BACTERIAL CONTAMINATION OF FEED AND FEED INGREDIENTS – IMPORTANCE OF CONTROL FOR FOOD SAFETY AND ANIMAL PERFORMANCE

ADAM SMITH

Anitox Ltd, Earls Barton, Northants, NN6 OHJ, United Kingdom

INTRODUCTION

Animal feeds can serve as a carrier for a range of microbial contaminants such as moulds, mycotoxins and bacteria (Maciorowki *et al*, 2007). Such contaminants have been shown to influence animal performance adversely and to compromise the safety of animal products. Whereas the importance of controlling moulds and mycotoxins in feed is widely known and practised, control of bacteria is less well understood and frequently overlooked. This paper will examine bacterial contamination of feed ingredients, as well as the potential for contamination and recontamination of feed during processing and delivery to the animal. Measures to control bacteria in the feed, their technological and economic advantages and importance for animal performance and food safety will also be reviewed.

BACTERIAL CONTAMINATION OF FEED AND FEED INGREDIENTS

Feed ingredients and complete feeds contain a wide variety of bacterial species, some of which are pathogenic to humans and animals. Examples of pathogenic species found in feed are Salmonella, E.coli, Staphylococcus, Streptococcus, Pasteurella, Pseudomonas, and Clostridia. Other bacteria present such as Proteus, Klebsiella and Citrobacter may not be recognised as pathogens, but can give rise to sub-clinical effects when presented to the animal in sufficiently high levels in feed.

Feed ingredients can become contaminated at any time during growing, harvesting, processing, storage and delivery to the feed mill. Contamination can occur through direct or indirect contact with the environment, or through cross-contamination with already contaminated ingredients. The primary sources of direct environmental contamination are soil, rodents, wild birds, predators, insects and dust. Indirect contact is through contaminated water, sewage or animal manure used in the fertilisation of crops.

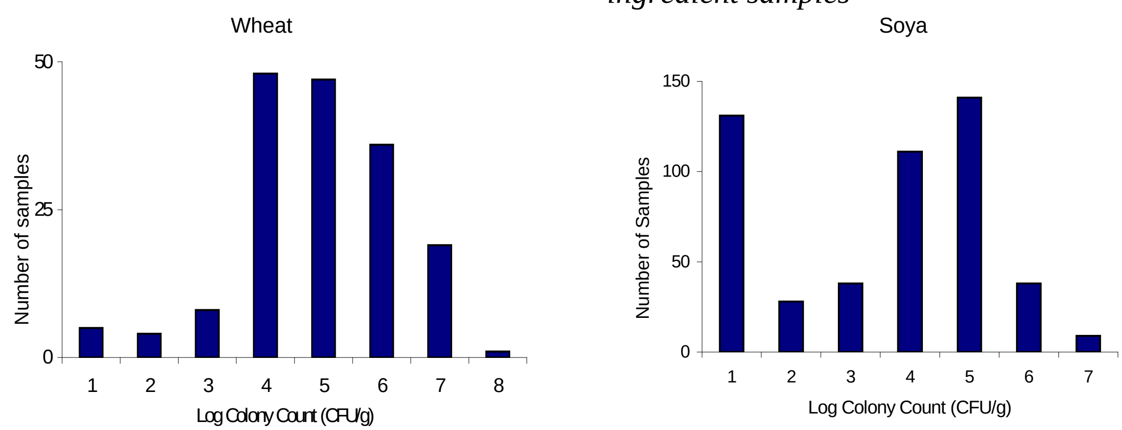
As the micro flora found in feed materials comes from a variety of ecological niches, it has to adapt to the conditions in feed and feed components in order to survive and/or grow. The microbial diversity in different feed types is, therefore, dependant on water activity, oxygen tension, pH and nutrient composition of the feed material. Microbial growth is dependant on the moisture content of the feed material. Whereas moulds have adapted to conditions without free water and can actively grow in stored grains, the majority of bacteria must exercise strategies to survive until there is sufficient water to support microbial activity.

Bacterial contamination of feed ingredients is often mistakenly thought only to be a problem in protein sources of animal origin. Various publications over the last few years such as PDV, (2007) and Barakat, (2004) have, however, shown vegetable protein sources, cereal grains and their by-products to have incidences of Salmonella similar to rendered animal proteins.

