallow		3.00		
Phytase		1.50		
Calcium carbonate		0.45		
L-Lysine HCl		0.49		
Monocalciumphosphate	210	0.05	0.10	0.32
Phytase		0.07		
L-Threonine		0.14		
Premix		0.50		
DL-Methionine		0.08		
L-Tryptophane		0.02		
Total		100.00	32.22	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Grower (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	20.00	6.00	18.47
Maize	19	9.42	1.79	5.51
Wheat, soft	27	35.00	9.45	29.08
Wheat middlings	91	7.27	6.62	20.36
Corn distillers	65	5.00	3.25	10.00
Palm kernel meal, expeller	32	4.00	1.28	3.94
Rapeseed cake		7.00		
Soybean meal, 50	47	3.40	1.60	4.92
Sunflower meal, undecorticated	92	2.32	2.13	6.55
Beet pulp, dried	19	2.00	0.38	1.17
Tallow		2.09		
Calcium carbonate		0.02		
L-Lysine HCl		0.48		
Phytase		0.01		
L-Threonine		0.13		
Premix		0.30		
DL-Methionine		0.05		
L-Tryptophane		0.02		
Phytase		1.50		
Total		100.00	32.49	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Pig Finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	20.00	6.00	15.62
Maize	19	6.93	1.32	3.43
Wheat, soft	27	35.00	9.45	24.60
Wheat middlings	91	10.00	9.10	23.69
Wheat gluten feed, starch 28%	61	3.04	1.85	4.82
Corn distillers	65	6.21	4.04	10.51
Palm kernel meal, expeller	32	5.00	1.60	4.17
Rapeseed cake		1.35		
Sunflower meal, undecorticated	92	4.98	4.58	11.93
Beet pulp, dried	19	2.50	0.48	1.24
Tallow		2.00		
Calcium carbonate		0.04		
L-Lysine HCl		0.50		
L-Threonine		0.14		
DL-Methionine		0.04		
L-Tryptophane		0.02		
Other		0.77		
Phytase		1.50		
Total		100.00	38.41	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, gestating (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	20.00	6.00	15.20
Maize	19	15.26	2.90	7.34
Wheat, soft	27	11.22	3.03	7.68
Wheat bran	74	12.50	9.25	23.43
Wheat middlings	91	7.50	6.83	17.29
Wheat gluten feed, starch 28%	61	5.00	3.05	7.73
Maize germ meal, expeller		7.50		
Palm kernel meal, expeller	32	5.00	1.60	4.05
Sunflower meal, undecorticated	92	6.11	5.62	14.25
Beet pulp, dried	19	5.50	1.05	2.65
Molasses, sugarcane	13	0.10	0.01	0.03
Tallow		1.91		
Phytase		1.50		
Calcium carbonate		0.48		
L-Lysine HCl		0.24		
Monocalciumphosphate	210	0.07	0.14	0.35
Phytase		0.07		
L-Threonine		0.05		
Total		100.00	39.48	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Sows, lactating (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	20.00	6.00	16.38
Maize	19	10.00	1.90	5.19
Wheat, soft	27	23.43	6.33	17.27
Wheat middlings	91	7.50	6.83	18.64
Wheat gluten feed, starch 28%	61	10.00	6.10	16.66
Soybean, full fat, extruded	40	1.39	0.56	1.52
Palm kernel meal, expeller	32	4.00	1.28	3.50
Rapeseed cake		6.00		
Soybean meal, 50	47	5.13	2.41	6.58
Sunflower meal, undecorticated	92	4.22	3.88	10.59
Beet pulp, dried	19	2.41	0.46	1.25
Tallow		2.16		
Phytase		1.50		
Calcium carbonate		1.02		
L-Lysine HCl		0.34		
Monocalciumphosphate	210	0.42	0.89	2.43
Phytase		0.07		
L-Threonine		0.10		
Premix		0.30		
DL-Methionine		0.02		
Total		100.00	36.62	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Starter Chicks (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	20.00	3.80	10.86
Wheat, soft	27	35.62	9.62	27.50
Wheat gluten feed, starch 28%	61	5.75	3.51	10.02
Soybean, full fat, extruded	40	0.69	0.28	0.79
Rapeseed cake		5.00		
Soybean meal, 50	47	19.79	9.30	26.60
Sunflower meal, undecorticated	92	7.94	7.31	20.89
Tallow		2.00		
Calcium carbonate		1.34		
L-Lysine HCl		0.07		
Monocalciumphosphate	210	0.56	1.17	3.34
Phytase		0.07		
DL-Methionine		0.16		
Premix		1.00		
Phytase		0.02		
Total		100.00	34.98	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Chicken reared for laying (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	15.00	2.85	7.39
Wheat, soft	27	41.54	11.22	29.10
Wheat bran	74	7.50	5.55	14.40
Wheat gluten feed, starch 28%	61	10.00	6.10	15.83
Corn distillers	65	2.50	1.63	4.22
