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AMINOCarp Based Diet Improves Growth Performances of Indian Carp, Rohu

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AMINOCarp® based diet improves growth performances of Indian carp, Rohu

Karthik Masagounder¹, Shivananda Murthy² and Girish Channarayapatna¹
¹Health and Nutrition, Evonik Industries, Singapore
²Mangalore Fisheries College, India

Introduction
Rohu, Labeo rohita (one of the Indian major carp) is the 9th largest produced fish in the world (1.17 million tonne/year), farmed mainly in Indian subcontinent (FAO 2012). Recently, the practice of using commercial feeds in rohu farming has gained much attention and is growing steadily. However, under commercial conditions, more importance is still given to crude protein (CP) content of feed than to their amino acid profile. This is partly because of lack of knowledge of the amino acid nutrition of carp. AMINOCarp®, a tool developed mainly for common carp, provides amino acid recommendations for a given growing period based on presumed growth and feeding rates, feeding frequency and contribution of natural food. This tool can be highly useful to rohu feed producers, but a validation test was needed given that the tool was developed mainly for common carp. The objective of this study was therefore to evaluate the growth performance of rohu fed diets formulated based on essential amino acid (EAA) levels found in commercial feeds in the market versus those recommended by AMINOCarp®.

Materials and Methods
A trial was conducted with fingerling rohu (~11 g, initial body weight) at Mangalore Fisheries College, India. Control diet was formulated based on the EAA levels found in the commercial carp feed samples (n = 14, CP: 29-34%) collected from major Indian carp feed producers during 2011-2012. Treatment diet (AMINOCarp®) was formulated based on EAA levels (89% dry matter) recommended by AMINOCarp® which was obtained by assuming that rohu would grow at 3.5% body weight/day (specific growth rate) when feeding them at 5% body weight/day, over a period of 60 days, with a daily feeding frequency of two times and zero natural feed. Amino acid contents of commercial diet were lower than those of AMINOCarp® recommendations for Lys
The study was conducted outdoors in cement tanks (25 m³, 5×5×1 m), with 6 replicate tanks per diet, and 25 fish per tank. Fish were fed twice daily to their apparent satiation for a period of 90 days which was 30 days longer than that initially planned. All the fish were weighed in each tank on days 0 and 90, and mean weight gain was computed for each tank. Feed consumption was recorded over the study period and FCR (feed conversion ratio) was calculated for each tank. Protein retention efficiency (PRE, % intake) of fish for each tank was calculated (body protein gain × 100 / dietary protein intake). Body protein gain was measured as the difference in the body protein content on day 0 (n=10 fish from initial stock, ~11 g) and 90 (n= 3 fish per tank). All the response variables (survival, feed consumption, body weight, weight gain, FCR and PRE) were subjected to Student’s t-test, where P <0.05 is considered significant. Economic analysis for both the groups was performed by computing income over feed cost (IOFC) where stocking density was assumed to be 100,000/ha. Feed cost and fish price were considered based on the local market price at the time of the study.

### Results

Results are presented in Table 1. Compared to the control group, the AMINOCarp® group showed a significant improvement in final body weight (by 9.78 g) and weight gain (by 9.33 g) over the 90-day trial period (Fig 1). No differences were observed in feed consumption between the two groups, however, compared with control group, FCR significantly improved in the AMINOCarp® group with significant (P < 0.05, t-test) improvement in body protein retention (by 4.6%). Economic analysis calculated based on income over feed cost (IOFC) showed higher income for AMINOCarp® group than for control group (Table 2). Results of this study demonstrated that the current industry carp diets are deficient of certain EAA and feeding rohu based on AMINOCarp® recommendations can produce better growth performances with higher profitability.

<table>
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<tr>
<th>Parameters*</th>
<th>Control</th>
<th>AMINOCarp®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival (%)</td>
<td>91.33 ± 3.16</td>
<td>94.00 ± 2.68</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>89.79 ± 1.93a</td>
<td>99.57 ± 7.75b</td>
</tr>
<tr>
<td>Weight gain (g)</td>
<td>79.34 ± 2.47a</td>
<td>88.67 ± 8.14b</td>
</tr>
<tr>
<td>Feed consumption (g/fish)</td>
<td>137.58 ± 2.58</td>
<td>131.84 ± 23.02</td>
</tr>
<tr>
<td>FCR (g/g)</td>
<td>1.74 ± 0.07a</td>
<td>1.48 ± 0.15b</td>
</tr>
<tr>
<td>Protein retention (%)</td>
<td>30.0 ± 1.21a</td>
<td>34.6 ± 3.80b</td>
</tr>
</tbody>
</table>

*Rows with different superscripts are significantly different, P < 0.05, t-test

Table 1: Growth performances (mean ± SD) of rohu fed experimental diets over 90 days
Fig 1. Growth pattern of rohu fed control versus AMINOCarp® based diet over 90 days

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>AMINOCarp®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking density (fish / ha)</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Final weight, g</td>
<td>89.8</td>
<td>99.6</td>
</tr>
<tr>
<td>Total harvest (kg)</td>
<td>8980</td>
<td>9960</td>
</tr>
<tr>
<td>Gross income at USD 1/kg</td>
<td>8980</td>
<td>9960</td>
</tr>
<tr>
<td>Feed consumption (g/fish)</td>
<td>137.58</td>
<td>131.84</td>
</tr>
<tr>
<td>Total feed required(kg)</td>
<td>13758</td>
<td>13184</td>
</tr>
<tr>
<td>Feed cost (USD/kg)</td>
<td>0.419</td>
<td>0.460</td>
</tr>
<tr>
<td>Total feed cost (USD)</td>
<td>5764.6</td>
<td>6064.64</td>
</tr>
<tr>
<td>IOFC (USD/ha)</td>
<td>3215</td>
<td>3895</td>
</tr>
<tr>
<td>Difference (USD/ha)</td>
<td></td>
<td>680</td>
</tr>
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</table>

Table 2: Economic analysis of the data of this experiment, expressed as income over feed cost (IOFC)
Conclusions

- Feed analysis for essential amino acids (EAA) revealed that commercial Indian carp diets contain lower levels of Met, Met+Cys and Lys compared with those of AMINOCarp® recommendations for fingerling (starter) rohu.

- Feeding AMINOCarp® based diets to rohu produced significantly better body weight gain, FCR and protein retention over a 90-d growing period.

- Results overall suggest that feeding rohu based on AMINOCarp® recommendations can be more profitable under commercial conditions.

More information

Karthik Masagounder, Ph.D., Technical Sales Manager (Asia South), Health & Nutrition-Feed Additives, Evonik Industries, Singapore
Empyreal® 75 is the first and only protein concentrate made from corn. This high-energy, naturally pure protein source provides the nutrition fish need in a highly digestible ingredient. With superior functionality, Empyreal 75 provides even, consistent expansion in extruded feeds and extraordinary binding capacity in pelleted diet applications. And industry experts are drawn to the fact that Empyreal 75 is manufactured in the U.S., bringing with it superior supply assurance beyond any specialized protein ingredient available to the industry.

To learn more, visit e75aqua.com. And be prepared for a whole new perspective on protein.
Enzyme booster for improved performance

By Jean Peignon, Aqua Technical Manager, Asia Pacific, Olmix

Shrimp farming started to develop in the 1970s. In 2012, world shrimp production was larger than four million tons and more than 50% of the shrimp eaten in the world today comes from aquaculture. South East Asia and China represent the largest and the most productive shrimp production area, accounting for 80% of the world production. Although, shrimp production has boomed during the last decades, farmers have to face a variety of issues to ensure their production. Shrimp are very sensitive animals and many disease outbreaks occurred in the past such as the white spot viral disease in 1994-1995 in South East Asia and some are still going on such as the Early Mortality in Shrimp syndrome since 2010 in South East Asia. Among them, one of the most important diseases is Vibriosis that kills some shrimp all along the production cycle. More than ten Vibrio species have been reported pathogenic for shrimp. Though Vibrio bacteria are part of the natural flora and culture environment of shrimps, Vibriosis can occur in a context of imbalanced environment and may cause total mortality of the reared shrimps. During the last two decades, mass mortality in growout ponds and hatcheries due to Vibrio were largely reported. Among the different Vibrio species, Vibrio harveyi is considered as one of the most important shrimp pathogens.

With very good management practices, it is possible to limit the Vibrio issue. In order to have a complete protection against the pathogen, it is important to find ways to avoid shrimp becoming contaminated by Vibrio. Antibiotics and chemotherapy are often used to manage disease outbreaks. However, these methods have limits, such as environmental hazards or the spread of antibiotic resistant bacteria.

Another way to prevent Vibrio disease is to improve the gut health. The gut is one of the most important entrances used by Vibrio to contaminate the shrimp. Favoring the natural defenses of the gut by preserving...
its natural balance to avoid Vibrio development and toxicity may be done. Olmix, with a unique expertise in clay and algae, has developed a new product aimed at the improvement of shrimp performance through boosted digestive enzyme activity and better digestive balance.

