Extrusion of Micro Aquatic and Shrimp Feeds
Advanced technology now allows for micro feeds of very small diameters. Feeds less than 3 mm in diameter can be produced at up to 15 tons per hour.

New Technologies for Superior Fish Feed Characteristics
Back pressure valve (Flextex) and Density Control system (ECS) - Combining two new process technologies for full feed controllability.

Boosting Fish Growth
More results on the use of diformates in tilapia diets.

Short Chain organic Acids
A key to healthier animal and safer feeds.

Ingredients Update
Avoid Rancid Feeds: But take care with synthetic antioxidants
Artemia: Not permitted in feed in the USA?
Mercury: less toxic with Selenium?
EXTRUSION OF MICRO AQUATIC AND SHRIMP FEEDS

Extruded starter feeds and increased production rates

By Joseph P. Kearns(1) and Dr. Addison L. Lawrence(2)
(1) Wenger Manufacturing, Inc.; (2) AgriLife Research Mariculture Laboratory

Micro-aquatic feeds are considered to be between 0.15 to 1.2 mm in diameter. These feeds can be produced by a number of methods including large pellet production followed by crumbling; a Spherizer Agglomeration System or simply directly off the extrusion process.

Raw materials for these processes need to be free of large particles and consistent in particle size. Typically flours are used with special care to ensure the fishmeal and animal proteins used are ground properly. Oils and other liquids as well as steam must also be filtered to remove particles from possible line build up. As in any feed processing operation, mixing requires a review of the coefficient of mixing and when making small feeds this becomes more critical to ensure the same formulation is in each feed particle.

Size reduction of formulas for micro feeds in general requires a pulverizer style grinder. They yield a consistent finely ground formula while developing low heat levels to prevent nutrient degradation. Screening after grinding is essential to ensure particle size is correct for continuous operation. Over-sized particles are recycled to maintain formulation consistency and the use of self-cleaning screens also allows for longer production runs.

<table>
<thead>
<tr>
<th>Micron Size</th>
<th>% Through</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>99.8%</td>
</tr>
<tr>
<td>350</td>
<td>99.2%</td>
</tr>
<tr>
<td>250</td>
<td>98.6%</td>
</tr>
<tr>
<td>149</td>
<td>97.8%</td>
</tr>
<tr>
<td>75</td>
<td>77.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Micron Size</th>
<th>% Through</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>100.0%</td>
</tr>
<tr>
<td>350</td>
<td>100.0%</td>
</tr>
<tr>
<td>250</td>
<td>100.0%</td>
</tr>
<tr>
<td>149</td>
<td>99.8%</td>
</tr>
<tr>
<td>75</td>
<td>80.8%</td>
</tr>
</tbody>
</table>
The pulverized only sample below yielded 99.2% through a 350 micron screen which is good but not quite what is needed if the extrusion die holes are 300 micron. The pulverized and sifted sample would result in a longer production run due to the 100% through a 250 micron sieve.

Direct extrusion of micro feeds is typically limited to feeds of 0.8 mm or larger for twin screw extruders and 1.2 mm for single screw extrusion. Some producers are making 0.6 mm feeds with attention paid to the above referenced critical points. Advantages of direct extrusion production methods are pasteurized feeds with high yields after post extrusion sifting. Disadvantages include the need for a dedicated line and pellet sizes. The historic disadvantages of high cost per unit and low production rates have vanished due to the development of methods of achieving higher rates per hour which will be discussed later in this article.

**Starter feed production with a Spherizer Agglomeration System (SAS)**

SAS is a low shear and low temperature extrusion of a uniform and pulverized formulation into agglomerated strands. These strands, by cyclonic motion, are then rounded into nutritionally homogenous pellets. The extrusion system is a specialized machine beginning with a Dual Conditioning Cylinder providing inline dynamic mixing, injection of oils and other fluids. The first-in first-out conditioning process with consistent
and manageable retention times, temperatures and gelatinization levels feed the specialized extruder barrel. In the extruder barrel the feed is compressed and densified instead of cooked and expanded as in normal extrusion cooking with the end result densities approaching 720 g/l.

The strands from the extruder are conveyed to the Sphere-izer which breaks the strands into small individual agglomerations. Each pellet is simultaneously shaped into spherical particles with use of variable retention time control. The spheres are conveyed to and pass through a fluid bed dryer/cooler where excess moisture is removed and the product is cooled. Spheres finally pass through a screener for size classification with the SAS process providing on-size yields as high as 95%.

The advantages of this production method are oil can be added internally while processing at moderately low
temperatures for pellet sizes approaching 0.15 mm with 95% yield after post-production sifting. These pellets are excellent in appearance and the system is perfect for making medicated and elevated vitamin inclusion micro feeds. Disadvantages include sinking feeds only with low pasteurization levels can be produced with relatively low production rates. Capacities are between 100 kg/hr for 0.15 mm pellets to almost 3,000 kg/hr for 1.5 mm products.

