AQUACULTURE IN CENTRAL AND EASTERN EUROPE – PRODUCTION AND MARKETS

An overview of global aquaculture and a closer look at the growing markets of central and eastern Europe will set the context in the opening presentation.

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Ann-Mari Haram works as project director of Eurofish International Organisation in Copenhagen. The objective of Eurofish is to contribute to the development of the seafood sector in Central and Eastern Europe in particular. She has previously worked for the Norwegian Ministry of Fisheries, Den Norske Bank ASA and the European Free Trade Association (EFTA).

ORGANIC AQUAFEEDS - INGREDIENTS AND IDEALS

For fish farming to be considered organic, it must satisfy a number of organic principles. Ideally, all ingredients for organic feeds would be certified organic, but as aquafeeds for carnivorous species sill rely heavily on wild caught marine resources, this is not possible. Therefore they must at least be demonstrably sustainable, 'local' where possible, and lead to the production of healthy food - providing a net benefit to food availability.
Currently, feeds for Soil Association organic fish are made primarily from the waste products of fish already caught for human consumption.
The UK currently produces approximately 50,000, and 12,000 tonnes of such trimmings fishmeal and oil per year, and the use of these ingredients is discussed, as is the Soil Association's partnership with the Marine Stewardship Council to pursue independently certified sustainable sources.
Organic feeds must also contain only natural pigmentation, and will shortly use only natural antioxidants. Goals for environmental contaminant reduction are also discussed.

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Peter Bridson has managed the Soil Association's Aquaculture Development Programme since January 2005, and is based in Edinburgh in the UK.
After completing a MSc in Fisheries Biology and Management at the University of Wales in Bangor in 1992, he worked on a private project to establish a small seabass hatchery and research project in North Wales.
He then worked as a fisheries biologist in the Arabian Gulf in 1995, before returning to aquaculture, taking a research post working on the development and testing of formulated shrimp hatchery micro-diets and live-feed enrichments.
This led to a research consultancy position with INVE Technologies in 2001, establishing feed testing programmes in SE Asia and Central America with further practical development of shrimp hatchery diets and enrichments.
A project on organic feeds stimulated interest in sustainable fish production and led to the appointment with the Soil Association in 2005 where he is currently responsible for standards development and research into the key aspects of organic fish farming.

AQUACULTURE INDEPENDENCE - SUSTAINABLE PRODUCTION OF HIGH QUALITY FISHMEAL SUBSTITUTE

World aquaculture production has been projected to grow from 45% to over 70% of world seafood consumption within the next 20 years. With fisheries stocks declining and world population increasing, the pressure on wild stocks, and particularly baitfish stocks, will increase dramatically. The very industry that has been called upon to bridge the gap between demand and wild supply is now fully dependent upon wild stocks for all of its diets. In order to expand and succeed in the future, the industry must develop its independence from fishmeal and wild stocks. Diet ingredients must be produced from sustainable sources to allow the unhindered expansion of global seafood production.

Many different sources of proteins have been explored to date. The difficulty in identifying a proper source arises from the requirement of most carnivorous species of a high quality animal-based protein source. Research is now underway with a high quality protein meal derived from insects, called Ento-protein™. Insects are naturally consumed in nature by most freshwater species, and represent one of the finest animal protein sources available. Controlled mass production of select insect species will produce a high quality, sustainable protein substitute for fish and livestock diets. Additionally, the controlled production of Ento-protein™ can provide an organic dietary source for certified organic seafood diets. Fishmeal elimination has been one of the key issues at the forefront of U.S. Organic Standard certification. Organically certified seafood represents an enormous market for producers.

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Mr. Papadoyianis has been an active figure in the Seafood/aquaculture industries for over 26 years. He co-founded Neptune Industries, Inc. in 1998 with the vision of creating a sustainable seafood and technology business. Together with Mr. Sal Cherch, they took the company public in 1999, and onto the OTC Bulletin Board in 2005. Mr. Papadoyianis was also the founder of Exotic Reef Technologies, and Marcon Development Corporation; and the co-founder of Aqua Biologics, Inc., and Blue Heron Aqua Farms, LLC. He is also a member of the Board of Directors of the Striped Bass Growers Association, where he represents that sector of the U.S. industry. He has appeared in numerous industry publications including Fish Farming News, Fish Farming International, South Florida Business Journal, Florida Sportsman, etc. Mr. Papadoyianis is the co-patent holder of the Aqua-Sphere™ and Aqua-Cell™ technologies. In May, 2005, he appeared on the CNBC's World Business Review with General Alexander Haig to discuss environmentally friendly technology.
He received his Bachelor of Science from Union College in 1981, and his Master's of Science from Northeastern University in 1985.