Clays and feed efficiency
While there is scientific evidence showing the benefits of clays in the prevention or treatment of digestive troubles and in the protection of the gut mucosa, much less is known about their capacity to improve feed efficiency. Yet, the improvement of the digestibility of feed is an integral property of clays. The mechanisms involved are thought to be multiple (Reichardt, 2008). The dominant hypothesis described in the literature is that clays slow down the transit of feed in the intestine, so the time for digestion is increased, hence a better digestibility of feeds and nutrients uptake. Nevertheless, it seems that the action of clays to enhance feed digestion in the intestine involves other mechanisms. Reichardt (2008) and Habold et al (2009) both report the ability of clays to favor the contact between enzymes and nutrients, and therefore to improve the rate of digestion of the feed. Indeed, digestive enzymes need to be in contact with their substrate in order for hydrolysis to occur. The physico-chemical interactions of the enzymes with clay particles seem to enhance the contact between the digestive enzymes and the feed, making clays a good supporting matrix for enzymes and acting as a meeting point for them to be in contact with their substrate. Indeed, Cabezas et al (1991) demonstrated that clay-enzymes complexes are formed at enteric pH values. These active stable complexes are resistant to proteolysis and increase the amount of active digestive enzymes in the intestine, thus improving
nutrient digestibility. In the same way, Habold et al (2009) observed higher pancreatic lipase activity in rats supplemented with Kaolinite; Xia et al (2004) showed an increase in small intestinal digestive enzymes activities on broilers supplemented with Montmorillonite; and Paolo et al (1999) observed an increase in protein and energy retention coefficients for growing pigs supplemented with clay. Some studies also suggest that the increased activity of enzymes in contact with clay not only comes from their stabilization, but also from the presence of cofactors in the clay (Reichardt, 2008; Habold et al, 2009). Cofactors are defined as thermostable non-protein compounds that form the active portion of an enzyme system. In other words, cofactors are helper molecules required for enzymes to be active. They can be organic or inorganic, most commonly vitamins in the first case and metallic ions in the latter.

Clays are layered mineral materials, composed of a succession of aluminium and silicium based sheets, which order varies according to the type of clay. In Montmorillonite, several metallic ions replace some aluminium and silicium ions in the structure. Known as the substitution phenomenon, this event provides Montmorillonite part of its physico-chemical reactivity. Moreover, the presence of metallic ions may contribute to the activation of some enzymes, through their action of cofactors (Niederhoffer, 2000). Thereby, copper is known to activate lipase and phospholipase A (Jondreville et al, 2002) and zinc is a required cofactor of carboxypeptidase (Williams, 1960), to mention only a few examples.

This unique combination of seaweeds and clay makes it a unique tool to boost enzymes activities through the action of biocatalysis.

The combination of the matrix support provided by the clay and the cofactor effect coming from the metallic ions present in its structure can be referred to as biocatalysis: the improvement of performance of a biochemical reaction through the action of an external compound, a biocatalyst.

Not all clays are equal

Due to a large variety of clay minerals, one can imagine that all clays do not have the same potential for biocatalysis depending on their type, their purity, their source or their treatment. As such, clay structure can be modified and associated with other materials in order to potentiate its biocatalytic properties. Such technology has been developed by Olmix group (France) in the frame of its research program conducted on seaweeds and clays.

The micronized form allows a fine dispersion of the product in the intestine, providing many sites of reaction of enzymatic digestion with more easily accessible metal ions. Moreover, it benefits from a synergy between clay and seaweeds in the process of biocatalysis, as seaweeds bring in many diverse metallic ions, sometimes absent in the feed, which are required cofactors for the activation of several enzymes. This unique combination of seaweeds and clay makes it a unique tool to boost enzymes activities through the action of biocatalysis.

MFeed+, the only product benefiting from this new technology, has proven its efficacy in several studies. Among them, MFeed+ has been tested on shrimp by researchers in Kasetsart University (Thailand). The aim of the study was to evaluate the effect of MFeed+ feed supplementation on digestive
and growth performance of *Penaeus vannamei*.

375 shrimp (6.3±0.2g weight) were distributed in fifteen 500 L glass tanks, containing 25 shrimp each. After a seven day period of acclimatization during when all shrimp were fed the basal diet, tanks were randomly allotted to one of three treatments (5 replicates per treatment): one control, fed the basal diet and two MFeed+ groups, for which the basal diet was supplemented with 0.1% or 0.2% of MFeed+. Growth performance parameters and mortality were recorded during the 60 days of supplementation. *Vibrio* bacteria were counted in the hepatopancreas and the intestine at 60 days as a marker of digestive health. Shrimp were fed three times a day to satisfaction. Feed amount was adjusted daily based on feeding ability of shrimps. Uneaten feed was siphoned out of the tank two hours after feeding. Water used in the experiment was seawater, with adjusted salinity to 12-15 ppt. Water in tanks was aerated with air stone and exchanged every two to three days at the rate 10-30% volume depending on its visible quality.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>MFeed+ 0.1%</th>
<th>Variation over control</th>
<th>MFeed+ 0.2%</th>
<th>Variation over control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average initial weight, g/ind</td>
<td>6.32 ± 0.13</td>
<td>6.32 ± 0.13</td>
<td>/</td>
<td>6.32 ± 0.13</td>
<td>/</td>
</tr>
<tr>
<td>Average final weight, g/ind</td>
<td>12.4 ± 0.8</td>
<td>13.09 ± 1.1</td>
<td>+5.6%</td>
<td>13.44 ± 0.1</td>
<td>+8.4%</td>
</tr>
<tr>
<td>Specific growth rate, %/d</td>
<td>1.22 ± 0.1</td>
<td>1.31 ± 0.1</td>
<td>+7.4%</td>
<td>1.34 ± 0.1</td>
<td>+9.8%</td>
</tr>
<tr>
<td>Total feed consumption, g/ind</td>
<td>8.66 ± 0.64</td>
<td>8.21 ± 0.92</td>
<td>/</td>
<td>8.52 ± 0.77</td>
<td>/</td>
</tr>
<tr>
<td>Feed Conversion Ratio</td>
<td>1.42 ± 0.1</td>
<td>1.22* ± 0.09</td>
<td>-14.1%</td>
<td>1.23* ± 0.1</td>
<td>-13.4%</td>
</tr>
</tbody>
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* *p-value < 0.05

Table 1. Growth performance

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
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<th>Variation over control</th>
<th>MFeed+ 0.2%</th>
<th>Variation over control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrio count at 60 days, x10⁴ CFU/g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· In hepatopancreas</td>
<td>3.07 ± 0.39</td>
<td>2.83 ± 0.31</td>
<td>-7.8%</td>
<td>1.17** ± 0.13</td>
<td>-61.9%</td>
</tr>
<tr>
<td>· In the intestine</td>
<td>1.67 ± 0.30</td>
<td>1.58 ± 0.25</td>
<td>-5.4%</td>
<td>1.13 ± 0.12</td>
<td>-32.3%</td>
</tr>
<tr>
<td>Survival rate, %</td>
<td>67.2 ± 4.38</td>
<td>78.4** ± 4.56</td>
<td>+16.7%</td>
<td>82.4** ± 3.58</td>
<td>+22.6%</td>
</tr>
</tbody>
</table>

** *p-value < 0.01

Table 2. Health performance
Feed Conversion Ratio was greatly improved in groups receiving MFeed+. As a consequence, average final weight and specific growth rate of shrimp supplemented with MFeed+ tended to be higher. (See Tables 1 and 2). Moreover, the better digestion performance contributed to improve the digestive status of the shrimps, as shown by the lower Vibrio count in the hepatopancreas and the intestine and the improved survival rate of the juveniles. This study highlighted the interest of MFeed+ to improve digestive and zootechnical performance of shrimp.

More information
Jean Peignon, Aqua Technical Manager, Asia Pacific, Olmix.
Krill are swarming pelagic euphausiids, similar in appearance to shrimp, and are an important member of the food chain and polar waters. They are relatively low in the trophic food web and form an essential part of the diet of diverse species such as fish, seabirds and whales. There are currently six krill species that are fished (Nicol and Endo 1997) particularly Antarctic krill *Euphausia superba*.

The Antarctic krill fishery is the largest extending to annual 10-year avg. of 145,000 tons. This catch represents only 1/50th of the total allowable catch where the standing stock is estimated between 55 and 160 million tons (Nicol and Foster, 2003).

The development of the market for krill meal and oil as an aquaculture ingredient is limited by technical difficulties, associated with catching and processing, and issues pertaining to its suitability of inclusion in the human food chain. Astaxanthin (Storebakken...
1988), proteins and lipids that are present in high concentrations in krill, degrade rapidly once captured meaning that krill must be immediately processed once on board. The extreme environment characteristics of a majority of oceans where krill are found increase the cost of exploiting this resource limiting future growth.