As mentioned above, high capacity micro aquatic feed production is now possible via direct extrusion with the use of specialized final screws developed for both single and twin screw extruders. Historically limitations existed for aquatic feeds smaller than 3 mm in diameter. These limitations were due to the final die open area and their location at the end of the extruder.

Benefits of this new technology for micro floating feed production is that the die can be properly located for maximum capacity and feed expansion. Larger correctly positioned dies allow for increased die hole population and increased production rates. In addition to the new cone screw technology special die extensions yield retention time and flow characteristics for sinking feeds with densities in the 650 gm/l range as well as 3 to 5 times traditional capacities.

The adjusted die designs allow for uniform cross-sectional flow with the desired results of higher rates, uniform size pellets and heavier density products.

<table>
<thead>
<tr>
<th>Product</th>
<th>Previous Technology</th>
<th>New Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5mm Sinking</td>
<td>1000-1500 kg/hr</td>
<td>3750-5000 kg/hr</td>
</tr>
<tr>
<td>1.8 mm Floating</td>
<td>1500-2000 kg/hr</td>
<td>3750-5000 kg/hr</td>
</tr>
</tbody>
</table>

**Feeding trials**

Finally, we will review results of recent shrimp feed trials with regards to grow out of shrimp on extruded feeds. This is mentioned as extrusion is again at the forefront for consideration as a profitable production method for shrimp feeds as single screw extruders with this new technology are now capable of capacities up to 15,000 kg/hr. When comparing extruders with traditional pellet mills, their use can be justified from a total cost perspective: extruders need less starch, do not require binders and allow for a wider ingredient selection - all while producing highly water-stable feeds.

Feed trials conducted at Texas A&M with Dr. Addison Lawrence were preformed with the following criteria:

- Feeding studies conducted with five shrimp per tank with 100 tanks utilized
- Water filtered recirculated and exchanged
- Water checked for salinity, temperature and dissolved oxygen daily
- Ammonia, nitrite, nitrate, and pH measured weekly
- Light regimen: 12 hours dark and 12 hours dim daily
- 35 days trial
- Feeding was 15 times per day
- Unconsumed feed removed daily
- Water recirculation: 4,193% daily
- Clean water system (no natural productivity)
- 150 shrimp/m3
- temperature range: 29 to 31°C
- oxygen levels: always above 5 ppm
- pH: between 8.0 and 8.2
- ammonia, nitrite and nitrate: very acceptable low levels and not limiting
- salinity: between 25 and 37 ppt

The results of the trials at Texas A&M were reported as Estimated Growth Rate/Week. It was noted that the % survival for all treatments was over 90%.

<table>
<thead>
<tr>
<th>Week</th>
<th>Size</th>
<th>Change in Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.26 Gms initial weight</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.65</td>
<td>0.39</td>
</tr>
<tr>
<td>2</td>
<td>1.30</td>
<td>0.65</td>
</tr>
<tr>
<td>3</td>
<td>2.60</td>
<td>1.60</td>
</tr>
<tr>
<td>4</td>
<td>4.30</td>
<td>1.70</td>
</tr>
<tr>
<td>5</td>
<td>6.00 final wt</td>
<td>1.70</td>
</tr>
</tbody>
</table>

The trials were continued until the linear growth phase was achieved which settled out to be 1.7 grams of growth per week on average for all trials. This equates to about 30 shrimp per kilo in 16 to 18 weeks.

In conclusion: advanced technology now allows for micro feeds of very small diameters, as small as 0.15 mm with the SAS system as well as direct extruded feeds down near 0.6 mm. The level of gelatinization as well as the microbe destruction level in the feeds can be engineered into the system. Extrusion capacities of feeds less than 3 mm in diameter are now up to standard large diameter pellet rates, with 5, 10 or even 15 tons per hour possible. These higher capacities justified trials preformed by Dr. Lawrence reconfirming that extruded shrimp feeds provide excellent growth rates.

*For more information about these processing systems, please contact [Joe Kearns](#) or visit the [Wenger website](#). For information about the feeding trials, please contact [Dr. Addison Lawrence](#).*

*This article is based on a presentation at [Aquafeed Horizons Asia 2010](#), March 3, 2010, Bangkok, Thailand.*
THE TASK OF extruding aquafeeds is primarily a matter of cooking the starch, but in addition to control the product density and thus the sinking or floating properties.

Typically the degree of starch cook varies according to the amount of carbohydrates in the formula, where 80% or higher is typical on trout feed but only approximately 70% on shrimp feed. By making a specific screw configuration of the extruder one can to a certain extent supply the specific mechanical energy (SME) necessary to produce a given product with an optimum degree of cook. The degree of cook...
is decisive from both a nutritional as well as a physical product quality point of view: the better the starch cook, the better the quality.