INLAND AQUACULTURE OPPORTUNITIES — INNOVATION IN CLOSED CONTAINMENT SYSTEM TECHNOLOGY, THE AQUA-SPHERE

Opportunities for new development and expansion in global aquaculture may heavily rely upon water-based environments for production of marine and freshwater species in the near future. The industry has already witnessed the infancy of offshore mariculture production. Near-shore and inland opportunities currently provide many cost, resource, and logistical benefits to farmers, however production system technology must advance to allow rapid expansion in these areas. The critical issues that have plagued cage and net-pen production include solid waste contamination, escapement, predation, maintenance, and others. The environmental issues become more critical in closed bodies of water such as quarries, mineral mines, and other man-made impoundments.
Eco-friendly, low-energy, cost effective floating containment systems provide the solution to these issues, and will allow fresh and salt water production to expand into remote and environmentally sensitive areas. The Aqua-Sphere floating containment system incorporates alternative energy and solid waste removal to provide a low-cost, eco-friendly solution. The security of raising crops in solid containment systems cannot be overstated. The global movement toward environmental legislation, as well as the market movement toward sustainable, eco-friendly seafood products have paved the way for fish farmers to search for alternative methodologies and technologies.

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Mr. Cherch, has over 50 years of business experience in developing, initiating, and operating companies in a broad range of industries. Over the last twelve years, he has devoted himself exclusively to the aquaculture industry. He is the co-founder of Neptune Industries, Inc; Aqua Biologics, Inc. and Blue Heron Aqua Farms, LLC. Together with Ernest Papadoyianis, Cherch is responsible for having developed Aqua-Sphere and Aqua-Cell closed containment technologies for use in fresh and marine applications.
He has served in an executive capacity for a number of privately held and public companies including Ford Motor Company. Cherch has extensive experience in designing and fabricating electronic, plastic

and fiberglass products. He has been responsible for the formation and funding of several privately held companies, which he brought to the public as IPO's. He founded and was CEO of National Early Warning Systems, Inc. (N.E.W.S.), OTC, National Electronics and Design, Inc., OTC, and served as an executive officer of Lancer Industries, Inc., AMEX. Cherch was instrumental in the design and patenting of several products for Lancer Industries and its subsidiary Universal Fiberglass Industries, Inc.

UPGRADING OF MARINE RAW MATERIALS AS A POSSIBILITY TO INCREASE DIETARY INCLUSION OF VEGETABLE PROTEIN SOURCES IN AQUA FEEDS

In the work to find replacements for fish meal in feed for fish, it is essential to know what nutrients are really being replaced. To date the majority of research has been focused on protein quality, essential amino acids and lipids. However, protein sources also vary widely in other nitrogen containing components or nutrients which may also affect fish growth and performance. Some of these components include taurine, anserine, nucleotides and free amino acids, which may vary widely in marine resources compared to plant protein sources. To date, marine ingredients cannot be totally replaced by vegetable protein sources without significant reduction in growth performance or feed efficiency for most fish species investigated. This is also the case when experimental diets are equalled in limiting amino acids and minerals and the levels of growth inhibitors in plant sources are reduced. It is therefore possible that other components that is present in fishmeal and absent in plant protein, also are important for the growth results.

Feed ingredients from marine resources and plants are different in other compounds than the macro nutrients, and there are increasing evidence that these compounds may be important in the evaluation of feed ingredients.

As part of the SEAFOODplus project, about 40 different feed ingredients were screened for the presence of about 30 different nitrogen extractable compounds. The various ingredients tested were mainly sampled from a commercial feed producer. The presentation will reveal data for the content of extractable compounds in feed ingredients. The possible impact of these components in fish feed is tested in feeding experiments with fish. Growth experiments with rainbow trout and cod indicates that small marine compounds present in marine raw materials affect both growth and feed efficiency. This is important in the discussion of replacing fish meal with vegetable protein sources in feed for fish.

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Dr Anders Aksnes is a biochemist and nutritionist from the University of Bergen, Norway. He has many years experience in research for feed development and biological performance. The main focus of research has been within marine biotechnology, raw materials, feed ingredients, digestibility of nutrients and growth experiments. Aksnes has also developed and commercialized new feed concepts for fish and shrimp larvae for use in very early stages.

REPLACING FISHMEAL AND FISHOIL IN AQUAFEEDS: AQUACULTURE – ESCAPING THE FISH TRAP

The production of compound aquafeeds, particularly feeds for carnivorous finfish species and marine shrimp, has so far been dependent upon the use of fish meal (FM) and fish oil (FO) as cost-efficient sources of dietary protein and fat.

The world production of these two key ingredients is based on a yearly average catch of 30-36 mmt of low-valued fish species, which are processed into 6-7 mmt of fish meal and 1-1.3 mmt of fish oil. Besides ecological and ethical opposition to the use of finite and valuable aquatic resources as a feed ingredient for high-value species, there is a growing economical concern about the uncertain market availability and cost of FM/FO.