Although krill has been successfully cultured in extensive ponds (Hirano et al. 2003) there is currently no research suggesting that intensive culturing methods may serve as a potential source of protein and-or oil for aquaculture feeds. Krill meal, and krill oil more specifically, are considered a rather new ingredient, although in the 70s the former Soviet Union krill fishing fleet was manufacturing both.

Whole fresh frozen, meats and feed-grade meals are major krill products with an annual 10-yr avg. of 70,000, 750 and 9,750 tons, respectively. In the same period, krill oil was close to 450 tons per/yr., triglycerides (TG) and phospholipids (PL) enriched oils. If current world production plans are fully accomplished, it will increase dried meal tonnage twofold and krill oils three times in the coming three to four years, a tonnage that will not ease shortages of other marine-origin meals and oils, particularly for oils as the primary target is pricy human-grade applications, predominantly the human health and supplement category. Nor is feed-grade TG-enriched krill oil a target, unless blended with phospholipids-enriched krill oils to help improve viscosity, and hence, ease of encapsulation.

South Antarctic Krill Fishing Effort
Krill Meal as a Feed Ingredient

Several of Aquafeed.com’s publications and articles have addressed Tharos research regarding protein, palatability, pigment, heavy metals, dioxins and other important krill meal compounds and their impact on aquafeeds.

Although pelagic meals and oils are getting scarcer, hence, expensive, krill meal is not called to become the main relevant protein source, rather one that allow vegetable proteins to take a leading share in the feed. Krill meals’ negligible amount of dioxins, PCB’s and heavy metals help this goal.

Krill meal is an excellent source of **protein** (avg. 60% dry basis) with the highest biological value.

Regarding **palatability**, krill meal has a low molecular weight of soluble compounds such as nucleotides, amino acids and high levels of trimethyl amine oxide, TMAO (190 MgN/100 g sample), all acting together as an effective attractant and flavoring agent. (Allahpichay and Shimizu 1984; Storbakken, 1988; Shimizu, et al., 1990; Ogle and Beaugz, 1991).

Arnd et al. (1999) show that a 5% inclusion increased palatability of highly fish oil/meal substituted feeds to levels comparable with traditional diets while Suontama et al. (2005) demonstrated excellent performance of both salmon and halibut fed diets based on krill protein and copepod oil.

The inclusion in feed formulations of ingredients that act as attractants has been proposed as a means of increasing feed consumption, hence, growth of farmed shrimp. Given a choice between a base feed and one containing krill meal for example, *P. monodon* show a significantly greater preference for feeds containing krill meal. (The efficacy of ingredients included in shrimp feeds to stimulate intake. D.M. Smith, S.J. Tabrett, M.C. Barclay & S.J. Irvin. CSIRO Marine Research, Cleveland, Queensland, Australia. November 10th 2010.)

In one research from the
Institute of Marine Research and the National Institute of Nutrition and Seafood Research (NIFES) in Bergen, Norway, using proteins from Northern krill (*Thysanoessa inermis*), Antarctic krill and Arctic amphipod (*Themisto libellula*), concluded that krill meal could successfully replace fishmeal up to 60%.

South Antarctic krill meal natural pigment (in the form of Astaxanthin) has a typical range of 115-175ppm dry basis, depending in processing, resource and fishing conditions. The end product contains the same type and coloring agent as naturally fed wild caught salmon adding a strong selling argument for feed manufacturers focused on natural or organic conscious buyers.

When Tharos Ltd introduced to the market, in the early 90s, krill meal sales separated by pigment content, it was a time when Japanese krill meals prevailed in the market sold primarily by protein content.

Tharos’ pigment segmentation lapses each 50ppm, 100ppm onwards for feed-grade meals. Less than 100ppm pigment meals are currently sourced off processes that extract oils from the meal, oils used in human health applications. Tharos’ selling principle stands for krill meal prices varying in a ratio of US$50 per ton for every 50ppm pigment difference.

Krill meal fat content, in an average of 15% (8 – 18%, up to 26-27% if used for human-grade krill oil extraction), depends on fishing season and processing conditions. For traditional krill meal-processing layouts, around 70% of raw krill original fat content remains bonded to krill meal protein. This fat contains high Omega-3 concentrations linked to phospholipids, whereas EPA & DHA are found in the range of 19 to 24%, or higher (as part of lipids). The fat has a high content of phospholipids (30-50% of lipids). Fish fed with diets containing krill meal increase their natural Omega 3 and natural astaxanthin content.

Krill meal is added in aquaculture feed diets in a range of 1 to 8% (*Dimitri Sclabos unpublished reports 2001 and 2005*), used at pre-harvest or throughout the whole rearing and growth phase, depending on diet’s target. Markets for these feeds include shrimp, trout and salmon-feed manufacturers.

Best krill meals are a result of fresh and whole raw krill processed on board (at-sea).
factory trawlers within the first two hours after the krill has been captured, allowing the highest freshness expressed in a very low TVN value in the range of 5 – 20 (mgN/100g). (Raul Toro, Mr. Dimitri Sclabos, independent report 1999-2003, unpublished data). One recent publication expands on this concept.

Krill Meal shows a remarkably low content of undesirable substances such as heavy metals and dioxins, closely related to the unpolluted waters where it is captured and processed (Dimitri Sclabos & Raul Toro Aquafeed.com report June 2003).

Arsenic inorganic form is found in krill in an amount of less than 0.01ppm while fish have 1-10ppm of As/kg (wet weight). In whole krill, Arsenic level reaches 3 ppm As/Kg (Deheyn, D. et al, 2000).

Methyl mercury found in fish feeds is accumulated in fish’s flesh and slowly eliminated. Tuna, halibut, sharks, and other predatory species accumulate higher mercury concentrations (0.5 – 1 ppm wet weight). The opposite is valid for species found at the beginning of the food chain, such as Antarctic krill that fed from plankton. It accumulates mercury at less than 0.1 ppm (wet weight).

The Fluoride Question

Soevik & Brekkan, 1979, first indicated the high fluoride content of the exoskeleton of krill for *E. superba* but all other krill species so far examined have similar high levels (Sands et al., 1998). It seems that high exoskeleton fluoride concentration is a general feature of euphasids, hence, feed users have to take this feature into account when assessing potential products.

Aquafeed.com has published Tharos research about krill Fluoride.

All krill species contain high levels of natural organic fluorine in their shells (Nicol & Stolp 1991; Soevik & Brekkan 1979; Virtue et al., 1995). However, South Antarctic krill is a key food source for a huge number of predators, fluoride being involved in the synthesis of bones and scales (Steffens, W. & Ilbrecht, M., 1982). Despite the high fluoride level of whole raw fresh krill, they are, however, suitable for aquaculture feed (Storbakken 1988).

Krill contain high concentrations of fluoride (up to 6,000 mg/kg dry-weight). However, krill derived fluoride has been shown to have a very low retention in salmon and cod (Moren et al. 2005) and, when retained, it is largely stored in the fish skeleton (Virtue et al. 1995).

Using a typical processing layout, with fresh raw krill, (including the exoskeleton), the resulting krill meal has natural organic fluorine content in a range of 1,000-3,000 ppm.

Many surveys have demonstrated that the use in aquaculture of crustacean meals, despite its high fluoride content, poses no risk to the animal’s health. Fish don’t accumulate fluoride in their fillets, so is not harmful for human consumption.

Since Soevik and Braekkan (1979) found high concentrations of fluoride in krill (1,300-2,400 ppm DW in whole krill), the problem in using Antarctic krill for human nutrition increased. Krill fluoride shows good bioavailability and high amounts of fluoride are toxic. Less than 4 mg F- daily is considered harmless to humans. In the long term, higher amounts lead to fluorosis with symptoms such as changes in bone structure and enzyme inhi-
A December 2006 study carried out at Kochi University (Japan) by Bunji Yoshitomi, Masatoshi Aoki and Syunichirou Oshima looked to totally replace fishmeal (FM) in diets by low fluoride krill (Euphausia superba) meal (LFK). The Yoshitomi, B. et al., study replaced fishmeal with LFK in experimental diets at the replacement proportion of 0.0%, 7.7%, 15.4%, 30.8%, 46.2% and 100.0%, fed to groups of rainbow trout (Oncorhynchus mykiss). In all experimental groups, feed intake, feed efficiency, specific growth rate and hepatosomatic index were unchanged compared with fish fed the control diet. After 95 days, the fluoride concentration in dorsal muscles of the fish of each experimental group, except LFK100, was below the detectable limit (1 mg/kg). The total replacement of fishmeal by LFK in aqua diets was successful, with no defects in growth performance.

**Krill Meal Lipids**

Is there a standard fat content in krill meal? Is the fat content stable throughout the entire season?