Rapeseed cake		5.00		
Soybean meal, 50	47	2.95	1.39	3.60
Sunflower meal, undecorticated	92	10.00	9.20	23.87
Tallow		2.00		
Calcium carbonate		1.79		
L-Lysine HCl		0.23		
Monocalciumphosphate	210	0.29	0.62	1.60
Phytase		0.07		
L-Threonine		0.03		
DL-Methionine		0.08		
Premix		1.00		
Phytase		0.02		
Total		100.00	38.55	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase I (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	20.00	3.80	11.35
Wheat, soft	27	38.18	10.31	30.80
Wheat gluten feed, starch 28%	61	0.47	0.29	0.86
Corn distillers	65	4.00	2.60	7.77
Soybean, full fat, extruded	40	8.36	3.35	9.99
Soybean meal, 50	47	5.93	2.79	8.33
Sunflower meal, undecorticated	92	10.00	9.20	27.48
Tallow		2.87		
Calcium carbonate		7.78		
L-Lysine HCl		0.23		
Monocalciumphosphate	210	0.55	1.14	3.42
L-Threonine		0.04		
DL-Methionine		0.07		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	33.48	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Layer Phase II (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	20.00	3.80	10.76
Wheat, soft	27	30.36	8.20	23.21
Wheat gluten feed, starch 28%	61	7.41	4.52	12.80
Corn distillers	65	4.00	2.60	7.36
Soybean, full fat, extruded	40	7.80	3.12	8.84
Soybean meal, 50	47	6.34	2.98	8.44
Sunflower meal, undecorticated	92	10.00	9.20	26.05
Tallow		3.40		
Calcium carbonate		8.48		
L-Lysine HCl		0.20		
Monocalciumphosphate	210	0.43	0.89	2.53
L-Threonine		0.02		
DL-Methionine		0.06		
Phytase		1.50		
Enzyme		0.01		
Other		<0.01		
Total		100.00	35.31	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Starter (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	30.00	5.70	18.53
Wheat, soft	27	28.16	7.60	24.72
Corn gluten meal	33	2.50	0.83	2.68
Soybean, full fat, extruded	40	15.00	6.00	19.50
Soybean meal, 50	47	18.41	8.65	28.13
Tallow		1.50		
Calcium carbonate		1.62		
L-Lysine HCl		0.44		
Monocalciumphosphate	210	0.94	1.98	6.43
L-Threonine		0.06		
DL-Methionine		0.30		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	30.76	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Grower (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	15.00	2.85	9.52
Wheat, soft	27	42.41	11.45	38.24
Corn gluten meal	33	1.56	0.51	1.71
Soybean, full fat, extruded	40	10.00	4.00	13.36
Rapeseed cake		2.50		
Soybean meal, 50	47	20.22	9.50	31.72
Tallow		4.44		
Calcium carbonate		1.38		
L-Lysine HCl		0.33		
Monocalciumphosphate	210	0.78	1.63	5.46
L-Threonine		0.05		
DL-Methionine		0.28		
Premix		1.00		
Phytase		0.02		
Other		0.05		
Total		100.00	29.95	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Broiler Finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat, soft	27	57.84	15.62	52.40
Corn gluten meal	33	0.68	0.23	0.76
Soybean, full fat, extruded	40	10.16	4.06	13.64
Rapeseed cake		2.50		
Soybean meal, 50	47	19.32	9.08	30.47
Tallow		6.00		
Calcium carbonate		1.38		
L-Lysine HCl		0.28		
Monocalciumphosphate	210	0.39	0.81	2.73
Phytase		0.07		
L-Threonine		0.06		
DL-Methionine		0.26		
Phytase		0.02		
Other		0.05		
Premix		1.00		
Total		100.00	29.80	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Starter (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	20.00	3.80	9.75
Wheat, soft	27	25.35	6.84	17.55
Soybean meal, 50	47	42.45	19.95	51.18
Fish meal, protein 70%	88	5.00	4.40	11.29
Calcium carbonate		1.99		
L-Lysine HCl		0.34		
Monocalciumphosphate	210	1.90	3.99	10.23
L-Threonine		0.08		
DL-Methionine		0.31		
Premix		0.25		
Salt		0.21		
Other		0.11		
Vegetable oil		1.83		
Other		0.15		
Total		99.82	38.99	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Grower (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	6.94	1.32	3.57
Wheat, soft	27	40.00	10.80	29.23
Soybean, full fat, extruded	40	2.00	0.80	2.17
Soybean meal, 50	47	41.24	19.38	52.47
Calcium carbonate		1.15		