Recent price increases of FM/FO have once more highlighted the total dependence of the aquafeed industry on the market fluctuations of FM/FO. This paper illustrates the bottleneck situation and introduces the different critical issues related to the replacement of marine ingredients from the point of view of dif-

ferent stakeholders in the aquaculture industrry, including ingredient suppliers, feedmills, farmers and consumers.

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Dr. Coutteau obtained a Ph.D. in Biological Sciences at the Laboratory of Aquaculture & Artemia Reference Center, University of Gent in 1992 on the filter feeding biology of Artemia and bivalves. He continued his research at post doc level till 1997 on lipid nutrition of bivalves, fish and shrimp and published over 40 refereed papers in scientific journals. In 1997 he joined INVE Technologies NV, the R&D company of the INVE group, where he was responsible for coordinating the research and product development in the aquaculture division till end of 1999. In 1999, he took up the responsibility for the expansion of a new field of research and development of specialty premixes and feeds to improve nutrition and health in on growing stages of fish and shrimp.
Current responsibilities within INVE's Business Unit Aquaculture Nutrition include Product Manager Feedmill Nutrition (involving global coordination of R&D and product development of feedmill specialties) and Manager of INVE Aquafeed Experts, a team of experts offering a range of specialized services to fish/shrimp feed mills and large farms worldwide.

DECONTAMINATION OF FISH OIL AND FISHMEAL - ALTERNATIVE TECHNOLOGIES AND CHALLENGES

The European Commission implemented in July 2002 new legislation on dioxin content in feed and food products. The legislation was amended in November 2005 to also include maximum levels for the sum of dioxins and dioxin-like PCBs (DL-PCBs) in addition to the present maximum levels for dioxins only. Consideration will be given by 31 December 2008 to significantly reduce the maximum levels. As regards fishmeal, fish protein hydrolysates and fish oil, this significant lower level shall be determined based on the technical possibilities of the most effective, economical viable, decontamination procedure. Fishmeal and fish oil contain higher levels of undesirable organic compounds compared to alternative non-marine feed ingredients. Special concern has been given to fishmeal and oil produced based on industrial fish stocks like sprat and herring in the Baltic Sea and herring, sprat, sand eel and blue whiting in the North Sea. The observed differences in dioxin and DL-PCB levels are reflecting the general pollution level in the respective fishing areas and will disfavour the North European fishmeal and fish oil producers on the world market.
Persistent organic pollutants (POPs) in fish derive predominantly from their diet and fishmeal and fish oil are the most important source of these contaminants in farmed fish feed.
Two main approaches can be used alone or in combination to reduce the level: Use of selected feed ingredients (marine and non-marine) with natural low levels of organic pollutants; Use of decontaminated fishmeal and oil.
The dioxin and PCB content in fish oil can be reduced by use of different processing alternatives like activated carbon adsorption, steam deodorization and short path distillation. Decontamination of fish meal can be achieved either by use of hexane extraction or oil extraction of intermediate products in the rendering process. oth processing alternatives transfer the POPs to a fish oil phase that can be decontaminated based on the same process alternatives as outlined above. An overview of alternative decontamination solutions and their impact on product quality will be presented.

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Åge Oterhalshas a M.Sc. degree from the Norwegian University of Science and Technology (NTNU), Trondheim, in chemical engineering and biotechnology. He has many years experience from projects related to processing technology, product development and quality aspects in the fish meal and oil, feed and health food industry. He is now engaged in research activity related to physicochemical properties of fishmeal, fish feed technology and development of alternative processes for the reduction of dioxins and PCBs in fish oil and fish meal.

KRILL AS FEED SOURCE

Antarctic krill has a large potential of commercial harvesting, with an estimated standing biomass of 44 mill tonnes, of which less than 120 000 tonnes was exploited in 2003/2004 (CCAMLR 2005). Antarctic krill is an excellent raw material source in commercial fish feed, already shown to promote high feed intake and growth in salmon, trout, cod and halibut.

Antarctic krill meal is nutritionally well balanced with high protein levels and with a balanced amino acid profile relative to the requirement of cold water species. Antarctic krill has a number of features that makes it attractive as ingredient in aquaculture feed, it acts as a feed stimulant, as natural source of carotenoid pigments, minerals, essential fatty acids and amino acids, and as an ingredient that improves larval fish survival.

The palatability enhancing properties of krill meal makes it a preferred ingredient in transfer feed for larvae during early weaning, and in salmon immediate following sea water transfer. As Antarctic krill meal is a good source of marine phospholipids and also of HUFA's such as eicosapentaenoate (C20:5n-3) and docosahexaenoate (C22:6n-3), it may function as a valuable health promoting agent both in fish and in the consumer. High natural contents of fluoride (about 1500 ppm) and cupper (about 75 ppm) may put some restrictions to the inclusion of krill meal in the diet. Feeding trials have shown that at least 30 % krill meal can be included in the diet to salmon without causing excessive fluorine deposition in bones or other tissues.