South Antarctic krill contains 4 to 5% of its natural weight composed of extractable lipids, more than half of which are in the form of phospholipids (PL) — phosphatidylcholine (PC) (33–36% of the sum of the lipids), phosphatidylethanolamine (15–17%), lysophosphatidylcholine (3–4%), and others (2–3%). Among phosphorus-free components, triacylglycerols predominate (32–35%). Among other factors, krill meal lipid content is related to the lipid content of raw fresh krill and size of each specimen.

South Antarctic raw krill lipid content also varies on seasonality and fishing ground. It is not possible to secure a grade krill oil. This oil is entirely extracted onshore from krill meal previously manufactured at sea and transported to onshore extraction facilities. Such extraction processes use chemical sol-
vents (e.g. acetone, ethanol) at one point of the manufacturing steps, a model that prevents valuable biological and chemical raw krill compounds from remaining in the oil. More at WorldFishing.net. Tharos’ newly patented process gets rid of all solvents, and extracts pure 100% solvent-free krill oil directly at sea.

Current Antarctic krill fishing operation models do not allow krill oil to become a competitively priced feed ingredient. It will remain a niche food, supplement and pharma ingredient with the USA as its biggest market (43% of world krill oil sales) and Asia in second place, for now.

Krill oil production (2013) is in the vicinity of 1,400 tons (PL-enriched krill oil) from which 65-75% was sold in the same year valued at US$105-135MM with a market potential of US$500MM within the coming three to four years. Krill oil key players are Norwegians Aker and Olympic, Canadian Neptune Technologies and Israeli Enzymotec, Aker being the solely vertically integrated company. Several Chinese krill oil manufactures have entered the market.

In terms of raw fresh krill, 1,400 tons krill oil equals approximately 50,000 tons, or 16% of 2014 raw fresh krill capture.

Current prices limit krill oil from expanding to the feed category, in the vicinity of US$125 per kilo FOB bulk for supplement/pharma grade krill oils. Prices will drop once new processing technologies go commercial and planned new krill operations enter the fishery (2015-2016).

Triglycerides-enriched krill oil prices were in the low US$1 per kilo range (early 2000s) up to US$7-23 per kilo range (early 2010s) subject to quality, used as a blender for phospholipids-enriched krill oils.

Krill Meal Pricing

Has krill meal price a direct relationship with fishmeal prices?

Krill meal can be sourced as a direct-target product (from raw krill), as a co-product of tail meat production (waste + raw) or as a by-product of oil production (waste from oil extracted from meal).

Krill meal prices have remained above US$1.5 per kilo FOB in the last 10 years and almost always above fishmeal prices. Given the main krill meal characteristics, the following products are relevant krill meal substitutes, either combined or independently; (a) Pigment (as astaxanthin), (b) fish and vegetable proteins, (c) lipids and (d) attractants. These components have seen significant ups and downs in the same period, although krill meal prices still show a rather stable trend.

Tharos’ mid 2000 market research estimated krill meal potential annual demand of around 117,000 tons of mid-high quality krill meal mostly for aquafeeds for salmonids and farmed shrimp.

Late 2000s Tharos developed a krill meal and oil econometric price predictive model whose key influencing variables, in different
proportions, proved to be market and through Tharos’ US$2.45 to US$2.85 per kilo rapeseed oil, soy oil, sunflower oil, fish oil, fish meal and fishmeal. The same FOB for meal 58% prot min, 10-yr. avg. prices shown below apply to high-quality krill meals traded in the open market and fishmeal model predicted the 4 to 6% price decrease seen since the end of Q3.’14, price expected to stabilize until Q2.2015 Future krill meal prices will be impacted by (a) feed sub-

![Graph showing US$ per ton FOB bagged](image.png)
stitutes prices and (b) krill meal demand used for krill oil extraction. The effect in krill meal prices might show a different path. FAO food price index on the downturn and expanded krill fishing operations and larger Chinese krill oil extraction facilities will impact krill meal prices in opposite directions.


<table>
<thead>
<tr>
<th></th>
<th>KRILL MEAL</th>
<th>FISHMEAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palatability</td>
<td>Low molecular weight compounds that act as an effective attractant and flavoring agent.</td>
<td>Less effective.</td>
</tr>
<tr>
<td>Antioxidant Properties</td>
<td>It has a high carotene (Asthaxanthin) content and natural tocopherols.</td>
<td>None.</td>
</tr>
<tr>
<td>Fluoride</td>
<td>High contents of natural organic fluorine.</td>
<td>Low content.</td>
</tr>
<tr>
<td>Natural pigments</td>
<td>Increases flesh pigmentation of farmed species. Acts as a powerful antioxidant.</td>
<td>None.</td>
</tr>
<tr>
<td>Steroidal components</td>
<td>Growth promoting agent.</td>
<td>None.</td>
</tr>
<tr>
<td>Chitin</td>
<td>Immune system stimulant for some fish species.</td>
<td>None.</td>
</tr>
<tr>
<td>Lipids</td>
<td>Sufficient Omega3 fatty acids content.</td>
<td>Sufficient Omega3 fatty acids content.</td>
</tr>
<tr>
<td></td>
<td>Fatty acids in the form of phospholipids (good bio-availability).</td>
<td>Fatty acids in the form of triglycerides (poor availability).</td>
</tr>
<tr>
<td>Undesirable substances</td>
<td>Low contents of Dioxins, PCB’s and heavy metals.</td>
<td>Risk of high contents of Dioxins, PCB’s and heavy metals.</td>
</tr>
</tbody>
</table>

More information

Dimitri Sclabos Katevas, General Manager Tharos Ltd., Chile
Why use BREED-S FRESH?

Recent expert opinions* have indicated that wild polychaetes (e.g. blood- & sandworms) can be one of the major carriers of *Vibrio parahaemolyticus*, the causing agent of EMS. Removing these worms from the broodstock's diet can therefore significantly reduce the risk of infection.

The BREED-S FRESH unique soft pellets completely eliminate the use of polychaetes. They further reduce the total use of fresh feed (e.g. bivalves & squid) to as little as 30%, guaranteeing a nutritional and, more importantly, a safe diet for your broodstock.

Available in 10 kg buckets.
More info on www.inveaquaculture.com

*Disease Risk Management panel at GOAL 2014
Due to the limited supply and skyrocketing prices of fishmeal, the aquaculture industry is shifting towards the utilization of alternative protein feedstuffs in aquafeeds. Among the alternative feedstuffs with increased utilization, soybean meal (SBM) has been the foremost alternative ingredient partial substituting for fishmeal. In addition to its wide availability and competitive price, SBM has high protein content and a reasonably balanced amino acid profile with high digestibility coefficients for many aquaculture species. Nevertheless, as in the case of other monogastric animals, the presence of anti-nutritional factors (ANFs) including non-starch polysaccharides and protease inhibitors in SBM can negatively affect the physiological status of fish. Especially in the case of carnivorous fish species, such as red drum, studies have shown that production performance and survival may be reduced when high dietary levels of SBM are used to replace fishmeal, thereby limiting its utilization.

To overcome this problem, a solid-state fermentation process has been employed by Nutraferma® as a novel technology for improving the quality of SBM. As a result, the PepSoyGen®, a fermented and functional soy protein ingredient was introduced to the feed industry. The production process of PepSoyGen involves the inoculation of specific microbes (*Aspergillus oryzae* and *Bacillus subtilis*) to dehulled, low-temperature sterilized SBM, utilizing solid-state fermentation and enzymatic hydrolysis which reduces the concentration of most ANFs, increases protein content and digestibility, and enriches the final product with beneficial microbes and important metabolites. Overall, these characteristics make PepSoyGen a promising alternative ingredient meriting evaluation in diets of aquaculture species.
In an 8-week feeding trial conducted at the Aquacultural Research and Teaching Facility of Texas A&M University, the nutritional value of PepSoyGen in the diet of red drum was accessed. All experimental diets were formulated to contain 32% digestible protein (DP), 12% lipid, and an estimated digestible energy (DE) content of 13.8 MJ/kg. In total, seven diets were formulated including a fishmeal reference diet (designated as PSG-0), designed to contain all its protein from menhaden fishmeal, and six PepSoyGen test diets designed to replace the DP from fishmeal in the PSG-0 diet on a isonitrogenous basis, at 15% incremental levels (PSG-15 to PSG-90). Diets were supplemented with taurine at 1% along with DL-methionine and L-lysine in excess of the established requirements for red drum, and glycine was added for palatability. In addition, the established vitamin and mineral requirements of red drum were met through the supplementation of mineral and vitamin premixes. All diets were prepared by mixing dry ingredients in a V-mixer. Then the dry mixture was blended with menhaden fish oil and water using an industrial mixer with a meat grinding attachment, and pelleted through a 3-mm die. Resulting pellets were dried for 24 h using forced air at 25°C and stored at –20°C until utilized. The Analyzed composition of the diets is presented in Table 1.