In order to improve profitability of aquafeed, formula cost must be reduced to a minimum. By improving starch cook the level of carbohydrates can be reduced, thus including additional cheaper protein sources, which all contributes to lower costs.

The physical quality of fish feed product can be defined by: density; shape and size; uniformity; durability and water stability.

The nutritional quality of fish feed can be defined as: recovery of essential amino acids and specific vitamins; digestibility.

On the most technologically updated extruders an optimum screw configuration can be established in order to apply the SME quantity necessary for matching a specific product, e.g. salmon or trout feed with a high content of fat/oil, internal oil or similar products with high nutritional value.

A screw configuration can be optimized to apply more SME by implementing the following components: screw design and geometry; shear locks; kneading blocks; reverse elements.

An optimum screw configuration is not always capable of applying sufficient SME to produce a given product. Frequently it is also necessary to optimize other parameters that can be used to increase the SME supply in the extruder: screw speed; open area of venturi die; open area of die plate; extruder capacity.

The task of producing aquafeed primarily consists of combining an optimal product quality (optimum cook) with minimal production costs. Changes in screw configuration and other measures, which may contribute with higher or lower SME values, are all operations that usually result in down time and increased production costs. Changeover procedures between ½-2 hours to adapt an extruder to a specific product are
not unusual.

Fig. 1 shows the difference in SME typically generated in a high shear extruder configuration, compared with the SME range used when operating the FLEXTEX system (high protein floating fish feed).

**The FLEXTEX system - Working principle**

With the development of the FLEXTEX system (patent pending) the following advantages have been observed:

- No need for changing extruder configuration regardless of SME requirement
- Consistent capacity of extruder
- Reduced number of adjustment parameters during the extrusion process
- basically only the SME is changed (set-point)
- Less impact by die plate design

The FLEXTEX system is based on being able to continuously control the SME applied in the extruder during operation without changing the extruder configuration or other parameters. The system adjusts the opening area in the venturi die plate, which is placed between the last screw and the die plate in the extruder. The venturi die is used in many extruders in a stationary design to decrease or increase the kneading zone in the extruder in order to control the SME applied. This is done by adjusting the size of the hole and thus the opening area and the pressure against it. The smaller the hole, the larger the pressure and thus the more energy consumption from the main motor (see fig. 2 and 3).
With the FLEXTEX system the opening area of the venturi die can typically be adjusted from 3000 mm² to 100 mm² (4.65 to 0.15 in²) depending on throughput. (See fig. 4).

With the FLEXTEX system the extruder operator can determine how much specific mechanical energy (SME) the product needs. From a control system, for example a separate control or alternatively a control integrated in the extruder control, the operator can make a set-point, e.g. kW/ton (HP/ton) dry matter. By means of a hydraulically controlled piston the FLEXTEX system automatically adjusts in relation to the set-point by decreasing or increasing restriction of the venturi die by moving a piston.

The FLEXTEX system - which in principle is a dynamic venturi die - controls and adjusts the SME supply continuously during operation. In short: the change of only this one parameter means the following for the production of fish feed: the starch cook (up to 100%) is completely controlled during operation; the bulk density of the product can be reduced by up to 30% and can be controlled with an accuracy of ±5 g/l (0.3 lbs/ft³); higher addition of oil and less starch in the formula without significant influence to bulk density and product quality.

The FLEXTEX system mechanical design

In principle the FLEXTEX system consists of three parts: the PLC control system; the venturi die and the piston system; the hydraulic station.

The FLEXTEX system is designed with focus on simplicity and consists of a few components only. The critical part of the system is however the piston, which - besides being used as a restriction for the meal flow - also distributes the meal to the die plate. When restricting the meal flow it is essential that this takes place synchronically in order not to hinder the flow ability. Changes in the meal flow will influence the visual quality of the product due to an uneven pressure at the die plate. The piston in the FLEXTEX system is moved axially and at the same time it is conical, so that the meal flow is not negatively influenced.
Increased bulk density - Density Control System (ECS)

The FLEXTEX system controls starch cook and subsequent reduction in bulk density. By using the system an increase in bulk density is controlled in the same way as in all conventional extruders. All parameters, which have a positive influence on increased bulk density, have a negative influence on starch cook, as increasing the bulk density in principle is a matter of reducing the SME and thus the starch cook.

To be able to control the bulk density of products in a wide range and at the same time obtain an optimum product quality, the Density Control System (ECS) is unique. The ECS concept (patented) is based on controlling the expansion in the extruder knife house without influencing the product quality. Thus all desirable parameters can be used in the extruder without regard to expansion. Main focus is product quality.