Many bacteria associated with environmental contamination of feed ingredients are from the family Enterobacteriacea. This family comprises 30 established genera including Escherichia spp, Enterobacter spp and Salmonella spp. Many of the genera exhibit pathogenicity towards man and animals and many of the pathogenic forms produce toxins. A number of the genera in this family occur regularly in association with animals and are found as indigenous members of the gut micro flora. Here they may exist without producing harmful effects, but are equally capable of causing disease. The Enterobacteriacea tend to be present in relatively large numbers in feed, are evenly distributed and their numbers can be quickly and easily determined in the laboratory. Their measurement, therefore, acts as a useful guide for assessing the bacteriological quality of an ingredient. There is also a recognized association between the risk of isolation of Salmonella and the degree of Enterobacteriacea contamination (Anon, 2001; Veldman *et al.* 1995).

In a comparison of Enterobacteriacea population over a large number of un-processed (whole cereals) and processed ingredient samples (Soya) patterns and levels of contamination were seen to differ (Figure 1). In the case of an un-processed material, the largest number of samples contained between $1x10^4 – 10^6$ colony forming units/g (CFU/g), with some as high as 10^8. With the processed ingredients, a high number of samples with very low bacterial counts (10^1CFU/g) were found, but also a high proportion with bacterial counts similar to un-processed materials (10^4 -10^5 CFU/g). This latter category represents those samples which have become recontaminated after processing.

Figure 1: Enterobacteriacea contamination of un-processed (wheat) and processed (soya) ingredient samples



BACTERIAL CONTAMINATION OF FEED AND SAFETY OF ANIMAL PRODUCTS

Over the last few years we have witnessed various food related scares, such as outbreaks of BSE, food borne microbial infections, dioxin contaminated feed, microbial resistance to antibiotics and the finding of drug and chemical residues. As a result, food safety has become a major concern to the food industry, consumer, legislators and producer alike.

Animal feed contaminated with bacteria pathogenic to humans can contribute to human food borne illness through the feed-animal-food-human chain. Humans can be exposed to such pathogens by consuming improperly prepared eggs, meat or milk from infected animals or from foods contaminated by the faeces of infected animals.

Mead *et al* (1999) estimated that 76 million people in the USA (25% of the population) suffer from disease caused by food borne pathogenic micro-organisms annually, that 325000 attend hospital as a consequence and that 5000 deaths occur. The economic burden on a country of such disease through lost productivity and medical costs is therefore high.

Feed has been shown to be a major vector for transmission of Salmonella to the farm and processing plant. Corry *et al*, (2002) compared the number of Salmonella serovars found in the feed mill of two integrated companies against those isolates found at their respective processing plants. The percentage of isolates found at the processing plant and feed mill were 56.3 and 54.5%, respectively. In a Danish study, looking at the human health impact of contaminated feedingstuffs, Hald *et al*, (2006) also found that of 82 Salmonella serotypes found in both production animals and humans, 45 of these were isolated in feed.

Whilst attention has been focussed on Salmonella, feed can also introduce other human pathogens into the poultry house and food chain, such as E.coli, Listeria and Clostridia. Some authors have even suggested that the prevalence of these bacteria in feed may be higher than that of Salmonella (Whyte *et al*, 2003).

Reports from Salmonella surveillance in the Netherlands (PDV, 2007) has shown that a significant proportion of isolates from Salmonella-positive feed materials and complete feeds are classified as serotypes enteritidis, typhimurium, infantis, virchow, hadar, java or agona. These are types currently specified in European legislation as critical for public health, and the former two are subject to a rigorous schedule of testing at primary production level under recently introduced European Zoonoses legislation.

Feed and feed ingredients are also known to be extensively contaminated with antibiotic resistant bacteria and can act as a source for introduction into the food chain. Multi-antibiotic resistant strains of Salmonella (MAFF, 1993), Streptococcus (Morris *et al*, 1999), E.coli and Enterococcus (P.M. da Costa *et al*, 2007) have all been found in feed.