The feeding trial was conducted in 110-L aquaria operated as a recirculating system, whereby waste water gravity flowed to a settling chamber, then to a biological filter and a UV-light system before being returned to the aquaria. Synthetic seawater was prepared using well water mixed with stock salt and Fritz brand synthetic sea salts to provide culture water of 7 - 10 g/L salinity. Water temperature was maintained at 26 ± 2°C by conditioning ambient air, and dissolved oxygen was maintained near air saturation using supplemental aeration. A 12h light:12h dark cycle was maintained using fluorescent lighting controlled by timers. Twenty red drum juveniles (mean weight of 1.5 ± 0.5 g/fish) were stocked in each aquarium and a 1-week conditioning period was given prior to the commencement of the feeding trial. Each of the test diets was randomly assigned to three replicate aquaria. Fish were fed twice daily for 8 weeks at a rate approaching apparent satiation. The feeding rate was adjusted weekly after group weighing all fish in each aquarium and maintained at a level that maximized intake without overfeeding. The feeding trial ended after 8 weeks of feeding, when red drum in each experimental tank were sampled for data collection and analysis.

With the present experimental design, PepSoyGen was evaluated as a potential replacement for fishmeal at levels ranging from 15% to 90% of DP, allowing the estimation of the maximum replacement value (MAX REPL) of PepSoyGen for fishmeal using regression analysis. Red drum survival in the study ranged from 70 to 85% and

<table>
<thead>
<tr>
<th>Proximate composition</th>
<th>PSG-0</th>
<th>PSG-15</th>
<th>PSG-30</th>
<th>PSG-45</th>
<th>PSG-60</th>
<th>PSG-75</th>
<th>PSG-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>57.8</td>
<td>60.3</td>
<td>63.2</td>
<td>64.2</td>
<td>66.3</td>
<td>73.5</td>
<td>75.5</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>431.8</td>
<td>428.8</td>
<td>428.5</td>
<td>429.5</td>
<td>426.6</td>
<td>430.8</td>
<td>421.4</td>
</tr>
<tr>
<td>Lipid</td>
<td>116.5</td>
<td>115.2</td>
<td>113.4</td>
<td>122.2</td>
<td>112.2</td>
<td>117.7</td>
<td>114.2</td>
</tr>
<tr>
<td>Ash</td>
<td>155.7</td>
<td>144.6</td>
<td>149.5</td>
<td>153.6</td>
<td>154.3</td>
<td>152.0</td>
<td>155.3</td>
</tr>
</tbody>
</table>

Table 1. Analyzed composition of experimental diets containing graded levels of PepSoyGen (PSG)
showed no relationship with dietary treatment. The overall production performance of red drum fed diets with incremental levels of PepSoyGen was best explained by second-order polynomial regression models. Weight gain expressed as a percentage of initial fish weight ranged from 1400 to 2000% (equivalent to the observed mean final weight of 25.1 and 36.2 g/fish, respectively), feed efficiency (FE) ranged from 0.86 to 1.03, and protein retention ranged from 35.1 to 41.3%. The results indicated that the MAX REPL of PepSoyGen for fishmeal in the diet of red drum was 52% for weight gain, 55% for FE, and 64% for protein retention (Figures 1-3, respectively).

Based on these results, PepSoyGen can be included in the diet of juvenile red drum replacing around 50% of fishmeal protein without affecting the overall production performance of the fish. Considering the actual market price of fishmeal (~ $1900.00 per metric ton), a 50% replacement of fishmeal with PepSoyGen in a 32% DP red drum diet would represent a 12 – 15% range reduction in formulation costs (depending on the cost of PepSoyGen). Therefore, PepSoyGen represents a cost-effective and environmentally sound alternative ingredient for red drum aquaculture. Further evaluations are needed to access its nutritional value in advanced stages of red drum production.
FAMSUN
Integrated Solution Provider

- Knowledge and expertise sharing
- Feed equipment and processing line
- Turnkey project
- Customer training and service

Integrated Solution Provider

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The extrusion process has been the dominating technology for production of feed and food manufacturing for the past 50 years. During this period, the process equipment manufacturers have consistently developed the essential extrusion process equipment in order to cope with the consistent developing requirements from the feed and food producers. In particular, changes in raw material availability and consistency, combined with a price-driven market, have resulted in substantial changes in formulation by means of alternative sources of raw material used. These circumstances have challenged feed and food producers in terms of proper control of the extrusion process, in order to run a profitable business from a manufacturing point of view.

Source Technology has consequently developed inline sampling and analysis technologies, in order for feed and food producers to optimize control of the product quality after each process step. This in order to ensure that both the nutrient and physical quality of the feed and food is according to specifications, thus avoiding substantial rework costs.

The Inline Sampling and Analysis Technology

The inline sampler consists of a mechanical driven and patented sampling cup technology, which is entered into the product flow at any given location of an extrusion plant, collecting either dry of wet extrudates. When a cup, full of product is collected, the sampling cup is removed from the product flow whereupon the actual measuring takes place externally (inside of the sampler, but outside the product flow). Multiple measurements, such as bulk density, moisture, product size etc., can be measured inside the sampler. The actual measured results are calculated by a control system and shown on a display or communicated to a general plant control system.
The sampler can be fitted with various analytical sensors, depending on the application and specific location in the plant. Figure 1 illustrates that up to eight different analytical sensors, each measuring a unique analytical parameter, can be installed inside an inline sampler. Measuring accuracy of each analytical parameter is mandatory, in order to use the inline analysis results to take over manual labor resources, but at the same time provide as accurate measurements as one would expect from a laboratory.

Figure 2 represents a typical extrusion line for feed and food. The inline analysis samplers are in the same locations, which typically are subject to manual labor resource demanding points of analysis. The most typical frequent labor resource demanding points of analysis are:

- Bulk density (after extrusion)
- Moisture (after drying)
- Lipid absorption (after coating)

When sampling and measuring takes place by means of manual labor resources, both measuring accuracy and sampling frequency are negatively affected. When using inline sampling and analysis technology, the product is analyzed typically every 30-90 seconds and the entire extrusion process can thereby be automated.
A control loop can be established between the inline analysis sampler and the upstream process equipment prior to, for example an inline moisture sampler and the dryer. Thereby, a fully controlled automation process without human interference can be operational. In this article, a few of such automated control loops for key extrusion process equipment are described.

Controlling essential key process equipment – Extrusion

During the last decade, new optimized process tools for the extrusion process have been introduced, in order to improve the thermal and mechanical energy input. Improved preconditioning processes for increased thermal energy addition as well as devices to improve mechanical energy, are today very typical for a state-of-the-art extrusion system.

In order to optimize for example starch gelatinization levels, new flow restriction systems for increased mechanical energy input inside of the extruder have been developed. When the mechanical energy is controlled, the bulk density of the pellets can be controlled. The bulk density is an important physical measured parameter, which ensures an adequate level of starch gelatinization, thus a texture that allows for lipid absorption in the coating process. The bulk density can also, depending on the application, affect the packing process as bulk density has an impact to the required volume of the bags. The bulk density is measured after the cutting system for the extruder as illustrated in figure 3. The device installed in the extruder to control mechanical energy, is typically placed at the outlet of the extruder, also illustrated in figure 3. By restricting the flow inside the extruder, a greater pressure is established requiring increased energy from the extruder motor, thus more mechanical energy.

Figure 3.
By means of the inline sampler, a product sample is removed from the process, whereupon an exact bulk density measurement is conducted. The bulk density result can be communicated to the plant extruder control system, whereupon the operator manually can adjust for example the mechanical energy of the extruder, which for example could take place by restricting the flow at the outlet of the extruder. It can however also take place automatically by means of a control loop as illustrated in figure 4.

The operator will typically use a reference bulk density set-point for the specific formula being produced. The sampler will measure the bulk density approx. every 30 seconds and provide feedback via the control system to the flow restriction valve. If there is a difference between the set-point and the actual bulk density, an adjustment of the flow restriction valve is made automatically, until the set-point and the actual bulk density is the same with a tolerance of ±5 g/l.

Figure 4.
Controlling essential key process equipment – Drying

From a nutrient mass balance and production cost point of view, the drying process has a significant impact on the final product quality. If the moisture level is not within specifications, this can result in essential nutrient parameters being out of specifications. Other consequences, such as poor lipid absorption during the coating process or mold, can also occur. From a drying energy cost point of view, there are advantages by accurately controlling the moisture, as too low moisture levels are a result of over-drying, which is wasted energy in form of gas or steam.

By measuring moisture inline, an automatic control loop can be designed in order to control the drying process without human interference. Measuring moisture, both at the inlet and the outlet of the dryer, can take place and provide important information with respect to the moisture levels. Figure 5 illustrates the location of the samplers at the inlet and outlet.

![Figure 5](image)

Depending on the difference between the operator set-point and the actual moisture level measured inline, an adjustment of the drying process can be made. There are typically three parameters, which effectively can be used for the adjustment, being:

- Retention time, controlled by the belt speed (horizontal dryer only)
- Airflow
- Temperature in the specific zones of the dryer

When designing an automatic control loop for a drying system, it must be determined, which of the three essential adjustment parameters are used. Typically, it can be benefi-
cial to use temperature, due to the fast response time, yet this will have an impact to the drying cost.