By adding compressed air in the knife house the pressure can be controlled and adjusted. This is made possible by mounting an airlock under the knife house (see fig 5). An increased pressure in the knife house results in a reduction of flash-off and thus an increase of bulk density (less expansion). The larger the overpressure, the larger the density (less expansion).

The FLEXTEX system and ECS - Combined

The FLEXTEX and the ECS systems can either be installed individually or as a combined concept. This is solely a question of each producer’s requirements in the production. Most frequently a FLEXTEX system is installed as a result of a requirement for either more starch cook, reduced formulation costs, or increased capacity.

Documented tests supported by experience from systems in full scale operations have shown significant opportunities for the FLEXTEX and ECS system.

During a series of tests the shrimp feed formula (70% protein) illustrated below was used:

The following tests were conducted:

A. FLEXTEX effect on starch cook
B. ECS effect on bulk density
C. FLEXTEX effect on water stability
D. Reduced starch cook by means of FLEXTEX

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (61% starch)</td>
<td>17.7</td>
</tr>
<tr>
<td>Wheat flour (88%) starch</td>
<td>4.4</td>
</tr>
<tr>
<td>Wheat gluten</td>
<td>5.6</td>
</tr>
<tr>
<td>Fishmeal (LT):</td>
<td>18.9</td>
</tr>
<tr>
<td>Soya (hi-pro)</td>
<td>46.9</td>
</tr>
<tr>
<td>Shrimp meal</td>
<td>4.9</td>
</tr>
<tr>
<td>Oil</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Test A - FLEXTEX effect on starch cook

By increasing the SME in the extrusion process by approx. 12% the cook rate was increased by 11.8%.

<table>
<thead>
<tr>
<th>rpm</th>
<th>w/FLEXTEX</th>
<th>w/o FLEXTEX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cook %</td>
<td>Bulk g/l</td>
</tr>
<tr>
<td>215</td>
<td>100</td>
<td>565</td>
</tr>
<tr>
<td>290</td>
<td>100</td>
<td>525</td>
</tr>
<tr>
<td>360</td>
<td>100</td>
<td>540</td>
</tr>
</tbody>
</table>

Test B - ECS effect on bulk density

The ECS can increase the bulk density by 25% by adjusting the pressure in the knife house only.

<table>
<thead>
<tr>
<th>w/FLEXTEX</th>
<th>w/o FLEXTEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density g/l</td>
<td>SME kW/t</td>
</tr>
<tr>
<td>490</td>
<td>34.8</td>
</tr>
<tr>
<td>535</td>
<td>34.6</td>
</tr>
<tr>
<td>615</td>
<td>34.9</td>
</tr>
<tr>
<td>635</td>
<td>34.3</td>
</tr>
<tr>
<td>640</td>
<td>34.5</td>
</tr>
</tbody>
</table>

Test C - FLEXTEX effect on water stability

By increasing the SME it was possible to increase the water stability by additionally six hours.

<table>
<thead>
<tr>
<th>w/FLEXTEX</th>
<th>w/o FLEXTEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water stability (hours)</td>
<td>Water stability (hours)</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

Test D - Reduced starch contents in formula by means of FLEXTEX

By reducing the starch contents by approx. 50%, equal water stability (8 hours) could be obtained as with original high starch formula, but without FLEXTEX (eight hours).
In summary, the FLEXTEX and ECS system provides significant flexibility in the production of feed for all fish species. By continuously controlling the SME during operation it is possible to achieve an optimal physical quality. At the same time using the ECS to control the density two unique tools for controlling finish product characteristics are present.

The advantages of the system can be summarized as:

- Increase starch cook by 10-15%
- Decrease bulk density by 20-30%
- Increase bulk density by 0-5%
- No change of screw configuration (reduced down time)
- Only two parameters needed for controlling starch cook, reduced and increased bulk density

For more information please contact Anne-Mette Lund or visit the Andritz Feed & Biofuel website.

For more information please contact Anne-Mette Lund or visit the Andritz Feed & Biofuel website.
The use of acidifiers in aquaculture is currently gaining more interest among researchers as well as practitioners. A wide range of different organic acids and salts have been tested so far (Lückstädt, 2008). Especially diformates have been used very regularly in tropical, as well as cold-water aquaculture, because of its high load of active ingredients on the one hand as well as its stability and handling properties in extruded feeds on the other hand.

Ramli et al. (2005) tested potassium diformate as a growth promoter in tilapia grow-out in Indonesia (as reported in the autumn issue of AQUAFEED: Advances in Processing & Formulation). Similar results were achieved by Zhou et al. (2008) in a dose response study with potassium diformate (0%, 0.3%, 0.6%, 0.9% and 1.2%), while Ng et al. (2009) tested the substance in a 14-week feeding trial in tilapia as well. All researchers reported a positive impact against pathogenic bacteria, lower mortality rates as well as improved performance of the fish.

