Extrusion technology for the production of micro-aquatic feeds and shrimp feeds

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Nowadays we often hear startling news such as, ‘seven billionth baby born’ or ‘world population may reach 9.2 billion by 2050’ (world news. msnbc.com). Hunger is the world’s number one health risk, it kills more people than AIDS every year, one in seven people in the world will go to bed hungry tonight.

To overcome these issues, farmers must produce 70 percent more food by 2050 to feed the population. But the impending crisis is that the earth may run out of food by 2050. 2.4 billion extra people, no more land, how will we feed the world in 2050!

At the same time we also hear in the news that global fish consumption has hit a record high. We have seen the commercial fishing trend is declining whereas aquaculture farming is growing rapidly all over the world.

Is this supply enough to feed the future population? May be not, but fish demand is growing every day all over the world. To maintain baseline consumption in every country, 159 million tons of fish is needed to feed the world population in 2030. This demand is driven by population and income growth.

If a country’s aquaculture production follows the recent trend, the expected aquaculture growth rate will need a four percent increase annually. To feed a growing world population, the required aquaculture growth rate is 5.6 percent annually.

Some of the main challenges to achieve these goals are proper and large-scale feed production systems for micro aquatic feed. Recently extruder manufacturers came up with new technologies which can solve some of the aquaculture issues related to large and commercial-scale feed, which is the key for growth of aquaculture industry. The fundamental components of extrusion systems have consisted of the following items for a number of years:

1) Feed delivery system
2) Preconditioning
3) Extruder
4) Die and knife assemblies

Although existing extrusion systems were able to produce a wide range of good quality aquatic feeds, the fundamental components of extrusion systems have consisted of the following items for a number of years:

Feed delivery system

Hoppers or bins are an integral part of a feeding device and are used to hold the dry ingredients above the feeders. The feed delivery system must be able to uniformly feed both a dry and/or liquid ingredient or a blend of ingredients.

Generally, when the added fat content of a raw formulation exceeds 12 percent, the portion of fat above the 12 percent level should be introduced into the extrusion system in a separate ingredient stream. The dry feed portion is delivered to the extrusion system through a specialised metering device capable of providing uniform flow at any desired extrusion rate.

Dry ingredients are usually free flowing, and there are a number of capable feeding devices which vary in their relative cost and complexity. However, gravimetric or loss-in-weight systems are necessary for the stable, precise metering of dry feed for the production of micro-aquatic feeds. The raw recipe is very finely ground or pulverized and does not possess good flow properties. The feed system must be able to handle these finely ground formulations and avoid bridging and non-uniform metering of the feed.

Automated feed delivery systems with PLC control are the norm. Slurry tanks and liquid feeding devices (pumps) are utilized to accomplish uniform metering of liquid ingredients. The slurry tanks are often jacketed for heating or cooking and are equipped with agitators as required. Positive displacement metering pumps deliver metered liquids at constant rates by varying length of stroke or speed of rotation. Slurries or liquids can be premixed with dry ingredients but are preferentially injected into preconditioning devices or the extruder barrel. The nutrient profile of larval feeds is critical and the precise metering ensures correct formulations.

Preconditioning

The dry portion of the feed and the liquid portion are separately introduced into a preconditioning device where they are continuously mixed, heated, and moisturised by the injection of hot water and/or steam. The intense mixing of water and steam added to the dry feed and the ability to extend the retention time during the preconditioning phase allows the moisture level to be maintained at an optimum.

This ability to maintain optimum moisture distribution not only initiates proper cooking but also is reported as a significant factor in the reduction of extruder barrel wear and extruder shaft power per ton of product processed. The higher mixing intensity of new preconditioner designs improves hydration and cooking, helping to capture the steam in the raw material. Excess steam can escape the preconditioner and create fugitive dust which creates housekeeping concerns in the plant environments.

Better cooking with new precondition-
Extruders give lower product viscosities which improves extrudate flow through small die orifices. The result is smaller pellets and more uniform pellet size. The higher mixing intensities in new preconditioner designs is the result of unique beater designs and more beater contacts per retention time.

Water, an excellent plasticizer, is typically injected into the barrel in the feeding zone to facilitate textural development, viscosity development, and to enhance conductive heat transfer. The kneading zone of the cooking extruder continues the compression started in the feeding zone, and the flow channels of the extruder screw have a higher degree of fill.

Extrusion

Extruders are generally classified as either being a single or twin-screw design. In both designs, the impact of final product characteristics are affected by screw and barrel profile, screw speed, processing conditions (temperature, moisture, etc.), raw material characteristics, and die/knife selection.

The feeding zone of the extruder is that area where the low-density discrete particles of raw material are transported into the extruder barrel inlet. This low-density, often preconditioned, material is then transported into the interior of the extrusion processing chamber. The flow channel of the screw is typically not filled in this zone due to the air entrapped in the incoming material. The incoming material is compressed slightly in this zone with the air being expelled.

As the degree of screw fill increases and pressure begins to develop in the extruder barrel, leakage flow (flow over the outside diameter of the screw in a direction toward the extruder inlet) and pressure flow both...
The mechanism of shear does not begin to play a dominant role until the screw flow channel is full. This full flow channel condition begins in the kneading zone.