L-Lysine HCl		0.22		
L-Threonine		0.08		
DL-Methionine		0.31		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	210	2.21	4.64	12.56
Salt		0.30		
Vegetable oil		5.00		
Total		100.00	36.94	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	11.74	2.23	6.32
Wheat, soft	27	40.00	10.80	30.58
Soybean meal, 50	47	39.50	18.57	52.57
Calcium carbonate		1.30		
L-Threonine		0.01		
DL-Methionine		0.23		
Other		0.05		
Premix		0.50		
Monodicalcium phosphate	210	1.77	3.72	10.53
Salt		0.30		
Vegetable oil		4.60		
Total		100.00	35.31	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Turkey Breeder (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	69.44	13.19	56.50
Soybean meal, 50	47	11.40	5.36	22.94
Feather meal	130	2.00	2.60	11.13
Calcium carbonate		7.60		
Dicalcium Phosphate	220	1.00	2.20	9.42
Premix		0.70		
Salt		7.40		
Other		0.30		
Total		99.84	23.35	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Duck, grower/finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat, soft	27	68.91	18.61	51.93
Wheat middlings	91	9.00	8.19	22.86
Soybean meal, 50	47	15.00	7.05	19.68
Calcium carbonate		1.20		
L-Lysine HCl		0.15		
DL-Methionine		0.12		
Dicalcium Phosphate	220	0.90	1.98	5.53
Premix		0.50		
Salt		0.40		
Vegetable oil		3.87		
Total		100.05	35.83	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Geese, grower/finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	10.00	3.00	9.53
Maize	19	34.00	6.46	20.53
Wheat, soft	27	20.00	5.40	17.16
Soybean meal, 50	47	33.00	15.51	49.29
Calcium carbonate		1.20		
Dicalcium Phosphate	220	0.50	1.10	3.50
Premix		1.00		
Salt		0.30		
Total		100.00	31.47	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf, milk replacer (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat gluten feed, starch 25%	62	5.00	3.10	13.65
Soy protein concentrate		10.00		
Maize starch		5.00		
Whey powder, acidic	64	30.65	19.62	86.35
Whey powder, partially delactosed		15.00		
Whey protein concentrate		11.00		
Lard		6.25		
L-Lysine HCl		0.60		
Premix		2.65		
Vegetable oil		13.85		
Total		100.00	22.72	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	0.54	0.16	0.46
Wheat middlings	91	7.00	6.37	18.18
Wheat feed flour	40	8.00	3.20	9.13
Linseed, full fat	45	1.25	0.56	1.61
Rapeseed, full fat	40	3.50	1.40	4.00
Soybean, full fat, toasted	40	5.37	2.15	6.13
Palm kernel meal, expeller	32	5.50	1.76	5.02
Rapeseed meal	65	1.94	1.26	3.60
Beet pulp, dried	19	5.50	1.05	2.98
Citrus pulp, dried	12	8.00	0.96	2.74
Molasses, beet	17	1.00	0.17	0.49
Vinasse, different origins		1.50		
Grassland, rich in grass, dehydrated	32	50.00	16.00	45.66
Calcium carbonate		0.51		
Premix		0.25		
Salt		0.36		
Magnesiumoxide		0.01		
Total		100.23	35.04	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Calf concentrate (complementary feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	1.08	0.32	0.85
Wheat middlings	91	14.00	12.74	33.46
Wheat feed flour	40	16.00	6.40	16.81
Linseed, full fat	45	2.50	1.13	2.95
Rapeseed, full fat	40	7.00	2.80	7.35
Soybean, full fat, toasted	40	10.74	4.30	11.29
Palm kernel meal, expeller	32	11.00	3.52	9.24
Rapeseed meal	65	3.88	2.52	6.62
Beet pulp, dried	19	11.00	2.09	5.49
Citrus pulp, dried	12	16.00	1.92	5.04
Molasses, beet	17	2.00	0.34	0.89
Vinasse, different origins		3.00		
Calcium carbonate		1.02		
Premix		0.50		
Salt		0.73		
Magnesiumoxide		0.01		
Total		100.46	38.08	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	18.90	5.67	18.52
Wheat, soft	27	17.50	4.73	15.44
Linseed, full fat	45	7.51	3.38	11.04
Soybean meal, 50	47	10.99	5.17	16.88
Beet pulp, dried	19	10.01	1.90	6.21
Molasses, beet	17	0.98	0.17	0.54
Grass silage	32	30.00	9.60	31.36
Premix		2.50		
Vegetable oil		1.61		
Total		100.00	30.61	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cattle concentrate (complementary feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	27.00	8.10	27.00