Recently, research groups in the Philippines as well as in Germany have concentrated their work again on the use of diformates in tilapia. Researchers from the Southeast Asian Fisheries Development Center - Aquaculture Department in Binangonan, Philippines looked at the effect of potassium diformate (KDF).

Twenty-five male Nile tilapias with a mean weight of 7.84±0.90 g were stocked in eight 240 l polyethylene tanks in a static-renewal system. Fish were reared for 74 days. Proximate composition of the commercial feed was 31.4% crude protein, 6.9% crude fat, 8.6% crude fibre, 52.3% NFE and 0.8% ash as well as a gross energy of 17.3 kJ g⁻¹. The fish in both the control and KDF treatment were given the appropriate feed with a daily ration equivalent to 5% of their body weight. Feed was dispensed thrice a day at 0800h, 1200h and 1600h. Water parameter as well as growth performance of fish were monitored regularly.

Diet supplemented with KDF yielded improved growth data, based on daily growth rate as well as specific growth rate (P<0.01). Tilapia in the control group reached a mean body weight of 45.5±1.1 g, while the fish fed with potassium diformate reached an average weight of 51.4±2.2 g. Likewise, feed conversion ratio was improved significantly (P<0.05).
The results show that addition of 0.3% KDF in the diets of Nile tilapia can help to improve its growth performance and thus, can achieve a more economic and sustainable tilapia production. Furthermore, the additive optimizes feed efficiency, which is in full agreement with previously reported improved digestibility parameters after the inclusion of KDF in fish feeds.

On the other hand, researchers from the Göttingen University in Germany concentrated their work on the most recently developed double salt feed additive - sodium diformate, which is also produced at ADDCON’s production site in Norway.

Preliminary data from a semi-closed re-circulating system showed promising results on the use of sodium diformate at 0.3% inclusion rate in tilapia fingerling rearing (see table 1).

Table 1: Growth performance of tilapia after 42 days fed with or without sodium diformate

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Sodium diformate (0.3%)</th>
<th>P-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fish</td>
<td>160</td>
<td>160</td>
<td>-</td>
</tr>
<tr>
<td>Initial weight (g)</td>
<td>34.0</td>
<td>33.9</td>
<td>n.d.*</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>70.9</td>
<td>75.5</td>
<td>n.d.</td>
</tr>
<tr>
<td>Weight gain (g)</td>
<td>36.9</td>
<td>41.6</td>
<td>0.098</td>
</tr>
<tr>
<td>FCR</td>
<td>1.46</td>
<td>1.29</td>
<td>0.007</td>
</tr>
</tbody>
</table>

*n.d. - not determined

Latest results from Auburn University, USA are in full agreement with the above mentioned trials.

Those three data sets from the Philippines, Germany as well as the United States will be presented in full during the 14th International Symposium on Fish Nutrition & Feeding in Qingdao, China at the end of May.

In general the authors concluded that data achieved under high hygienic conditions at laboratory scale will lead to even more pronounced effects of diformates in the field. It is therefore highly recommended to include organic acid salts, like diformates, in the ration of growing fish under tropical conditions.

For more information or to obtain literature references, please contact:

Dr. Christian Lückstädt
Organic acids are widely used throughout the industrial world. They have two actions as antimicrobial agents. Their primary action is through pH depression and secondly is the ability to change from the undissociated to dissociated form, depending on the environmental pH, making them effective antimicrobial agents. When an acid is in the undissociated form it can freely diffuse through the semi-permeable cell wall of micro-organisms into their cell cytoplasm. Once inside the cell, where pH is normally maintained near 7, the acid dissociates and pH decreases, thus disturbing and finally killing the micro-organism. The important anti-bacterial activity of organic acids enables such products to be widely used in agricultural applications as additives for animal feed and silages.

Nevertheless, liquid organic acid usage remains limited due to some detrimental properties. The use of organic acids causes major handling and usage problems due to their corrosive nature and they can seriously damage equipment and work areas, while thorough cleaning needs to be undertaken after use. Staff involved with the use of these chemicals should always wear suitable personal protective equipment such as gloves and goggles to avoid any harmful contact. In addition, many organic acids have a very strong smell making working environments unpleasant and also very often leading to reduced feed consumption.

SOFTACID, what it is and its advantages

SOFTACID (Borregaard) technology effectively reduces to a minimum all the above mentioned drawbacks. It is a patented mixture of organic acids and modified and functionalized lignosulfonic acid, which moderates the aggressiveness of the acids, hence the name Soft. SOFTACID has been formulated in order to maintain its efficiency in all its applications. The unique properties of lignosulfonic acid and the other organic acid mixtures are protected by Borregaard technology, which significantly reduces corrosion and volatility. This protection also enables animals to absorb the organic acids more easily making this product a cheap and efficient solution for controlling bacterial populations throughout the feed process (feed production, drinking water treatments, within the digestive tract etc.).