Little is known about possible impacts of high dietary cupper. Astaxanthin in Antarctic krill is present almost entirely as mono-ester (20%) and di-ester (80 %) of long-chained fatty acids in the hydroxyl positions of the astaxanthin molecule. Although esterified astaxanthin from Antarctic krill meal is efficiently hydrolysed into free astaxanthin in the intestine, and further absorbed and deposited in the tissues of Atlantic salmon, the efficiency of body retention and flesh deposition is lower as compared to free astaxanthin from Carophyll Pink. Dietary impacts of watersolubles from Antarctic krill meal are poorly documented due to high technical loss during processing of krill. Results from relevant projects on Antarctic krill as feed ingredients to farmed fish will be presented.

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Dr. Sissel Albrektsen is a fish nutritionist educated at the University of Bergen, Norway. Her main scientific experience is on micro-nutrients such as vitamins, minerals and astaxanthin, lately with a special focus on phosphorus and calcium utilization in salmon and cod. Nutrient utilization from a number of different marine and vegetable protein ingredients with respect to growth and product quality of farmed fish has been one of her main occupations for several years. For the last years she has been responsible for developing research activities related to increased utilization of marine by-products in cod feed.

THE USE OF PHYTASE IN AQUAFEEDS

Phytases are hydrolytic enzymes that initiate the release of phosphate from phytate (myo-inositol hexakisphosphate), the major phosphorus storage form in plants. These enzymes can be supplemented in diets for food animals to improve phosphorus nutrition and to reduce phosphorus pollution of animal excreta.

The rationale for the use of phytase in aqua feeds is linked to the increasing use of plant-based feed ingredients as an alternative to expensive fish meal protein source in order to make aquaculture, sustainable.

Main targets for phytase application are:

- The use of phosphorus from plant-based raw materials as it is not available to aquatic species, being stored in the form of phytate. Most of the aquatic species do not have an intestinal phytase activity.
- The reduction of the phosphorus excretion in the environment in order to cope with regulations on phosphorus discharge from fish farming systems.

Phytate and phosphorus content of vegetable protein sources, phosphorus requirement and availability, influence of phytase supplementation on phosphorus digestibility, retention, bone mineralization, protein digestibility and performance are reviewed for carnivorous aquatic species and omnivorous fish. Results

show that the optimisation of the availability of these protein sources to aquatic species requires the use of phytase in order to maximize performance and minimize phosphorus excretion in the environment.

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Dr. Verlhac is the principal scientist at DSM Nutritional Products, in charge of aquaculture research at the Research Center for Animal Nutrition and Health in Village-Neuf (France), dedicated to the development of feed additives to improve performance, quality and health of farmed animals. Dr. Viviane Verlhac got her PhD in General and Comparative Immunology in 1987at the University of Limoges in France; since then she has worked on nutrition and health relationships as well as nutrition of aquatic animals for the developpement of feed addtives at Hofmann-La Roche and now DSM Nutritional products.

SOFTWARE TOOLS FOR TACKLING TODAY'S HOT FORMULATION ISSUES

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Mrs. Webster is the Managing Director of Format International Ltd, a leading international supplier of formulation software to the aquafeed, animal feed, pet food and other industries. In more than 15 years with Format, Merryl has been responsible for the implementation of formulation software around the world, and this has given her a unique insight into its use, potential and the challenges faced by its users. Merryl also has wide experience of Format's clients' point of view from using this type of software whilst working for a major feed manufacturer and then premix producer prior to joining Format.

THE DEVELOPMENT OF PHEROMONE-BASED FEEDING ATTRACTANTS FOR SUSTAINABLE AQUACULTURE

Since 2001 the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) have been developing novel feeding attractants based on fish and shellfish pheromones to support the development of sustainable aquaculture. The pheromones, which are isolated, characterised and subsequently produced synthetically have been shown in a series of laboratory tank trials to increase feeding activity in a range of fish species. The feeding attractants, which are in the form of a liquid formulation are added to the water prior to the addition of the feed. The feeding attractants developed for European cod, (Gadus morhua) tilapia (Oreochromis niloticus) and a penaeid shrimp (Litopenaeus vannamei) have recently been tested under commercial conditions in hatcheries and production facilities in Norway, China and Thailand. Initial results from the feeding trials indicated that application of the feeding attractants produced a significant increase in the growth of all three species. For instance, in a 3 month trial on European cod, the group treated with the feeding attractants had the highest mean weight (25.8 g) compared to the two control groups (23.2 g) and (23.4 g), and a higher growth rate (SGR- 1.95 % day-1) compared to the controls (SGR -1.85 % day-1 and 1.83 % day-1). In addition the treated group required the application of ~10% less feed than the control groups suggesting better feed utilization in these fish. The results of the study are also discussed in relation to the application of the feeding attractants for use with non-fish protein based commercial feeds.