Wheat, soft	27	25.00	6.75	22.50
Linseed, full fat	45	10.70	4.82	16.05
Soybean meal, 50	47	15.70	7.38	24.60
Beet pulp, dried	19	14.30	2.72	9.06
Molasses, beet	17	1.40	0.24	0.79
Premix		3.60		
Vegetable oil		2.30		
Total		100.00	30.00	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on corn silage)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat middlings	91	0.96	0.87	3.04
Corn gluten feed	53	0.95	0.50	1.75
Corn gluten meal	33	1.15	0.38	1.32
Palm kernel meal, expeller	32	1.78	0.57	1.98
Rapeseed meal	65	6.18	4.02	13.99
Rapeseed cake		0.59		
Soybean meal, 50	47	7.83	3.68	12.82
Beet pulp, dried	19	2.61	0.50	1.73
Molasses, beet	17	0.24	0.04	0.14
Vinasse, different origins		0.36		
Grass silage	32	26.89	8.60	29.97
Corn silage	19	50.23	9.54	33.24
Calcium carbonate		0.06		
Premix		0.12		
Magnesiumoxide		0.04		
Total		99.99	28.71	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy cows TMR (based on grass silage)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat middlings	91	1.74	1.58	5.16
Corn gluten feed	53	1.72	0.91	2.97
Corn gluten meal	33	2.08	0.69	2.24
Palm kernel meal, expeller	32	3.22	1.03	3.36
Rapeseed meal	65	4.39	2.85	9.31
Rapeseed cake		1.07		
Soybean meal, 50	47	3.97	1.87	6.08
Beet pulp, dried	19	4.72	0.90	2.92
Molasses, beet	17	0.43	0.07	0.24
Vinasse, different origins		0.64		
Grass silage	32	49.18	15.74	51.32
Corn silage	19	26.46	5.03	16.39
Calcium carbonate		0.11		
Premix		0.21		
Magnesiumoxide		0.06		
Total		100.00	30.67	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dairy concentrate (complementary feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat middlings	91	8.10	7.37	19.04
Corn gluten feed	53	8.00	4.24	10.95
Corn gluten meal	33	9.70	3.20	8.27
Palm kernel meal, expeller	32	15.00	4.80	12.40
Rapeseed meal	65	15.00	9.75	25.18
Rapeseed cake		5.00		
Soybean meal, 50	47	10.30	4.84	12.50
Beet pulp, dried	19	22.00	4.18	10.79
Molasses, beet	17	2.00	0.34	0.88
Vinasse, different origins		3.00		
Calcium carbonate		0.50		
Premix		1.00		
Magnesiumoxide		0.30		
Total		99.90	38.72	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)		Dairy cows mineral feed (min. 40% crude ash)		
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize starch		0.17		
Calcium carbonate		30.50		
Dicalcium Phosphate	220	8.80	19.36	50.21
Salt		22.60		
Diammonium phosphate	300	6.40	19.20	49.79
Magnesiumoxide		24.60		
Magnesiumchloride		2.80		
Trace elements		4.13		
Total		100.00	38.56	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, breeder (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	2.00	0.60	1.22
Wheat bran	74	46.00	34.04	69.09
Soybean meal, 50	47	9.00	4.23	8.59
Alfalfa, dehydrated	26	40.00	10.40	21.11
Calcium carbonate		2.10		
Other		0.10		
Premix		0.30		
Salt		0.50		
Total		100.00	49.27	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Rabbit, grower/finisher (complete feed)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Barley	30	23.00	6.90	16.23
Wheat bran	74	12.00	8.88	20.89
Soybean meal, 50	47	5.00	2.35	5.53
Sunflower meal, undecorticated	92	10.00	9.20	21.64
Beet pulp, dried	19	10.00	1.90	4.47
Lard		2.00		
Alfalfa, dehydrated	26	35.00	9.10	21.41
L-Lysine HCl		0.10		
DL-Methionine		0.10		
Dicalcium Phosphate	220	1.90	4.18	9.83
Premix		0.30		
Salt		0.40		
Vitamin E		0.05		
Antioxidant		0.05		
Total		99.90	42.51	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (wet)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat, soft	27	14.90	4.02	7.61
Fish meal, protein 70%	88	55.53	48.87	92.39
Fish oil		18.92		
Seaweed		10.64		
Total		99.99	52.89	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Salmon feed (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat, soft	27	7.42	2.00	3.50