The flow channel fills, first, with loose granular material which is compressed and worked by shear as it passes through the kneading zone. It is in the kneading zone where the discrete particles of material begin to agglomerate because of their temperature increase resulting from conduction, direct steam injection, and viscous energy dissipation. Here, the discrete particles begin to form a more integral flowing dough mass.

At the discharge end of the kneading zone, the extrudate most typically reaches its maximum compaction. The shear in this area of the extruder barrel is moderate and the extrudate temperature begins to increase. The final cooking zone is that area where amorphousizing and texturing occur. Temperature and pressure typically increase most rapidly in this region as shear rates are highest because of the extruder screw configuration and maximum compression of the extrudate. The pressure, temperature, and resulting fluid viscosity are such that the extrudate will expel from the extruder die to form the desired final product texture, density, color, and functional properties.

Twin-screw systems are preferred for extrusion of aquatic feeds smaller than 2 mm diameter due to their positive transport and self-wiping characteristics which prevents significant product build-up in the extruder barrel which could later dislodge and plug the small die orifices. The CXT system is a co-rotating system that includes a tapered screw diameter which de-erates the extrudate and makes it easier to create high density feeds for good sinking characteristics without the need for vented barrels, pressurized density control devices, or double extrusion. By adding a BPV (Back Pressure Valve) after the extruder, the necessary restriction is provided to expand the product if floating pellets are desired.

Die assemblies

The die is the most critical part of the complete system as it determines product shape and size, but also determines throughputs and buoyancy properties of the final aquatic feed. As pellet diameters became smaller, the die created more restriction and drastically reduced throughputs.

One die assembly design that allowed an increase in throughputs by increasing die open area is the ODT (Oblique Tube Die). This die actually increased die open area (the number of orifices) by two to three times which maintained high throughputs even for small diameter products due to larger die hole populations. The tubes created longer retention times for improved cooking. Pressure drop in the tubes created a denser product so that micro-aquatic feeds could be cooked thoroughly but still maintain high densities for sinking characteristics. The process was still a short time/high temperature process, which minimised nutrient destruction. Floating products are possible by simply decreasing die open area.

Process guidelines

Process guidelines required for die holes smaller than 1.2 mm diameter:

1) Recipe to contain adequate starch levels for binding (at least 25% starch for floating feeds).
2) Maximum particle size of the recipe must be smaller than one third the die hole sizes.
3) A spring-loaded knife blade is recommended.
4) All mass flow inputs must be free of material that is large enough to block or partially block the die openings and this includes the steam, water, fat, and other liquid inputs. The water and steam lines going to the extruder system need to be fitted with screen filters having 30 mesh (0.6 mm) openings and these should be adequate if maintained. The fat line (and fat source) also needs to be filtered to remove debris larger than 30 mesh (0.6 mm). All strainers or filters must be easy to clean or they will get removed ‘in the heat of a run’ where liquid flows are interrupted due to plugged filters. It may be necessary to have a dual filter set up for fish solubles and fat lines. With this installation, if one filter is plugged you can close the valves to the primary filter for cleaning and open the valves for the second for continued operation.
5) The dry feed must pass through a vibrating sifter after the grinder and before the extruder live bin. This sifter must be sized to remove particles of the same size or larger than the die openings. High fishmeal diets plug vibrating sifter screens very easily and the industry often employs rotary sifters to avoid this bottleneck.
6) Pneumatic conveying is required from the extruder die to the dryer inlet for several reasons:

   a) For product containment around the die/knife area. The small diameter feeds results in spillage in this area and will cause sanitation problems.
   b) For product separation. Floating feeds have a tendency to stick together when wet on belt or HVH conveyors and pneumatic conveying enhances separation.
   c) For separation of ‘tails’ from pellets. Pneumatic systems ‘scrub’ the product and remove tails for later separation during sifting.
   d) Fluid bed dryers are recommended for products under 1.2 mm diameter in size although horizontal dryers with polyester screens can work with some products.
   e) Final product sifting after dryer and before coating. This sifting operation is critical for three reasons:
      a) To remove ‘overs’ (large tails and ‘doubles’) for regrind.
      b) To remove ‘fines’ for regrind. This prevents a mess during coating step where the fines are also coated and cause build up.
      c) To separate good pellets into several different diameters depending on the client criteria for size. The expectations from the industry will be for tight specs on pellet size and this can easily be controlled at this point by sifting product and producing several different sizes at the same time and setting the standard for the industry. The primary-sized product can be sent on through the system for coating and into final product bins. The secondary sizes can either be reworked or saved separately in tote bags for coating and bagging later.
   f) Production procedures. This small diameter product requires a dedicated line, strict startup and shutdown procedures to avoid die plugging, and thorough cleanup techniques. The extruder and coater areas should be considered as ‘wet areas’ for cleaning. The coater may need to be cleaned between each different pellet size to avoid cross contamination.

By following these guidelines and using newly innovative extruder parts micro-aquatic floating feed can be produced on a large scale basis. This micro-aquatic floating feed will be the foundation to start fish farming on commercial scale to fulfill the fish demand in the world.