The operator set-point is typically provided by the specifications of the formula, which is defined, based on an optimal nutrient mass balance as well as costs. The inlet moisture sensor will give the operator an indication to the overall moisture, entering the dryer. The outlet sensor measures the actual outgoing moisture level. If the moisture set-point differentiates more than 0.5%, the dryer settings will need to be adjusted. Figure 6 illustrates the control loop. The temperature is selected as the master adjustment parameter and is therefore gradually increased, until the outlet moisture level is within specifications.

Figure 6.

**Controlling essential key process equipment – Coating**

How much lipid has to be absorbed by a given extruded product depends on the product characteristics. Typically, both bulk density, texture as well as the moisture level of the product will have an impact on the absorption. It is typically not a problem to apply the level of lipids (oil or fat) required by the formula, but to achieve an acceptable absorption can be more demanding. If the absorption is not properly completed by the time of packing, multiple consequences such as poor visual appearance, lumping, contamination etc. can occur. Therefore, it is imperative that the operator in charge can assess whether the lipids are sufficiently absorbed. However, since the level of absorption is an individual visual assessment, the approval of an acceptable level of absorption may vary from operator to operator.

By using a sampling technology, combined with vision technology (camera), an automatic control of the lipid absorption can be made. The system removes a sample from the product flow, typically after the coater (see figure 7) or alternatively after the cooler, and take a picture of the coated product, subject to software analysis.

Figure 7.
The shininess of the feed or food product is converted to a percentage value between 0-100% where 0% is a complete dry product and 100% is a very wet, not properly coated product. Figure 8 illustrates the different levels of absorptions.

Figure 8.

An automatic control loop between the sampler and, in this example, a vacuum coater, can be established. The formula will ask for a given percentage of lipid, which the operator will try to achieve in order to ensure the final nutrient mass balance of the product. However, maybe or maybe not, the product will be able to absorb the added amount of lipid. Figure 9 illustrates the control loop. A set-point for the level of absorption required is made by the control system. The sampler analyses the product and provides an actual absorption level. If there is a difference between the set-point and the actual value, adjustments of the vacuum coater is required. In this example, the vacuum pressure is automatically adjusted, until the required level of absorption value is achieved.

Figure 9.

More information
Thomas Jorgensen, Managing Director, Source Technology
Introduction
Aquatic feeds are primarily processed by extrusion systems to not only include nutritional value but also develop desirable physical product characteristics. Starch gelatinization, floating/sinking properties, fat uptake and durability in water are critical characteristics in the industry that impact nutritional and physical pellet considerations. Starch gelatinization of aquatic feed during extrusion is important as it affects feed digestibility in some species and contributes to water stability in all feeds. Floating/sinking properties of the feed are species specific and affect feed efficiency through proper presentation for consumption. Feed not immediately consumed must be water stable to protect the nutrients in the feed but also water quality. Extrusion process variables such as SME (specific mechanical energy) impact these important product properties. The purpose of this study was to describe the effects of extrusion SME on starch gelatinization and to investigate the correlation between feed bulk density and floating/sinking characteristics and the potential to absorb fat coatings through vacuum infusion and atmospheric coating techniques.

Materials and Methods
An aquatic feed diet consisting of 77.7% Menhaden fish meal, 11.0% wheat flour,
9.0% tapioca starch, and 2.3% soybean meal was ground through a 1500 micron screen and then extruded on a Model 8.1 C2TX co-rotating, conical twin screw extruder (Wenger Mfg., Inc.) Starch gelatinization was evaluated on the aquatic feed extruded at six different SME inputs. SME was adjusted by varying extruder screw speed and the orifice opening size in a backpressure valve (BPV). Starch gelatinization values were determined by the modified glucoamylase method. The bulk densities of extruded and dried samples were measured before and after maximum fat absorption.

Maximum fat absorption for each extruded aquatic feed sample was determined by two methods – vacuum infusion and atmospheric coating. The vacuum infusion method consisted of submerging in a closed vessel a known mass of aquatic feed in excess fish oil heated to 60º C. A vacuum of 7.0 kg/m² was maintained for two minutes in the system and then released. The feed sample was removed from the oil bath, excess oil drained for two hours, and then the feed reweighed to determine fat absorption.

% Fat absorption = (final weight – initial weight)/ initial weight x 100

The atmospheric coating method was identical to the vacuum infusion method except no vacuum was applied to the system. Bulk density was determined by measuring the mass of a one-liter sample. The “% sinking” value for each sample was determined by placing 100 aquatic feed pellets in 3.5% salt water at 20º C and recording the number of pellets that sank within 30 seconds.

Photo 1 shows the dry density before coating, the density after coating and the relative oil uptake. Notice that some of the feeds were not at sinking densities before coating, the oil filled the air pockets in the

Photo 1. Densities and coating levels of salmon feeds
pellets and thus density increased to above sinking requirements.

Photos 2 depicts the relationship between SME and pellet cell structure. Cell Structure is a critical element in oil uptake and the pellet holding the oil until delivery to the fish. Cell structure also is related to pellet durability and strength. The Larger cell structure holds less oil and softens in water faster. The smaller cell structure hold more oil and is also more durable in water. Pellet softening in water has been a recent topic for select fish. Pellets that soften in water are more desirable to some fish species. Specific processes are available for making sinking or floating softer feeds. These techniques would involve semi moist extrusion technology.

**Results**

As the SME level was increased during extrusion, the starch gelatinization in the aquatic feed increased as seen in see Figure 1. Figure 2 indicates a direct correlation between product bulk density and sinking properties of aquatic feed in seawater. An aquatic feed bulk density of at least 580 g/l was required to achieve 100% sinking properties. As aquatic feed bulk density before coating increased, fat absorption via vacuum infusion and atmospheric coating decreased in Figure 3 also seen in Photo 1.

**Conclusion**

Extrusion SME can be an effective process variable to control starch gelatinization in
aquatic feed production. Although not a part of this study, an increase in extrusion SME also improves water stability of extruded aquatic feeds. Final product density correlated well with sinking properties of aquatic feeds. Bulk density before coating of aquatic feeds can be used as an indicator of the potential fat absorption properties.

Figure 3. Effect of Bulk Density on Fat Absorption by Vacuum Infusion and Atmospheric Coating

More information
Joe Kearns, Vice President-Aquafeed Division, Wenger Manufacturing, Inc.
TX-3000 RAISES THE BAR ON AQUATIC FEED PRODUCTION

Our business in life is not to get ahead of others, but to get ahead of ourselves.
—Stewart B. Johnson, Dutch Artist

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The combined features allow increased production capacity of up to 30 percent compared to previous and competitive aquatic machines — totally redefining cost/benefit. The TX-3000 can be equipped with either the High Intensity Preconditioner (HIP) or the High-Shear Conditioner (HSC) to match specific process and capacity requirements, making it ideal for processing a full range of aquatic feed products.

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Turning ideas into opportunities.
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Within previous editions of Aquafeed, it has been discussed how Insta-Pro International has developed a low-cost, easy-to-use, and durable Medium Shear Extruder for small-to-medium producers of fish feed pellets (see Aquafeed, Autumn 2013, volume 5, issue 3, pages 41-45). The Medium Shear Extruder was built with decades of extrusion experience to back it up. Notably, the machine uses high shear, dry extrusion techniques for recycling aquatic co-products thereby utilizing more of the original raw material available for aquaculture diets in place of expensive fish meal (see Aquafeed, Spring 2014, volume 6, issue 1, pages 32-34).
When producing aquaculture pellets for fish feed, pellet diameter size is critical. The correct pellet diameter maximizes feed intake and performance, especially in young fish. Tilapia is a good example of the varying pellet size needs. Tilapia fry (0.1-2 g body weight) require either pellets less than, or equal to, 2 mm in diameter (1). This can include crumbled pellets, or mash feed, which are about 0.6-1.5 mm. Fingerling tilapia (10-20 g body weight) need pellets with a diameter of 2.5-3 mm (1). Growing and finishing tilapia are fed to weights of 0.5-1 kg and are progressively fed pellets with greater diameters (1).

Fish feed manufacturers face challenges when smaller pellet diameters are desired. To make smaller pellets, the dry mix of ingredients is forced through small dies at the end of the extruder barrel. As such, particle size of the dry mix must be smaller than the die openings.

Typically, the dry mix must be at least one-third smaller than the die opening. Additionally, uniformity is an important factor in pellet generation. One randomly large, amorphous particle easily blocks the die opening and prevents pellets from being made. Therefore, in order to make small pellets, fine-grinding capabilities are requisite.

