Aqua Feed
TWIN SCREW EXTRUSION TECHNOLOGY

BY CLEXTRAL
AQUAFEED TWIN SCREW EXTRUSION PROCESSING

Source of the article: International Aquafeed - May/June 2011

The aquafeed manufacturing industry is widely recognized as one of the fastest expanding food industries in the world. Fish meal is the main protein source in aquafeed, but supply is limited, which means that alternative sources must be used. From a processing point of view, extrusion is the most efficient way of turning plant protein into fish feed. Twin screw extruders offer a definite advantage in this.

The goal for production of aquatic feed is to manufacture a nutritionally complete product that achieves the desired product characteristics. While all aspects of the process are important, a number of the unit operations of the manufacturing process are critical to achieve this goal.

These operations are organized along the process as follows:

Intake raw materials → Pre-Grinding & Grinding → Weighing Dosing → Micro Ingredients → Thermal Energy

Mixing Formulation → Thermal-Mechanical Energy

Precondition. Extrusion → Drying → Vacuum coating → Oil → Cooling → Sifting → Packaging

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Selecting Raw materials

The first step of the aquafeed process line is feed mix preparation—selecting a combination of ingredients with the proper levels of essential nutriments required for the animal species. The formulation is also based on cost, availability and chemical composition of the raw materials. Ingredient selection has a direct impact on final product characteristics.

According to their functions, these ingredients can be divided into three groups:
- Nutriments: to meet the requirements of fish
- Functional product: binders, expansion, hardness
- Palatants and attractants

Pre-grinding / grinding

It is essential to decrease the particle size to a powder state before mixing the ingredients. Post grinding achieves the best final performance. In addition, particle size is dependent on the final size of the pellets. For die openings up to 3mm, the largest particle size should not be larger than 1/3 of the die opening. Smaller particles improve pellet durability, water stability and decrease pellet friability.

Mixing

Mixing accuracy depends on the properties of the components, which should be similar in density and particle size. Additives or micro ingredients are added at this step. The required mixing time depends on the type of mixer technology used, as well as dry ingredient mixing time before liquids are added.

Extrusion cooking

This step of the aquafeed processing line can be divided into three stages: preconditioning, thermo-mechanical cooking and die texturization-shaping

• Preconditioning

The primary objective of preconditioning in an extrusion cooking process is to initiate the hydration and the cooking of the feed mix. The dry feed mix and the liquid parts (slurry, oil,…) are separately introduced into the preconditioner where they are continuously mixed, heated and moisturized by the injection of water and steam. The intense mixing created by the rotating double shafts adjusting paddles assembly maintains the feed particles at the optimum moisture between 20 – 23 % and temperature around 90°C during 2 to 3 minutes average retention time. Preconditioning helps to maintain starch and nutriment quality and allows increased extrusion capacity, while reducing extruder screw wear and mechanical energy requirements.

• Twin Screw Extruder / Thermo-mechanical cooking

The preconditioned feed mix is submitted to the controlled thermo-mechanical cooking which is the main stage in extruding aquafeeds.

Thermo-mechanical cooking of the feed mix in an extruder requires two energy inputs:
- Mechanical energy input defined mainly by screw speed and screw configuration which can be varied extensively to modulate this energy and,
- Thermal energy input determined by direct steam heating and indirect barrel heating.
Twin screw extruders are able to process a large range of raw materials consistently with high levels of flexibility and pumping efficiency. The intermeshing screws allow handling of viscous, oily, sticky or very wet materials and provide a very intense mixing, where macromixing and micromixing result in a very homogeneous melt with excellent lipid binding.

In a co-rotating twin screw extruder, throughput and screw speed are not interdependent; for a given formulated feed mix, the multiple operating points combine with a high control efficiency of the barrel temperature and consequently ensures efficient control of the expansion of the melt at the die.

In comparison with single screw extruder, twin screw is more responsive. By varying the cooking parameters it is possible to maintain more precise limits on product characteristics such as density to achieve floating, low sinking and sinking pellets.

Expansion can be further enhanced by injection of steam into the extruder barrel which increases thermal energy inputs. Where higher product densities are required for certain feeds, the extruder barrel can be configured to include a vent stuffer to reduce product temperature through evaporative cooling. Vacuum regulation can be connected to the vented stuffer barrel to increase the product density even further with higher degrees of evaporative cooling.

- **Texturization-shaping of aquafeed pellets**
  The end of the last barrel of the extrusion chamber is capped with a final die which serves two major functions. First, the die restricts product flow thereby causing the extruder to develop the required pressure and shear; and second, the die shapes the extrudate.

A face cutter is used in conjunction with the die, which consists of cutting knives revolving in a plane parallel to the face of the die. The relative speed of the knives and the linear speed of the extrudate result in the desired product length.

Die design —cutter assembly is one of the most important sub-units of the aquafeed processing line as it determines the physical quality of the final product.

- **Micro-aquatic feeds** often used as starters are products smaller than 2.0mm.

Specific die design allows direct extrusion of micro-aquatic feeds down to 0.5 mm. Products are pasteurized and very nicely shaped. Water stability is excellent and floating products are possible. Raw material must be carefully ground and sifted to achieve proper particle size before extrusion.