SOFTACID is far less aggressive than organic acids alone because of two main chemical properties. It is believed that at low pH the dissociated lignosulfonic acid anions migrate towards positively charged solid surfaces (e.g. concrete and steel) forming insoluble complexes which act as a protective film.
Secondly a specific ionic attractiveness ion occurs between organic acids and lignosulfonic acids. This affinity disappears in the digestive tract upon contact with endogenous hydrochloric acid thus releasing the organic acid molecules. Due to additional benefits described above, SOFTACID is at least as efficient as pure organic acids.

Trials have been performed over recent years on several species such as pigs, poultry and latterly fish and in almost every application (animal feed, pellets, silage, wet feed and drinking water).

In wet feed applications a reduction of 50% to 75% in sedimentation of solids has been achieved with 1% SOFTACID, thereby providing a homogeneous feed and resolving feed intake differences. Additionally, biofilm, that often develops in pipes either by the presence of nutrients or from hard water and water stagnation which may lead to sanitary problems, and can be removed completely with a 1% SOFTACID solution held in the pipes for 2-4h and then flushed through all the nozzles where biofilm sludge could have accumulated. It has been verified that SOFTACID technology not only protects organic acid but is also compatible with the fragile feed additives very often used in farms such as vitamins, antibiotics, oligo-elements and vaccines.

Borregaard has developed special products for each application, including SOFTACID 4+ for animal feed production and drinking water, SOFTACID P+ for grain preservation, SOFTACID Ensimax for silage, SOFTACID Aqua E for fish preservation and for fish by-products (SOFTACID Aqua M). Moreover, a wide range of products including formic, lactic, acetic and propionic acid are available individually.

Compared to traditional organic acids, SOFTACID is much easier to handle and reduces associated risks. Corrosion of stall equipment and evaporation of the acid is appreciably reduced as shown in Figures 1, 2 & 3 making the working environment both healthier and safer. SOFTACID is also not subject to ADR* for the transport and storage of dangerous goods where pure organic acids are.

SOFTACID products are brown in color and are currently available in liquid or in powder form.
SOFTACID “protection” mechanisms

**Mechanism 1** - Chemical Complexation: Due to their specific charge repartition the lignosulfonic acid macromolecules and the organic acid molecules create intermolecular ionic links.

**Mechanism 2** - Steric hindrance: The specific lignosulfonic acids used for SOFTACID® technology have a high molecular weight thus the free migration through the media associated with smaller organic acid molecules.

**Mechanism 3** - Surface Chemistry: Lignosulfonic acids naturally orientate themselves in a layer minimizing their structural energy and thus creating a protective layer.

**Release of SoftAcids**

Organic acids are readily released when the environment changes (pH mainly) lowering the strength of the bond between lignosulfonic acid and the organic acids (for example in the stomach) making them available to interact with any micro-organisms which are present. Moreover, it has been proven that SOFTACID concentrate has an inhibiting effect on specific bacteria, thus improving organic acid action as explained below in Figure 4.

**Antimicrobial effect of SOFTACID in vitro**

In a very recent in vitro trial in the Hellenic Centre for Marine Research, SOFTACID (DP485) was found to have antimicrobial effects on Gram (-) *Pasteurella* bacterium (*Photobacterium damselae subsp.piscicida*).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bacteria colonization/ extermination</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Bacterial colonization</td>
</tr>
<tr>
<td>Pure organic acids at 5Kg/T</td>
<td><img src="image2.png" alt="Image" /></td>
<td><strong>Bacteriostatic effect:</strong> Due to low levels of organic acids, not all the bacteria are killed and there is a natural balance between colonization and bacteria extermination.</td>
</tr>
<tr>
<td>Pure Organic acids at 20Kg/T</td>
<td><img src="image3.png" alt="Image" /></td>
<td><strong>Bactericide effect:</strong> All bacteria are attacked by organic acid molecules and killed</td>
</tr>
<tr>
<td>SOFTACID® At 5 Kg/T</td>
<td><img src="image4.png" alt="Image" /></td>
<td><strong>Bactericide effect:</strong> A consistent part of the bacteria are killed by organic acid penetration and the ones surviving are inhibited by Lignosulfonic acid.</td>
</tr>
</tbody>
</table>

*Figure 4. SOFTACID® inhibition effect on specific bacteria*
Specifically, a minimum concentration of 2500ppm (1:400) was found to inhibit the growth of the pathogen. This results could be very promising if in vivo trials with SOFTACID in fish show similar results. If this will be the case then Boregaard product could be also used to prevent microorganisms such as Pasteurella to be developed in fish environment avoiding at the same time the use of antibiotics or other pharmaceutical treatments.