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Dr. Moore gained his PhD in Marine Biology at the University of St. Andrews, Scotland specializing in the neurophysiological basis of sensory perception in marine invertebrates. He continued with this research as a post-doctoral research assistant before taking up a permanent post in the Salmon and Freshwater Fisheries Group at the Centre of Environment, Fisheries and Aquaculture Science, Lowestoft, UK.
He is presently Head of Salmon and Freshwater Fisheries at CEFAS. His principal research interests

are fish behavior and conservation and the development of pheromone-based feeding attractants for sustainable aquaculture, commercial fishing, sport fishing and the ornamental fish industry.

IMPROVING ANIMAL PERFORMANCE, FEEDING EFFICIENCY AND PRODUCT QUALITY IN AQUACULTURE SPECIES

The financial success of an aquaculture species is dependant on an advanced understanding of the biology, nutrition and environmental management of the production cycle. Optimal growth and performance can be affected by disease outbreaks and physiological and immune status. Stress and environmental conditions are closely interlinked (Varsamos et al., 2006) and can lead to reduced performance and susceptibility to diseases. Short periods of sub-clinical challenge with opportunistic pathogens can affect productivity and disrupt gut integrity leading to poor nutrient uptake and unbalanced gut microflora. Functional nutrition and prophylactic prebiotic strategies are proving to be successful and cost effective methods of improving fish health status and performance. They also improve stress and disease resistance, alter gut morphology and microbiology and promote optimal nutrient uptake.
Products derived from specific fractions of the yeast, *Saccharomyces cerevisiae*[1026] , chosen for the biological activity and characteristics of its components, offer nutritional tools and physical characteristics that are advantageous in aquaculture nutrition and health management. These technologies are now being successfully incorporated into advanced feeding strategies improving performance and health status of a number of important aquaculture species.
Nupro is considered to be a functional nutrient that not only provides nutritional benefits but also has other activities that influence the health and production performance. Its high protein content (50%) and excellent essential amino acid profile is suitable for many aquaculture species. It also represents an excellent source of nucleotides (5%). Nucleotides have been described as "conditionally essential" nutrients as they demonstrate significant benefits under certain conditions where rapid cell proliferation is required. These conditions occur in rapidly growing animals, and when the animal is under stress or immune challenge. This paper reviews recent trial work carried out with these products in salmon and trout, carps, catfish, tilapia, sea bass, sea bream, sole and shrimp.

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John Sweetman has over 25 years experience in the culture of a wide variety of freshwater and marine finfish. He has worked extensively in Europe, SE Asia and in the Americas and has designed, constructed and managed a number of marine hatcheries and farms worldwide. Recent work has focused on the diversification of marine finfish hatchery production, namely with Cod in Norway and Scotland and a number of warm water species in the Mediterranean and America.
In addition his consultancy company, Ecomarine Ltd, is engaged in a number of activities including management structuring and restructuring, development of cost efficient production strategies, technical auditing, performance analysis and problem identification and solution development in industrial production facilities.
Currently he is technical manager for Alltech Aqua Europe responsible for research and development and the practical application of Alltech Aqua's natural product ranges in providing modern solutions for improving health and performance aquatic species.

PHYSICOCHEMICAL PROPERTIES OF FEED INGREDIENTS - IMPACT ON FEED PROCESSING AND QUALITY

Fish meal is one of the most variable ingredients used in aqua feed production. The physical and chemical variability of fish meal has a significant impact on feed quality and is at high inclusion levels a critical ingredient with respect to feed processing and quality management.
Fish meal is produced by use of coagulation and a mechanical and thermal dewatering process. The process is fairly standardized worldwide and product quality is mainly dependent on raw material type and quality and drying type and conditions.

Production of extruded fish feed pellets demands a strict processing control to obtain acceptable density and physical product characteristics. Introduction of new pellet density control systems based on venting head steam pressure, back-pressure and expansion chamber pressure regulation have improved the adjustment possibilities. Combined with fundamental knowledge and understanding of physicochemical properties of feed ingredients and their impact on the extrusion process these tools will help the producers to improve their process control and product quality.

We have investigated the extrusion properties of fish meals produced based on different industrial raw materials and drying technologies. Both water soluble protein level and the physical shape (fibrous vs. granular) of the fishmeal particles had a significant effect on the melt viscosity and thereby dissipation of mechanical energy in the extruder barrel. Partial least squares regression analyses were used to establish empirical models for prediction of feed pellet quality. The study was based on standardized extrusion conditions and documented the possibility to develop a model explaining pellet hardness and durability based on fishmeal chemical composition and physical properties. The strengths and weaknesses of the empirical model will be discussed. The effect of fish meal quality on extruded pellet density and fat absorption will also be presented.