Continuous improvement is a core value at Insta-Pro International so we regularly conduct internal research to broaden our range of solution-oriented products. Recently, we
experimented with a new die and cutter-head apparatus in an attempt to improve the production of smaller pellets on the MS3000 Medium Shear Extruder. A typical blend of ingredients and formulation for omnivorous fish feeds was used in these experiments. The dry mix was finely ground to an average particle size of 0.5 mm. This fine mix was then preconditioned and extruded to gelatinize the starch, denature the proteins, destroy microorganisms, and produce shaped pellets. New 1.5 and 2 mm die plates were used, and following cooling and drying, 10 pellet samples from each die plate were evaluated by measuring the diameters with calipers. This data was then compared with diameters of pellets made using older versions of the 1.5 and 2 mm die plates to determine if any progress was made with the new designs.

The results are shown in the graphs on the next page. First, the new dies successfully reduced pellet diameters. Pellets produced with the new 1.5 mm die were just under 2 mm in diameter, while those made with the old design were nearly 2.5 mm. Similarly, pellets produced with the new 2 mm die were 2.7 mm in diameter, while those with the old design were 3 mm. Note that actual pellet diameters are almost always bigger than the die size due to expansion during the extrusion process.

Secondly, it’s important to track pellet uniformity by measuring pellet diameter variation (shown below as coefficient of variation). With the new 1.5 mm die, variation actually increased slightly versus the old 1.5 mm die design. With the new 2 mm die, uniformity increased.

New die designs successfully reduced pellet diameter, which means that feed for younger, smaller fish can be produced. However, with the new 1.5 mm die, pellet
diameter variation increased slightly, which indicates the need for further development. Pellets produced through the Medium Shear Extrusion process expand upon exiting the new dies (as shown above) and float thereby ensuring that the fish have access to quality nutrition. In addition, Medium Shear Extrusion from Insta-Pro adequately cooks the dry mix to produce highly-digestible nutrients in the pellets. This is shown by the high degree of starch gelatinization in fish pellets (2).

Insta-Pro International prides itself on a culture of continuous improvement and is pleased to be helping processors produce small, floating fish feed pellets to deliver high-quality nutrition for aquaculture.

References
Low cost Medium Shear Extruder for pet food and aquafeed, Aquafeed Autumn 2013, page 44, figure 5.

More information
For more information, please contact Dave Albin, PhD, Applied Nutrition Technologist, Insta-Pro International, USA.
Sanitary Design Cooler
For highest food safety standards
AquaME to provide platform for fresh wave of investment in to food security and production of fresh fish

AquaME, formally a vertical of the Agrame exhibition, will become the regions first standalone platform dedicated to the burgeoning aquaculture and fishing industry.

The show, which will take place March 16-18, 2015 at the Dubai Exhibition and Convention Centre, has been officially launched in partnership with the Ministry of Environment and Water and Nor-Fishing Foundation, and will feature a dedicated conference, the regions first aquaculture awards ceremony and a dedicated business to business buyer programme.

At the official signing of the partnership, His Excellency Abdelrahim Al Hammadi – Assistant Undersecretary of Support Services for the Ministry of Environment and Water said “We are very pleased with this partnership which is a move to consolidate and encourage investment in the aquaculture sector. This falls in line with the UAE’s strategic objectives to promote food security and environmental sustainability contributing to the UAE’s Vision 2021.”

According to the Ministry of Environment and Water, the total current market valuation of investments in to the UAE aquaculture sector stands at US$ 321 million, with 20 million of that amount being invested in to the Sheikh Khalifa Bin Zayed Al Nahyan Marine Research Centre. The project, which was launched in...
February 2013, aims to enhance the country’s natural resources, and contribute to food security through protecting overexploited species and supporting their habitat.

There are currently nine registered farms in the UAE, with five still under development, all of a different scale and integrated culture systems. The UAE aquaculture production in 2012 was 540 tons of wet fish, while total production capacity of these farms stands at 4903 tons per year.

“The decision to create the regions first exhibition dedicated to aquaculture was not a tough one. In a nutshell, it is the fastest growing food processing industry in the Middle East, and to put it in to perspective, a recent report by The World Bank projected aquaculture production in MENA is set to rise 75.9% by 2030, hitting a production size of approximately 1.9 million tons. This incredible growth could simply not be ignored.” said Richard Pavitt, Exhibition Director, AquaME.

Saudi Arabia and Oman round-up the total investment figure. The Saudi Arabian Ministry of Agriculture, who are leading the way in terms of investment, will inject an additional USD 10.6 billion into aquaculture projects to produce one million tons of fish in the next sixteen years. Oman, which has long been at the forefront of aquaculture in the Gulf region, announced that it plans to invest USD 1.3 billion in fisheries development leading up to 2020.

“Feedback from the industry was clear. We had a 64 percent increase in visitors to AgraME earlier this year, who attended to specifically source companies from the aquaculture and fishing industry. We have tried to create a holistic approach to this exhibition, integrating the regions first dedicated conference agenda on aquaculture, a buyer’s program and an industry awards ceremony.” added Pavitt.

For more information, visit www.aqua-middleeast.com

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**CALENDAR**

**Upcoming Industry Events**

**2015**

**FEBRUARY**

Feb 19 - 22: Aquaculture America
New Orleans, La., USA

Mar 25-27: Extrusion Course
Ås, Norway

**MARCH**

Mar 16-18: AquaME
Dubai, UAE

**MAY**

Jeju Island, South Korea

**JUNE**

Jun 9: Aquafeed Horizons Conference
Cologne, Germany

Jun 10: FIAAP International Conference
Cologne, Germany

Jun 9—11: FIAAP/VICTAM/GRAPAS
Cologne, Germany

**NOVEMBER**

Nov 5-7: Expo Pesca/Acui Peru
Lima, Peru

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More events on the [Aquafeed.com Calendar](http://www.aquafeed.com)
Specialized Extrusion Course in Norway

Australian company FoodStream, working with extrusion expert Dennis Forte, has been presenting extrusion and related training programs in Australia and the surrounding region, including Thailand, for almost 20 years. Feedback from participants has been excellent. One participant from the Philippines commented “The Extrusion Course is unique in that it is able to present the blend of the fundamental principles of extrusion technology with its practical applications. The speakers transcend the hurdles of mathematical and engineering concepts by using appropriate learning and citing their vast production experiences.”

FoodStream has now teamed up with the Centre for Feed Technology (FôrTek), in Norway, to present a short course specifically directed at Aquafeed Extrusion Technology at FôrTek from 25 to 27 March 2015. Course organiser and co-presenter Gordon Young commented “We are looking forward to working with FôrTek. Accessing their excellent pilot plant facility for a demonstration is a major advantage.”

The 3-day program covers the principles of extrusion, the design of extrusion processes, and the formulation of extruded aquafeeds. Topics cover the basics of extruders and their configuration, through what is happening chemically and physically inside the extruder barrel, to an understanding of extruder dies and extruder instability. Examples in product formulation and the design of extrusion processes demonstrate application of the theory. Principles learned will be applied during the practical demonstration in the FôrTek pilot plant.

For more information, visit www.foodstream.com.au/events.

Industry and leading edge researchers headline 2015 Aquafeed Horizons conference

Applied aquafeed scientists from the Norwegian University of Life Sciences and NOFIMA, Norway, as well as SPAROS, Portugal, along with three of the world’s foremost aquafeed extrusion engineering experts, Format International and the International Feed Industry Federation (IFIF) are confirmed as presenters at Aquafeed.com’s technical conference, Aquafeed Horizons 2015.

The program will focus on how extrusion effects the physical and nutritional quality of fish feeds, aquafeed processing considerations when using novel ingredients and future trends and possibilities in aquafeed production.

The 8th Aquafeed Horizons 2015 will take place along-side VICTAM/FIAAP/GRAPAS 2015, the world’s largest feed and grain exhibitions, creating a must attend event for anyone concerned with staying abreast of feed production developments. 2015 is the 50th anniversary of Victorin and visitors can expect a number of special events, adding even more value to the experience.

When & Where: Aquafeed Horizons 2015 will take place June 9, 2015, on the first day of the trade show at the Koelnmesse, Cologne, Germany.

Registration: Registration is required for a confirmed place. You are strongly advised to register early (Hurry—“Early-bird” discount is ending soon!) Special rates are available for students and groups.


The 2015 conference is sponsored by Andritz, Buhler and Wenger Manufacturing.
As an "aqua person", chances are that EuroTier is not at the top of your list of shows to visit - but that might well change. Organized by the Frankfurt-based German Agricultural Society (DLG), the long established EuroTier is a massive animal production event. The 2014 edition, which took place November 11-14, saw 156,000 trade professionals descend on the Hanover Fairgrounds - 30,000 of whom came from outside Germany. What drew them is the breadth of animal husbandry solutions to be found: 2,360 exhibitors from 49 countries - as well as technical programs addressing health and nutrition and species specific issues. And alongside was EnergyDecentral 2014, presenting solutions for the entire value chain of decentralized energy supply.