There is clear evidence from Sweden that control of bacterial contamination in animal feed can produce significant human health related benefits through a reduction in human food borne illness. In 1991, Sweden introduced a HACCP program to monitor S.enterica contamination in animal feed as part of a comprehensive 'farm to fork' Salmonella spp control system (Crump *et al*, 2002). Over 7000 samples of feed were tested annually and detection of a positive feed sample initiated more extensive testing and corrective measures. The results of an integrated surveillance program covering animal feed, livestock health, processed foods, carcasses and human health, suggested the HACCP program had been successful. S. enterica had been virtually eliminated from animal feed and in meat. In addition, the annual rates of human salmonellosis had dropped from 14 cases per 100,000 people in 1991 to 8 cases per 100,000 in 2000.

BACTERIAL CONTAMINATION OF FEED AND ANIMAL PERFORMANCE

Bacterial contamination of feed can affect animal performance. Important clinical conditions can, on occasion, be related to known pathogens introduced through feed. It is, however, the effect that bacteria have on the form and functioning of the gastro-intestinal tract which is generally of more importance with regard to animal performance.

The gastrointestinal tract is inhabited by a complex bacterial community of up to 10^{13} bacteria, which constantly evolves during the life of the animal. Variation in this composition is heavily influenced by the environment to which the animal is exposed, including its feed. The composition of the gut flora, in turn, affects gut health, the expression of the animal's genetic potential and, therefore, the commercial performance of a livestock enterprise. High levels of bacteria in the feed have been shown to be associated with productivity problems in poultry and swine (Tabib *et al,* 1981; Anderson and Richardson, 1999; Derouchey *et al*, 2004) and this is thought to be through their effect on gut health.

When foreign bacteria from feed enter the intestinal tract, they compete with the normal micro-flora for binding sites on the intestinal epithelium and disrupt the homeostatic environment of the intestinal tract. Bacteria in feed also elicit a mucosal immune response, which diverts energy from growth and creates an inflammatory response. During this process, the characteristics of the mucosal epithelial cells change, resulting in increased mucus secretion, paracellular permeability and increased feed passage. This reduces the amount of time available for nutrient digestion and absorption. Certain bacteria present in feed, such as E.coli, Clostridia, Streptococcus and Staphylococcus, also produce toxic compounds or hemolytic enzymes, which damage the integrity of the intestinal epithelium, thus reducing absorptive capacity.

CONTROL OF BACTERIA IN FEED

The careful selection of ingredient suppliers and implementation of a successful HACCP scheme in the feed mill is critical to minimizing bacterial contamination of feed. Control of rodents, wild birds and dust will form important parts of such schemes. A thorough understanding of where cross contamination could occur during processing or where bacteria could accumulate and contaminate future batches is also important. In most situations, however, chemical or physical control measures will also be required to provide the desired level of security. The aim of such measures should be to eliminate pathogenic bacteria and prevent recontamination of the feed prior to its consumption by the animal.

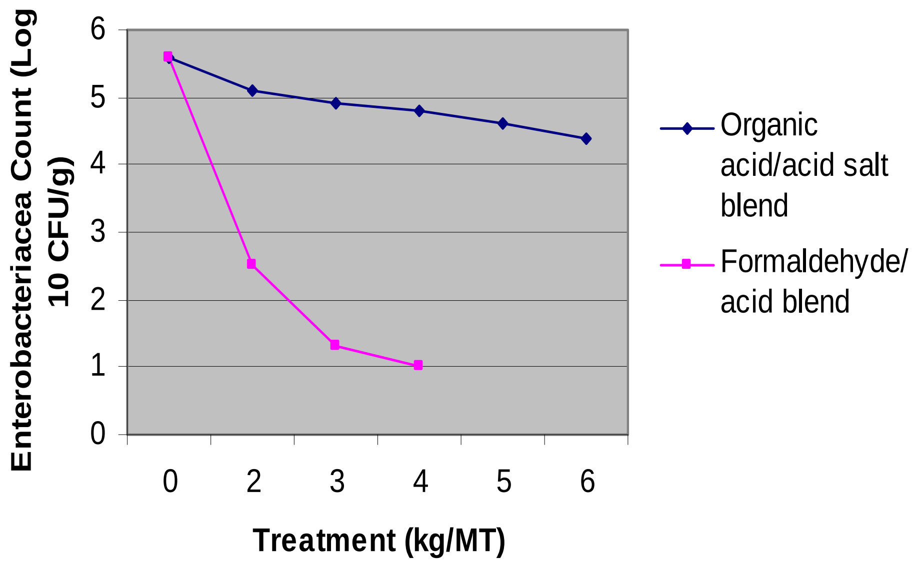
Available methods are irradiation, thermal treatment and chemical treatment. Irradiation is cost-prohibitive in commercial feed production, fails to prevent against recontamination and can damage vitamins and amino acids. Thermal treatment, during conditioning, pelleting or extrusion can be beneficial in controlling bacteria, but its effectiveness is dependant on temperature, time and moisture content in the feed.