The information can be used by the aquatic feed industry to better understand and correct the observed variance in extrusion properties and pellet quality and to improve the product specifications used by fish meal producers and purchasers.

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Tor Andreas Samuelsen, Senior Scientist, Fiskeriforskning, Bergen, has a M.Sc. degree from the Norwegian University of Science and Technology (NTNU), Trondheim, in chemical engineering. He has many years experience from projects related to processing technology and product development for the feed and food industry. The main focus of his research activity has been within marine raw materials, feed and food ingredients, fish feed technology, feed development and the physicochemical properties of fish meal. Samuelsen has also worked as a Process Development Manager in one of Norway's leading food groups in the fields raw material handling and quality, raw material processing, food processing technology and marine food ingredients.

RAW MATERIALS AND THEIR IMPACT ON THE EXTRUSION OF AQUA FEEDS

High temperature, short time extrusion cooking has been utilized to process aqua feeds for many years. These cereal, marine, and animal based products are pasteurized and shaped by extrusion cooking. They have been engineered to provide optimum nutritional balance and functional properties with favorable processing costs which are lower than many other thermal processes known today. The unique features of extrusion cooking (high shear and elevated pressures and temperatures) present an interesting challenge in the assessment of nutrient retention. During extrusion, the formulation and its constituent molecules are subjected to a succession of almost instantaneous treatments. These variables include moisture and temperature profile, extruder configuration, speed of screw rotation, and preconditioning of the material prior to extrusion.

Raw material utilization and cost-effective formulation are key operational factors. Raw material quality standards will continue increasing because of the demand by aquaculturalists for higher quality final products. The ability to alter processing conditions and raw material formulations to keep formulation costs at a minimum, while maintaining high quality standards and minimum operating costs, is a challenge for every processor.

Ingredient selection has a tremendous impact on final product texture, uniformity, extrudability, nutritional quality, economic viability, and the ability to accept high levels of liquid coatings when desired. Within certain limits set by a nutritionist, the extrusion cooking process can control a wide range of product characteristics including shape, density, rehydration, texture and, to some degree, color.

A thorough documentation of the effects on nutritional value is essential in formulating feed products for the industry. The most common formulation components that have been studied include starch, protein, fat, and vitamins. Studies indicate that the degree of starch gelatinization, protein denaturation, and retention of nutrients depends on the type of materials processed, the processing conditions, and on the

configuration of the extruder.
In general, during the extrusion cooking of cereal grain and protein blends, the moistened granular or floury materials are converted into dough. The starchy components gelatinize, resulting in a substantial uptake of moisture and an increase in dough viscosity. Protein constituents may impart elasticity and gas-holding properties that are characteristic of hydrated and developed glutinous dough. Other proteinaceous materials, especially those with low protein solubilities, such as meat byproduct meal and fish meal, may contribute less to the adhesive and stretchable functional properties.

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Brian Plattner is the Processing Engineering Manager at Wenger Manufacturing, Inc., He graduated from Kansas State University in 1997 with a Bachelor of Science Degree in Biological and Agricultural Engineering. He went on to earn his Professional Engineering License in 2002.
Brian joined Wenger in 1998 as a Process Engineer. He joined a team of engineers in conducting extrusion research and analysis in developing new products and processes as well as improving existing ones. In 2001 he became a Test Run Coordinator and was given the responsibility of coordinating test runs in the Wenger Technical Center. In January of 2005, he became the Technical Center Manager.
As Technical Center Manager Brian coordinated the activities of Wenger's agrifood laboratory, which is staffed by processing specialists who are devoted to research and development in the field of extrusion and drying. The Wenger Technical Center also provides technical training, customized research, process engineering, process scale up and product development throughout the world.
In November of 2006, Brian was promoted to Process Engineering Manager. In his current position, Brian is responsible for process specification in helping customers specify new lines and improve existing ones. He continues to work directly with the Wenger Technical Center as well as with the Wenger Design Engineering Group to develop improvements and new innovations for Wenger's line of extrusion equipment.

EFFECT OF RAW INGREDIENT FORMULATIONS AND EXTRUSION PROCESSING PARAMETERS ON NUTRITIONAL AND TECHNICAL QUALITY OF AQUAFEEDS