Soybean meal, 50	47	20.00	9.40	16.44
Fish meal, protein 70%	88	52.00	45.76	80.05
Premix		0.61		
Other		0.01		
Fish oil		20.00		
Total		100.04	57.16	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Trout feed (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat, soft	27	2.87	0.77	2.04
Corn gluten meal	33	11.80	3.89	10.25
Soybean meal, 50	47	55.00	25.85	68.03
Maize starch		3.00		
Fish meal, protein 70%	88	8.50	7.48	19.68
L-Lysine HCl		0.50		
DL-Methionine		0.50		
Premix		1.50		
Other		0.20		
Other		0.09		
Other		0.04		
Fish oil		16.00		
Total		100.00	38.00	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Dog food (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Maize	19	27.80	5.28	10.10
Rice, brown	17	7.30	1.24	2.37
Maize starch		2.78		
Beet pulp, dried	19	4.30	0.82	1.56
Brewers' yeast, dried	64	1.10	0.70	1.35
Lard		9.60		
Meat and bone meal, fat <7.5%	109	40.62	44.28	84.63
Calcium carbonate		0.80		
DL-Methionine		0.13		
Premix		2.20		
Whole egg powder		2.87		
Sodium phosphate		0.50		
Total		100.00	52.32	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

INRA (2004)	Cat food (dry)			
Feed material	mg Zn/kg feed material	% feed material	mg Zn/kg complete feedingstuff	Zn (% contribution)
Wheat, soft	27	12.21	3.30	4.43
Wheat feed flour	40	20.00	8.00	10.76
Wheat gluten feed, starch 25%	62	2.06	1.28	1.72
Linseed, full fat	45	3.00	1.35	1.82
Brewers' yeast, dried	64	1.80	1.15	1.55
Fish meal, protein 70%	88	1.00	0.88	1.18
Feather meal	130	18.00	23.40	31.47
Meat and bone meal, fat <7.5%	109	29.76	32.44	43.63
Meat and bone meal, fat >7.5%	110	2.33	2.56	3.45
Tallow		7.97		
DL-Methionine		0.30		
Premix		0.50		
Salt		0.43		
Other		0.50		
Other		0.14		
Total		100.00	74.36	100.00

INRA. 2004. Tables of composition and nutritional value of feed materials. Wageningen Academic Publishers, The Netherlands & INRA, Paris, France; For mineral sources element concentrations were used from Batal and Dale. 2008. Feedstuffs September 10, p. 16

General abbreviations

AAFCO	Association of American Feed Control Officials, US
AsB	Arsenobetaine
AsC	Arsenocholine ion
ATSDR	Agency for Toxic Substances and Disease Registry, US
BfR	Bundesinstitut für Risikobewertung (Federal Institute for Risk Assessment), Germany
bw	body weight
Cd-MT	Metallothionein bound cadmium
CVB	Centraal Veevoederbureau, the Netherlands
d	day
DM	dry matter
DMA	Dimethylarsinic acid
DMSe	Dimethylselenide
EPA	United States Environmental Protection Agency, US
EVM	Expert Group on Vitamins and Minerals of the Food Standards Agency, UK
GfE	Gesellschaft für Ernährungsphysiologie, Germany
GPX	Gluthathione peroxidase
GSH-Px	Gluthathione peroxidase
IARC	International Agency for Research on Cancer
INRA	‘l Institut National de la Reserche Agronomique (French National Institute for Agricultural Research), France
IOM	Institute of Medicine, US
IZiNCG	International Zinc Nutrition Consultative Group
JECFA	Joint Expert Committee on Food Additives
m	month
$MeAs^+$	Tetramethylarsonium ion
MMA	Monomethylarsonic acid
MMSe	Monomethylselenol
NRC	National Research Council of the National Academies, US
PAA	Phenylarsonic acid
PbB	Blood lead level
RIKILT	RIKILT Institute of Food Safety, the Netherlands
RIVM	Rijksinstituut voor Volksgezondheid and Milieu (Institute for Public Health and the Environment), the Netherlands
SAH	S-adenosylhomocysteine

SAM	S-adenosylmethionine
SCAN	Scientific Committee for Animal Nutrition
SCF	Scientific Committee on Food
SeCys	Selenocysteine
SeMet	Selenomethionine
T3	3,5,3’-triiodothyronine
T4	3,4,3’,5’-tetraiodothyronine
TMA	Trimethylarsine
TMAO	Trimethylarsine oxide
TMAP	Trimethylarsoniumpropionate
TMSe	Trimethylselenonium
TRH	Thyrotropin-releasing hormone
TSH	Thyroid stimulating hormone
WHO	World Health Organization
y	year