And now EuroTier has taken the step of incorporating aquaculture. At EuroTier 2014, DLG introduced "Growth in Water" with the concept of growing biomass in water, rather than from the land. The showcase focused on the diversity, innovation and potential of water as a production medium. This development was driven by what the organizers described as the huge international interest in aquaculture, water conditioning and water treatment experienced at previous exhibitions. They even had live fish: Göttingen University displayed African cichlids from their applied research, known as "Tilapia Augusta,"

There was also an Aquaculture Forum (with presentations in German or English), which included 12 sessions and three panel discussions with more than 50 national and international experts, practitioners and researchers. In addition to the companies who took part in the "Growth in Water" section, EuroTier had numerous exhibitors with products for aquafeed but who were there to target the terrestrial animal feed market.
Temperature Adapted Feeds

The interest in aquaculture was borne out by at least one dedicated aquaculture feed manufacturer: Aller Aqua chose EuroTier to launch their Temperature Adapted Feeds™ concept. Dr. Hanno Slawski, Research & Development Manager at Aller Aqua, introduced their new line during a presentation in the Aquaculture Forum.

Environmental temperature affects both speed and efficiency of fish metabolism. Thus, feed intake of fish and nutrient digestibility vary with temperature. Adapting feeds to seasonal temperature differences on a fish farm creates a great potential for growth and vitality of fish and has become a core principle in our feed formulation.

Aller Aqua’s Temperature Adapted Feeds concept, ensures a higher feed intake and nutrient digestibility throughout all seasons.

Temperature Adapted Feeds for different species and seasons are developed in collaboration with international research institutes, fish farms and Aller Aqua Research.

The subject was well received and prompted interested parties to start exchanging experiences and ideas of seasonal feeding requirements for various types of fish.

Aller Aqua supplies feed to the world’s first ASC-certified trout farm, Christiansminde Dambrug, which was certified in July 2014. ASC-certification requires strict documentation of the entire production chain, including feed, and has generated an increased awareness and control of the production process. Aller Aqua’s experience with the label in Denmark – both advantages and disadvantages were discussed with the audience, and the subject covered in depth by Dr. Maike Oehme, Quality & Technology Coordinator, Aller Aqua, during the Forum.

More information on Temperature Adapted Feeds: Website | Email | Brochure (pdf)

Marine algae

For years, Olmix has extracted essential elements from algae and turns them into different products for improvement of hygiene in animal production, binding mycotoxins in feed, enhancement of digestive and immune systems of animals. Based mainly on ‘Ulvans’, sulfated polysaccharides found in green algae of the genus Ulva, they are unique elements that are not found in terrestrial plants and therefore more efficient in improving health and growth performance of the animals. Utilization of algae is also sustainable because they can be harvested sustainably from natural populations which grow without the need of fresh water, fertilizer and pesticides. At EuroTier, Olmix introduced its new product ‘MFeed+’, a unique association of clay particles and different seaweed extracts (See page 7 in this issue for details) and presented the topics covered by their Breizh Algae Tour 2014, which took place in France a few weeks before EuroTier and was attended by over 500 participants from over 43 countries.

“Algae offer an exceptional untapped potential. Molecules extracted from algae represent a new source of innovation for biotechnology,” said Hervé Balusson, Olmix’ CEO.

We now know that algae extracts can have a favorable influence on the digestive ecosystem, act on the microbiota, stimulate both the enteric nervous system and the myriad of receptors of the immune system lining, the intestinal wall. “This new knowledge opens up very encouraging prospects which make algae a new avenue for approaching health through nutrition,”
said Pr. Bernard Kloareg, Director of research CNRS 8227 and Director of the Biologic Station of Roscoff UPMC, Roscoff, France.

The rise in aquaculture production - particularly in Asia is creating challenges that algae can tackle. In particular the sourcing of raw materials. Algae can be a solution in substitution of fish meal to a more sustainable vegetable meal as a protein source in aquafeed. One of the other challenges of aquaculture production is health. Dr Loc Tran, one of the scientists who discovered the pathogen responsible for Early Mortality Syndrome, said algae can be a part of the solution.

Fascinating facts that emerged from talks by experts on the tour, included:

~ Our digestive system contains ten times more bacteria than the total number of our cells

~ The gut is a second brain that contains 200 million independent neurons: our small intestine is a concentrate of intelligence, the equivalent of that of a small pet. A significant part of our neuronal activity occurs in the gut.

~ Nutrition helps to regulate the balance of the enteric nervous system and even the central nervous system. Therefore, we can influence the nervous system by what we eat, by changing our enteric ecosystem in direct connection with our brain.

~ Algae extracts can have a favorable influence on the digestive ecosystem, act on the microbiota, and stimulate both the enteric nervous system and the myriad of receptors of the immune system lining the intestinal wall.

~ Additives, pesticides and antibiotics can be replaced by natural elements extracted from algae along the entire food chain.

Farm management

Based on 60 years of expertise, InVivo Animal Nutrition and Health has strengthened its investment in aquaculture in terms of nutrition, R&D, health and feed quality, to meet all aspects of the aquaculture value chain. The company now holds a leading position in hatchery feed with the acquisition of BernAqua.

With a presence in major global aquaculture growth areas such as Mexico, Brazil and Asia, InVivo NSA offers a range of global and innovative services.

Bringing together its network of experts, InVivo NSA has developed InMyFarm, an innovative solution supported by decision-making tablet software. Created for working in real time alongside farmers on their farms, InMyFarm deploys a multidisciplinary and holistic approach to optimizing aquaculture farm management. This solution supports customers to better reach their results, uncovering the keys to progress and success.

Recognizing the historical growth rate of aquaculture, InVivo NSA sees aquaculture as having fantastic potential for its growth in the following decade. InMyFarm is now being deployed gradually worldwide by technical experts from InVivo NSA.
Fish protein concentrates
Sopropêche is an international group that has specialized in innovative nutrients for over 45 years. It offers two soluble fish protein concentrates (CPSP®). CPSP® "90" (84 % proteins) and CPSP® "G" (72 % proteins), obtained by a unique process of enzymatic hydrolysis, are considered as one of the best marine protein sources. The presence of highly digestible proteins improves growth and FCR. Bio-active Peptides strengthen the immune system and contribute to the synthesis of neurotransmitters; they also proved to have strong anti-stress effects. Their content of free amino-acids makes them specially attractant and confers excellent palatability to aquaculture feeds.

Incorporation of 3-5% CPSP® "90" or "G" of low molecular weight and high PUFA content in starter diets ensures growth, well-being and support of vital metabolic functions.

Zinpro Performance Minerals® for Aquaculture
Trace minerals play a vital role in overall nutrition for fish and shellfish. Improved trace mineral nutrition is one path to improve production, efficiency and profitability. Fish, shrimp and other aquatic species require trace minerals such as zinc, manganese, copper, iron and selenium for numerous basic metabolic functions, such as growth and development; immunity and reproduction.

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The Availa® Mins line of Zinpro Performance Minerals® include Availa® Zn, Availa® Mn, Availa® Cu, Availa® Fe, Availa® Se and Availa® Cr. Research shows that optimal trace minerals nutrition can consistently provide better weight gain, feed conversion, survivability and profit for aquaculture production.

For more than 40 years Zinpro Corporation has focused solely in trace mineral nutrition, and it is the leader in its field thanks to an emphasis on extensive animal research to prove animal performance.

Microbial solutions
Lallemand Animal Nutrition shared its range of solutions and services aimed at helping animal producers express the full potential of their animals in a natural way. The management of microbial communities within aquaculture systems is one of the most promising areas of progress. It is now understood that the fine balance of bacteria found within the digestive tract or surrounding environment have a huge effect on the immune system, nutrition and physiology. Lallemand has developed a range of microbial-based nutritional solutions to safeguard health and performance of aquatic farmed species in a natural way.

Aquaculture product range from BIOMIN
BIOMIN has been serving the aquaculture sector for more than a decade and established expertise in a wide range of disciplines.

Mycotoxin control is becoming increasingly important as the industry moves to ever higher inclusion levels of plant materials. BIOMIN offers its Mycofix® product line of specially developed feed additives that protect animal health by deactivating mycotoxins found in contaminated feed. BIOMIN has a long history of probiotic research focused on aquaculture. These projects have shown that different strains within the same species can be very important when searching for the most suitable strains for aquaculture. This underlines the importance of a multi-strain product to take advantage of the strengths of each strain. Other products in its aquaculture range include selected blends of organic and inorganic acids and their salts, immune modulators and pond management and bioremediation products.

Jules Tournut Award 2014
The European Probiotic Association (EPA) awarded the Jules Tournut Probiotics Prize 2014 to Dr Steven Frese during EuroTier, for his innovative research project on the evolution of the host-microflora interaction.

On this occasion, industry members and Scientific Committee of the EPA, FEFANA, and journalists discussed the potential of probiotics for sustainable animal production, with benefits beyond zootechnical performance, in animal health and welfare.

Read more at Aquafeed.com.
Under the patronage of
H.E. Dr. Rashid Ahmad Bin Fahad, Minister of Environment & Water

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