Fish feed is formulated in order to meet the target species need for nutrients and energy. Raw ingredients from different sources are combined by least cost equations combining the ingredients to satisfy nutritional requirement. Extrusion processing technology has become of major importance in the production of modern feeds used in intensive aquaculture.
Extrusion is a process where the feed is subject to mixing, shearing and heating under high pressure before the extrudate finally is forced through a die. The feed constituents undergo transformations during the processing that can be beneficial if the nutritional value is improved or detrimental if nutrients are destroyed or become resistant to digestion. Knowing that feed cost comprises 40-60% of the variable cost in aquaculture worldwide feed quality should be high in order to ensure a good feed utilization. In this context bioavailability of the nutrients and the physical quality of the feed both are of great importance. Research carried out at AKVAFORSK and Aquaculture Protein Centre (APC) has shown that processing parameters such extrusion temperature within a modest range (100-150oC) to a small extent interferes with nutrient digestion in rainbow trout. Physical quality of the feed reported as durability index and hardness was, however reduced at the highest temperature.
Investigation of physical qualities of commercial extruded feed particles (i.e. particle hardness, durability, and water stability) has unveiled that quality are highly variable. Physical quality is affected by several variables among which formulation and extruder parameters are recognizes as having great influence. Not only differences in chemical composition, but also pre-processing history of the raw ingredients are affecting physical quality of the feed, either directly or indirectly through interactions with extrusion parameters. Significant differences were observed in technical quality of fish feed when fish meal was replaced with either toasted or untoasted soybean meal. Inclusion of soybean meal generally improved the technical quality in terms of hardness index and durability.
Resent research published by AKVAFORSK has indicated that there is a strong connection between

pellet water stability and degradation pattern of feed particles in the gastrointestinal tract that moreover interferes with gastrointestinal transit rate and digestion in rainbow trout. Feed with low water stability caused separation and accumulation of dietary oil in the stomach of rainbow trout that may have resulted in oil belching and reduced lipid digestibility. Results from investigations carried out by AKVAFORSK and Aquaculture Protein Centre will be presented at Aquafeed Horizons.

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Her main research interests include feed processing, in particular extrusion processing of fish feed and how different extrusion conditions affect the nutritional and physical quality of fish feed. The main activities include studies of digestibility and utilization of protein and amino acids in salmonids fed diets processed under different conditions.
She is also interested in different raw ingredients and how the various ingredients affect nutritional quality, processing of the feed and technical quality.

EXTRUSION TECHNOLOGY IN AQUATIC FEEDS

The single most important objective in the production of aquatic feeds is to manufacture a complete nutrition at minimal cost and maximum efficiency. Beside its nutritional value, many physical quality parameters have a significant influence on the overall conversion rate of aquatic feeds.
The nutritional requirements vary greatly between the various species. The formulas, consisting of raw materials from vegetable and animal sources proteins, starch, fats, fibers, have a big influence on the rheological properties of the dough and on the texture of the final product.
The extruder transforms the solid components into a visco-elastic mass which virtually can be pressed through any size orifice. Non soluble, oversize particles that can clog the die holes have to be screened out before the extrusion process.
The key parameters for obtaining the various objectives of extrusion are water, temperature, shear (mechanical energy dissipation) and time.
Mechanical energy is needed to disintegrate the soft, granular macromolecules into a highly viscous fluid. The dissipation of specific mechanical energy increases the temperature of the dough and changes its rheological properties. Adjusting the screw configuration or its shearing action allows compensating for the effect of changing material properties, its water and oil content.
Steam pressure is the driving force and the viscosity the resisting force for expansion. By regulating these two major process parameters, the product density and its buoyancy can be regulated over a very wide range. Beside the solids composition, fat and water content, the viscosity of the dough is influenced by shear and temperature. It can therefore greatly be influenced by the specific mechanical energy input. The steam pressure in the expanding mass is a function of the dough temperature.
By controlling the specific mechanical energy input (SME) and the steam pressure before the die, largely independent from each other allows producing a large range of formulations and applications with one single machine setup. Highly sophisticated automation control is changing extrusion from art to science and makes operators understand it for what it is – a thermo-mechanical cooking process, controllable, understandable and predictable.

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Konrad Munz is the senior extrusion technologist with Buhler Switzerland. He
Joined Buhler 1978, has been working for the extrusion department since 1988. He predominantly is involved in R&D, developing customer specific solutions, specialized in Aquatic feeds and Petfood applications.

INCREASING AQUATIC FEED PRODUCTION THROUGH PLANT OPTIMIZATION

Conducting a simple line audit can identify bottlenecks to higher throughputs

Bottlenecks that potentially limit throughputs of an extrusion line include the following:

- Preconditioning capacity
- Extruder power
- Volumetric capacity
- Die open area
- Down time
- Upstream / downstream unit operations
- Each product may have a different bottleneck
- As each bottleneck is identified and eliminated, a new bottleneck will appear
- As the auditing process continues, a cost/benefit analysis is necessary to determine favorable economics

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Galen Rokey is the Process Manager for the Applications Group within Wenger Mfg., Inc. Prior to this position, he was Manager of the Wenger Technical Center. He has 32 years of laboratory, extrusion process and research experience with Wenger Mfg., Inc. Galen graduated from Kansas State University in 1973 with B.S. degree in the Chemistry Option of Grain Science and Management. A past member of the American Association of Cereal Chemists and the Institute of Food Technologists, Galen has authored numerous publications regarding the extrusion process. He was the recipient of the Alpha Mu Distinguished Service Award in Extrusion Technology from Kansas State University in 1990.