Trial results obtained with SOFTACID in fish diets

Acid preservation of fish and fish viscera to produce fish silage has been a common practice and the final product has been widely used in fish feeds with reported beneficial effects (Asgard & Austreng, 1981). The beneficial effects of acid preserved products caught the attention of the scientific community prompting investigation into the dietary effects of using these short chain acids on fish directly (Luckstadt, 2006).

In a recent trial the inclusion of an organic acid blend, mainly consisting of formate and sorbate, in rainbow trout diets resulted in improved weight gain and feed conversion ratio (de Wet, 2005). Similar results have been reported for the inclusion of lactate in Arctic charr diets (Ringo, 1991). In contrast to these positive results, attention should be paid to propionate as the addition of propionate in Arctic charr diets has shown a depressing effect on growth when compared to a control diet (Ringo, 1991).

Taking into consideration the above studies, the use of organic acid blends appears to be a promising way to improve growth performance and feed efficiency of fish culture and thus the income of a farm. For these reasons a study was conducted in the Hellenic Centre for Marine Research in Greece to determine the effects of 0.25% (SA 0.25) and 0.5% (SA 0.5) inclusion of SOFTACID (DP 485 containing lignosulphonic acid blended with formic acid) in gilthead sea bream (Sparus aurata) extruded diets (Table 1) on growth performance, mortality and feed utilization. Extrusion of the diet was performed in

<table>
<thead>
<tr>
<th>Feed Ingredients</th>
<th>Control</th>
<th>SA 0.25</th>
<th>SA 0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Meal</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Wheat Meal</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Fish oil</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Corn Gluten</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Vitamin &amp; Mineral pre-mix</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Cellulose</td>
<td>1.7</td>
<td>2.5</td>
<td>2.2</td>
</tr>
<tr>
<td>SOFTACID</td>
<td>-</td>
<td>0.25</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Proximate composition</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>8.3</td>
<td>7.6</td>
<td>8.2</td>
</tr>
<tr>
<td>Protein</td>
<td>44.1</td>
<td>43.9</td>
<td>44.2</td>
</tr>
<tr>
<td>Fat</td>
<td>18.3</td>
<td>18.5</td>
<td>17.8</td>
</tr>
<tr>
<td>Ash</td>
<td>6.4</td>
<td>6.4</td>
<td>6.6</td>
</tr>
</tbody>
</table>
laboratory conditions in a 50cm barrel of a single screw extruder. Total time of the feed in the barrel was approximately 20sec and temperature applied in the front die was 60°C, outlet die temperature 100°C and maximum temperature in the barrel 110°C.

**Growth and feed utilization results**

Independent of diet treatment, incidents of mortality were scarce and random in all groups. Differences in the growth parameters measured show a positive effect for the fish fed the supplemented diets.

Specific growth rate (SGR) was significantly higher for fish fed the SA 0.5 diet compared to the control group while fish fed the SA 0.25
diet showed improved growth, however this was not significant. The feed conversion ratio (FCR) showed statistically higher values for the group fed the high level (SA 0.5) of organic acid blends. Table 2 and Figures 5a and b show the growth performance and feed utilization of gilthead sea bream.

Conclusions

The addition of short chain acids in fish feeds has still not been investigated thoroughly and it is not common practice yet. However, the results of recent research with trout, Arctic char and gilthead sea bream are very positive in terms of growth performance. SOFTACID combines benefits related to feed preservation, handling of the product and fish performance and it has proved to be very effective when included at the 0.5% level in a sea bream diet. All these benefits would improve cost effective production in commercial fish farms in the Mediterranean area.

References


For more information, please contact Dr. Stella Adamidou or visit the Borregaard website.
Fatten up your bottom line. Buhler high-performance animal and aqua feed production systems are used by leading companies around the world. These producers know they can rely not just on the technology itself, but also on the support that accompanies it. A service combing local presence with global expertise both lowers feed mill operating costs and increases capacity utilization. So the question is not whether you can afford to choose Buhler – it’s how a solution from Buhler will feed your profits. To find out more, visit www.buhlergroup.com.
MARINE-BASED FEED ingredients are an extremely valuable source of protein and fatty acids for most farmed species. However, the high unsaturated fatty acid content makes marine raw materials and ingredients prone to oxidation, causing loss of nutrients and reduced exploitation of amino acids. Oxidation also leads to the formation of noxious substances in the feed.

Oxidised feed causes anaemia, discoloration and damage to the gills, liver and kidneys, including tumors. Oxidized feed is not utilized as well by the fish.

Synthetic antioxidants - not all good news

Affordable synthetic antioxidants are added to the feed to prevent oxidation. The use of these is currently regulated and takes into account both safe transport and consumer health, but not the biology of the aquatic organisms. The vast majority of synthetic antioxidants used in aquaculture today are probably calculated from trials on land animals.