Ekperigin *et al* (1990) reported that for successful control of E.coli and Salmonella spp feed must be exposed to a temperature of 85.7^{o}C for 4.1 minutes with 145g moisture/kg. However Clostridium perfringens can survive pelleting at 90^{o}C due to the heat-resistance of its spores (Greenham *et al*, 1987; Maciorowski *et al*, 2004). Very few mills expose feed to such conditions for the required duration and with rising energy prices the cost of doing this is increasingly becoming less attractive.

It should also be realized that heat treatment does not prevent recontamination during later handling. In addition, in the first few minutes after a feed plant goes on-line heat treatment is often not operating at optimal temperature. Contaminated feed will, therefore, pass through to the cooler, contaminating the cooler inlet and subsequent batches. Feed arriving in the cooler is also exposed to conditions of warmth, moisture, nutrients and oxygen, ideal for bacterial proliferation to re-commence. Consequently, if Enterobacteriacea are mapped through the feed milling process, the numbers of colonies are seen to reduce during heat treatment, but then, for a proportion of batches, to increase again as feed passes through the cooler and conveying to out loading.

Chemical disinfection can both control bacteria and prevent recontamination. Treatments available comprise organic acids, organic acid salts and formaldehyde/organic acid blends. Vanderval (1979) demonstrated that levels in excess of 10kg/tonne of a single organic acid were needed to control bacterial levels satisfactorily. Although combination products are undoubtedly more effective than single acids and can be used at lower inclusion rates, formaldehyde/organic acid combinations appear the most effective at low, commercially viable, dose rates (Figure 2). Such products will also prevent against recontamination for more than 21 days.

Figure 2: Formaldehyde based products provide more effective bacterial control in layer mash than organic acid/acid salt blends



ANIMAL PERFORMANCE CAN BE IMPROVED BY REDUCING BACTERIAL LEVELS IN FEED

Control of bacteria in feed has been shown to improve production performance in poultry and to reduce the incidence of Salmonella in breeding animals in the farm environment, on carcasses and in eggs. In breeders, Mo & Na (1996) examined the effect of feed microbial quality on mortality in flocks experiencing fowl typhoid. During the 15 week trial, mortality in the group consuming cleaner feed was lower than the control group (2.57% vs. 5.47%). More recently, a series of eleven commercial trials in over 2.5 million broilers, given feed with or without use of a formaldehyde-based feed treatment to reduce bacterial levels in feed and prevent recontamination demonstrated a consistent improvement in feed conversion ratio, mortality and the number of culled birds (Table 1).

Table 1: Control of bacteria in feed can improve broiler performance – average of 11 commercial trials in 2.5 million broilers.

Parameter	Control	Treated	Benefit
Liveweight (kg)	2.39	2.38	-0.01
FCR (g/g)	1.835	1.797	-0.038
Mortality (%)	4.25	3.58	-0.67
Culls (%)	2.05	0.94	-1.11

In commercial laying hens, given feed treated with a formaldehyde based product to control bacterial levels from 17-66 weeks of age, egg production was improved by over 4 eggs per bird. Enterobacteriacea counts on the eggshell were also reduced from 11660 CFU/g to 1460 CFU/g (Anderson and Richardson, 1999). As Salmonella growth on the shell and penetration into the egg has been shown to be highly correlated (Messens *et al*, 2005), this has implications for product safety.

CONCLUSION

The quality of animal feed is frequently compromised by presence of pathogenic bacteria. Such contamination has been shown to be an important factor affecting the safety of animal products. Although mostly traceable to ingredients, other steps in the feed production process can also give rise to contamination. Measures to control bacteria in feed are, therefore, essential. Chemical treatments, which not only control bacteria but also prevent recontamination until the point at which the animal eats the feed, may offer one solution. Such treatments have also been shown to give consistent improvements in animal performance. Rather than being seen as an extra cost, bacterial control in feed should therefore be seen as a method of improving the economic performance of a farming enterprise.

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