AQUAFEED DRYING

A review of aquafeed techniques and technology

Andy Sharpe, Regional Director, Aeroglide Europe

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Andy Sharpe is the Regional Director for Aeroglide Europe which covers Europe, Middle East and Africa. He has 24 years experience in thermal processing for food and feeds. His extensive Feed and Aquaculture thermal processing knowledge has been acquired working with plants in many areas of the world. Andy's background is in Mechanical Engineering. He received his full membership at the Chartered Institute of Purchasing and Supply in 1986. This was followed by a Diploma in Marketing from the Chartered Institute of Marketing in 1989.

VACUUM COATING PELLETED FEED

The process of using the vacuum coater or vacuum infusion in order to add high levels of liquids (fats) to salmon diets for fish feed was introduced in 1991 and since this time, the concept has been widely accepted by the pet food industry as well.

In this report we study the challenges of applying this new vacuum coating technology experienced by the fish and pet food industries during the last 15 years to the pelleted animal feed industry, mainly in poultry, turkey and pig diets.

This paper analyzes the results of trials conducted at Forberg International AS by FeedTech Services in Larvik, Norway and later duplicated by the Catholic University of Temuco, Chile, whereby pelleted broiler diets were subjected to different levels of fats under different conditions in order to determine the integrity of the pellet durability index of the pellets.

We also looked at the high density found in animal pelleted feed that does not allow for a good air-liquid exchange that would permit proper penetration of oils and fats to the core of the pellet under vacuum infusion.

These trials look for answers in the following areas of concerns with the vacuum coating process: Group I diets with low over all fat content originating from the raw materials used in the diet. Finding the upper level of fat addition to pelleted diets and still maintain good pelletability index.
Group II diets with high overall fat content originating from the raw materials used in the diet plus formulated fat. Finding the upper level of fat addition to pelleted diets and still maintain good pelletability index.
Analyzing the pelletability index of pellets with fat added prior to the pelleting process (at the mixer) vs. adding the fat by means of vacuum infusion. Searching for ideas for controlling the density of pellets in order to allow for greater liquid carrying capacity under vacuum infusion.
The limitations and opportunities found in the process of liquid additions with the vacuum coater when liquid is added to pelleted feed.
A number of possibilities exist for adding different liquids and levels to animal feed diets through the process of vacuum infusion. There are key concerns that must be studied further such as the temperature of the oil, the temperature of the pellets, the amount of formulated fat prior to the pellet press vs. added fat after the pelleting process.

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Eduardo Pérez worked for Ralston Purina Feed Company for 18 years and also Nutrena Cargill Feeds in the International Engineering Department and the feed division of Hubbard Milling Company as Manager of Production and Engineering. Eduardo has held positions of quality supervisor, personnel manager, plant manager, production coordinator, project engineer and director of production in Mexico and Turkey. He had extensive overseas experience before coming before moving to Norway and becoming FôrTek's General Manager. After eight years as General Manager and building the plant from the ground up and helping with the creation of The Master Degree of Feed Technology, Eduardo became Assistant Professor at Norwegian University of Life Sciences (UMB), formerly The Agricultural University of Norway, and took the position of Marketing Director with FôrTek until 2005.
In May 2004 The Chilean Government awarded Eduardo with the country's highest award, The title of "Grand Comendador (Knight) of the order of Gabriela Mistral" for his work in aquaculture and feed technology education between Chile and Norway.
At the present time Eduardo works as Senior Feed Technology Consultant for UMB assisting NORAGRI Institute and the Department of Continuing Education (Internet Education).

PARAMETERS AFFECTING THE FINE GRINDING OF AQUAFEEDS USING A HAMMERMILL
Recently the grinding system in the aquaculture has passed several stages. Due to the increase of the energy cost as well as the concerns of the farmers, feed millers and manufacturers have taken some time to investigate the grinding process.
This investigation resulted in a new grinding lines design having less grinding steps, higher capacity with acceptable and very homogenous particles size. Thanks to the feeder, any foreign materials like steel but also high density materials such as stones, sand, stainless steel are easily removed from the raw material just before its reduction into fine particles which occurs within a short time, thus affecting the quality of the grinding.
The power consumption, which depends on the design of the hammermill and its feeder, as well as the needed downtime when performing unexpected maintenance operations, has reached very low limits, thus improving the financial performance of the feedmill as well as the physical and nutritional qualities of pellets.

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A graduate of the French milling school, Olivier Rousseaux worked in the flour-milling industry with the Bread Research Institute & Australian Wheat Board (Australia). He joined Stolz in November 1997 where he has held the position of Technical assistant during commissioning, Project manager, Asia Sales assistant and Asia Sales manager.