Studies carried out on aquatic species, at among other places, the National Institute for Nutrition and Seafood Research (NIFES) show that biological disposition of synthetic antioxidants in salmon is different from that in land animals (rats and mice), are unique in the same farmed organism and varies between farmed species.

The trials also show that synthetic antioxidants or combinations of these have a growth reduction effect on farmed shrimp, and some synthetic antioxidants cause more extensive tissue damage in farmed shrimps than others and are consequently more noxious.

Some synthetic antioxidants are transferred from the feed to the brain in salmon, and can cause enlargement of the heart and liver in salmon (such effects were not reported in land animals).

A poor choice of synthetic antioxidants can influence the quality of the feed and the health of the animal and in doing so reduce farming efficiency.
“The increasing demand among consumers for utilization of marine raw materials to high value products, total utilization of the raw material and increased negative focus on the use of additives in aquaculture demands new thinking concerning the use of antioxidants,” said Victoria Bohne, a scientist at Nofima Ingrediens.

The choice of antioxidants in early phases of production of marine raw material and ingredients should cover all links in the supply chain - from the catch of pelagic species from both the fisheries and aquaculture industries. Bohne believes that the approach should be holistic, interdisciplinary and knowledge-based concerning for example:

- seasonal variations in chemical composition in pelagic species;
- the biology of the farmed species and the effects of antioxidants in feeds;
- increased production efficiency associated with the correct choice of antioxidants;
- animal health and welfare related to antioxidants in feeds;
- development of new products from traditional and new marine raw materials, including by-products.

“The connection between the type of synthetic antioxidant, reduced growth and the health of farmed organisms has not been in focus previously and should be studied more closely and parallel with the development of new feed types, perhaps particularly with a view to new species in aquaculture or species which have not been farmed successfully,” said Bohne.
ARTEMIA

Not permitted in feed in the USA?

DESERT LAKE Technologies, a long-established US-based company that specializes in hatchery feeds, had several shipments of artemia cysts seized by the U.S. Food and Drug Administration (FDA) at the end of February and was informed that although they have been used for many years in the USA as larval feed, artemia are not GRAS (Generally Recognized as Safe) and therefore cannot be used in aquaculture nor the ornamental fish industry as larval feed.

Howard Newman, president and CEO of Desert Lake Technologies observed that this is not his problem but a problem with the potential to impact the entire industry. “Growers, hatcheries, suppliers—we are all in this and need to mount a defense that enlists the help of congressmen, senators, government officials and artemia associations. What are the fish food manufacturers going to do as they all utilize artemia in their formulations? What’s going to happen to Tetra, which sells $20 million worth of tropical fish feed in just the USA? Will Tetra be required to pull all its fish foods out of Wal-Mart and every tropical fish store in the USA?”

At time of press the FDA had released a container of raw artemia and also frozen marine polychaetes and Newman was optimistic about a shipment of decapsulated artemia cysts still to be released.

Richard Sellers, the American Feed Industry Association however confirmed to Aquafeed.com that artemia was not and never had been approved for feed.

Newman said that his attorneys are petitioning to get artemia cysts grandfathered in since he had provided the FDA with ample peer reviewed papers showing use of artemia prior to the GRAS certification mandate of 1958. Unless resolved, the situation has the potential to cripple the US shrimp industry.
MERCURY LESS TOXIC WITH SELENIUM

SEAFOOD IS NATURALLY rich in selenium, but it may also contain the environmental pollutant methylmercury. New research indicates that methylmercury is less toxic to mice if they are simultaneously exposed to selenium.

Mercury is known to have detrimental effects on the nervous system, especially in the early phases of development of the foetus. In a study carried out by the National Institute for Nutrition and Seafood Research (NIFES) pregnant mice were fed a diet which was spiked with either methylmercury or the mineral selenium, or both. The level of methylmercury in the feed was around 100 times higher than is normally present in seafood. The results from the study showed that the mice which had been exposed to both selenium and methylmercury through the mother had a better balance than the mice that had not been given the selenium supplement. The results indicate that selenium may counteract some of the negative effects of methylmercury on the nervous system.

Selenium and methylmercury in seafood

Seafood is a natural source of the mineral selenium which is important for a number of metabolic processes in the body. Mercury occurs naturally in several different chemical forms, and methylmercury is known to be one of the most toxic forms. Seafood may contain methylmercury, but usually in concentrations that are considerably lower than the EU’s upper limit for mercury. The limit is 0.5 mg per kilo of fillet for most species and 1 mg per kilo for some predatory fish species, such as tuna and Atlantic halibut.

Comprehensive knowledge about the effects of environmental pollutants is important to enable public authorities to assess seafood safety.