**Indication of final pellets bulk density/ floating or sinking properties:**

<table>
<thead>
<tr>
<th>Feed characteristics</th>
<th>Fast sinking</th>
<th>Slow sinking</th>
<th>Neutral floatability</th>
<th>Floating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density gr/l</td>
<td>&gt;640</td>
<td>540 - 600</td>
<td>480 - 540</td>
<td>&lt;450</td>
</tr>
</tbody>
</table>
- **Macro-aquatic feeds** with sizes up to 30 mm emphasize the physical quality of the pellet and the related process history. A combination of twin screw mixing and cooking, special Rotante drying technology and dedicated die design will produce pellets with sufficient resistance to avoid breakage and dust, yet porous enough to deliver all the nutrients to the digestive system of the fish.

**Pellet drying**

The primary purpose of reducing pellet moisture level is to make the product shelf stable. Most aquatic products are best processed at moisture levels between 20-28%. Moisture levels as low as 20% can be required for some light density aquafeed pellets. Some moisture is lost during flash evaporation as the cooked product exits the die. Then, the products are conveyed to the dryer to reduce the moisture content from 18 – 24% down to 8 – 10%, this corresponds to a water activity (aW) around 0,5 – 0,4, in order to obtain satisfactory water stability.

Several factors control the water removal from the aquafeed pellets:
- Air related factors: depending on the air flow characteristics around the pellets, temperature and humidity of the drying air.
- Pellet related factors: depending on the initial moisture content and temperature, porosity and size of the pellet.

The drying parameters must be applied to remove the moisture while maintaining pellet quality. (i.e.,limiting fine generation, maintaining palability and pigment ingredients, minimum energy losses and moisture variance).

Floating and sinking product characteristics can be influenced by the drying conditions. Elevated temperatures can lower residual moisture and improve floatability. Sinking aquatic feeds are preferably dried at moderate temperatures until the storage stability of the pellets is obtained.

In aquafeed processing lines, extruded pellets are generally dried on one of the following dryer designs:
- Horizontal belt dryer
- Vertical counter flow dryer
- Fluidized bed dryer
And recently, rotary dryer technology: the Rotante type rotary dryer was previously designed to process other cereal-based products. Through gentle stirring of the product to eliminate build-up, the "Rotante" design achieves excellent heat exchange close to that obtained in a fluidized bed. Other advantages include a perfectly controlled residence time with virtually no dispersion, of type FIFO (First In, First Out) and precise product moisture homogeneity at dryer output. To master the drying barema, temperature & moisture are precisely regulated, which helps to prevent product cracks. Clextral’s Research & Test Center in France is equipped with a "Rotante" and tests have proven this dryer to be particularly efficient for fish feed, ensuring complete homogeneity of drying with lower energy consumption.

Fat coating
Fat addition is commonly done after dryer, while the dried extrudates are still warm. For that, the oil is sprayed directly on pellets. During this stage, fats, pigments, attractants and even powdered ingredients can be added.

Species / product characteristics example:

<table>
<thead>
<tr>
<th>Species</th>
<th>Salmon</th>
<th>Trout</th>
<th>Cod</th>
<th>Carp</th>
<th>Tilapia</th>
<th>Cat fish</th>
<th>Shrimp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final pellet total fat %</td>
<td>&gt;35</td>
<td>15 - 35</td>
<td>15 - 25</td>
<td>5 - 15</td>
<td>5 - 10</td>
<td>5 - 10</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Texture bulk density</td>
<td>Slow sinking</td>
<td>Slow sinking</td>
<td>Slow sinking</td>
<td>Floating</td>
<td>Floating</td>
<td>Floating</td>
<td>Fast sinking</td>
</tr>
</tbody>
</table>
Cooling of pellets

On completion of the fat coating process, the pellets are cooled and sieved before the final conditioning. Cooling is required to remove excess heat to prevent condensation from occurring in the storage bins or the final packages. At this stage, the aquafeed pellets’ temperature should be cooled down to a temperature range close to the storage or transportation temperature.

Conclusion

Clextral systems can easily produce high energy feed, allowing a delicate balance of proteins, oils and carbohydrates, processed for total digestibility with no waste. It’s the right formula for high quality products that “turn feed into flesh.” Output range from 25 to 30,000 kg/h.

Thanks to twin screw extrusion, high quality aquafeed pellets are achieved:

- Denaturing of proteins
- Gelatinization of starch
- Reduction of anti-nutriments
- Flavouring improvement
- Protein/lipid complexes
- Increase digestibility
- Texturization, shaping
- Expansion, density
- Hygienic, salmonella-free pellets

Challenges ahead

The major challenge is to expand sustainable aquaculture to achieve enhanced food security and economic development for the global population as a whole. In the context of substitution of fish meal with plant-derived feedstuffs, extrusion technology has a role to play in reducing the level of anti-nutriments. (Kaushik 2006)

Twin screw extrusion technology has contributed and will carry on the tremendous improvements, both in terms of nutritional value and in terms of physical quality characteristics of the aquafeeds.

With the continued economic development of aquaculture, each venture, and species will be subject to important research efforts so as to obtain, under acceptable economic conditions, efficient feeds delivered at the right time, which are non-polluting and which care for the health of the fish as well as the consumers.
Leveraging its core expertise in twin-screw technology, Clextral provides its customers with turnkey processing lines that integrate extruders, dryers and ancillary equipment. Its reliable and innovative systems are quality and excellence benchmarks in its three key markets: Food & Feed, Green Industries and Powder Industries. For 50 years, Clextral has also been designing and manufacturing high-precision DKM industrial pumps for the energy and chemical markets. Its global offering includes upstream design and testing of industrial solutions, equipment manufacturing, on-site installation and full maintenance and continuous process improvement services. Based in Firminy (France), Clextral is present on all five continents, providing local support to its customers in 88 countries.