What would my response be when asked by neighbors what is it that I do for a living? “Extrusion cooking of course, which is the process where expandable biopolymers, such as protein and starch, are plasticized in a tube by a combination of heat, shear and pressure resulting in the denaturation of the protein, the gelatinization of the starch and the exothermic expansion of the extrudate.” In any case, an extruder is a machine where the sum of the inputs results in the final output, which happens to be, in this case, aquatic feeds. These inputs or dry raw materials, such as cereal grains, fishmeals, vegetable proteins, minerals, water, steam and other liquid and/or dry ingredients, all need to be introduced in the process in an even manner so that continuous and predictable results are obtained. Exacting density, expansion rates, shape and other product characteristics of the desired feeds require precise inputs that will lead to predictable results. Let’s review the aquatic feed process and how the tools have changed to accomplish the task at hand.

The preparation of the dry raw formula requires grinding the to a fine even particle size suitable for the diameter aquatic feed being produced. The dry feed is normally metered into a preconditioner by a feeder screw and live bottom bin that yields an accurate and even flow of that portion of the mix. The preconditioner function gives the final preparation to the feed mix prior to extrusion. The device homogenizes the dry and liquid ingredients typically into a free flowing moistened and heated powder that flows into the extruder barrel. Additional liquids can be introduced into the extruder barrel as well, if desired. The extruder barrel can manage the variety of characteristics required for a full range of aquatic feeds by extrusion cooking.

Extruder manufacturers are required to constantly stretch the limits of what can be made with their equipment. Levels and sources of proteins in the formula, starch levels, final fat levels, stability in water, floatability and densities are all typical characteristics that are defined for each product. These may require not only formulation changes but also system changes for different style aquatic feeds. In addition, in some aquatic feed plants the changes take place hourly. Control of the variables and the need to manage them easily, coupled with reduced down time for equipment changes, can justify a review of the possibilities available for a multiple purpose plant or for improvements for specific defined processes.

Table 1. Vegetable Proteins in Salmon, Trout and Shrimp Diets.

<table>
<thead>
<tr>
<th>Vegetable Protein Source</th>
<th>Max. Substitution for Fish Meal (%)</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize Gluten Meal</td>
<td>40</td>
<td>Yellow Pigmentation of Flesh</td>
</tr>
<tr>
<td>Wheat Gluten Meal</td>
<td>25</td>
<td>High Cost</td>
</tr>
<tr>
<td>Soybean Meal</td>
<td>50</td>
<td>Palatability and Growth Inhibitors</td>
</tr>
<tr>
<td>Soy Concentrate</td>
<td>75</td>
<td>High Cost</td>
</tr>
<tr>
<td>Canola Meal</td>
<td>67</td>
<td>Low Protein Content</td>
</tr>
</tbody>
</table>

( Hardy 1999)

Equipment manufacturers need to point out the needed changes in the equipment for the reduction of fishmeal and increases in vegetable protein levels inasmuch as the equipment does require processing those ingredients differently. The variety of aquatic feed characteristics vary greatly, the possible ingredients are include a range of diameters from 0.8 mm sinking and 0.8 mm floating feeds up to 30 mm and sometimes larger diameter feeds. Feeds in the 300 micron range are produced in the Extru-Tech Sphere-izer Agglomeration System™. Semi-moist feeds are also produced and seem to be gaining use in selected aquatic feed areas, such as for sea urchins and abalone. There is a tremendous variation in feed ingredients around the world, but the pointed decline or flattening in fishmeal availability is considered a global problem. Hardy (1999) pointed out the possible substitution levels of various vegetable protein sources and the possible disadvantages of their use in salmon, trout and shrimp diets as seen in Table 1.
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also in constant flux for a number of factors. Why then should the machine not have a few additional advantages in its tool box for the just right application?

Obviously one of the biggest topics in aquatic feed production is density. To get a better idea of what is meant by this topic, the buoyancy properties chart in Table 2 defines aquatic animals by feed floatation properties. Some of these animals are saltwater species and others freshwater species. There is a difference in buoyancy of feeds in salt and freshwater. In seawater at 20°C at 30 ppt salinity, feeds float right at 480 g/L, whereas they need to be 440 g/L to float in freshwater at 20°C. Conversely, fast sinking feeds need to be 640 g/L in the same salinity saltwater and 600 g/L in freshwater. This would be the density of the finished feeds, not the feed as it exits the extruder. Production is required to make the adjustment to the density needed based on the level of coating to be applied following extrusion.

Having mentioned the density or buoyancy of feeds with regard to fat coating levels, Table 3 illustrates the importance for sinking feeds as it indicates the various standard fat ranges seen, as well as the associated densities needed to achieve those levels with additional related standard extrusion parameters. An important factor when coating feeds with elevated oil levels is the ability of the feed to retain the oil. The moisture level during extrusion, as well as the amount of energy imparted into the process in the form of specific mechanical energy (SME), has a big effect on the fat levels applied. The importance of density and SME allows for the control of floating/sinking properties, pellet durability for feeding or handling and transportation devices, attractive pellet appearance in terms of shape and size, proper fat absorption characteristics and the effect of rapid water absorption while maintaining pellet integrity.

In looking at the mechanical devices developed to easily control and simplify the production and maintain the characteristics in a range of feeds by extrusion cooking, preconditioning is an aspect that must be mentioned. This is because the variations in the raw materials used in aquatic feeds has resulted in the need to understand the various moisture levels required for the various protein sources now being used or considered. Water and steam were always added in a controlled fashion, but the effectiveness of the additions was based on the retention time in the conditioner. The development of retention time controlled preconditioning is based on load cells and computer controls. Known inputs into the cylinder, coupled with a controlled discharge device, results in the retention time being adjustable on line without mechanical down time.

The extruder barrels for both conventional twin-screw designs, as well as singles, have also received some attention, mainly because of the increased SME requirements and the styles of cook now used for aquatic feed production. Extruder configurations have evolved with new rotating element designs to transmit the additional energy required into the feed mix. Beefed up drives to handle the additional power inputs allows for the higher SME required diets at maximum capacity. Development and acceptance of high horsepower variable frequency drives has also given the process an additional variable allowing speed changes that, when increased, impart higher levels of specific energy and the opposite when the speed is reduced. When used within reason, it allows for expansion or density control.

(Continued on page 69)
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There are many possible adjustments on an extruder that allow density control. Most require stopping the equipment for mechanical changes. Balancing the extruder barrel design with the use of back pressure valves (BPV) and/or what is referred to as the mid-barrel valves (MBV) allows for adjustments during extruder operation to overcome variable parameters. Extruders have always had methods of disrupting the flow of material to increase the shear or energy inputs. The two in-barrel valves allow for adjustment easily and quickly by the operator to provide pellets of the density and internal cell structure control needed by the aquatic industry today. They simply are great aids in the operation and reduction of down time caused by ingredient fluctuations or equipment wear.

The effect of the MBV when operated at 50 percent closed achieves a wet density of 400 gm/L with 28 kWh/t into the feed. Simply by closing the valve to 92 percent, the density goes down to 279 gm/L and 55 kWh/t imparted into the feed.

The BPV is presently the valve of choice because of the numbers working in the field and the quick response seen as it is mounted directly behind the die plate. The BPV photo shows a negative pneumatic hood and the BPV hinged off a support structure for ease in use.

Another technology is the mid-barrel atmospheric vent, which can be used in conjunction with a product retaining screw and possible vacuum assist. This technology has been selectively used on feed pellets for some tuna feeds because of the diameter, oil levels and reduced fines generation.

The external density management system (EDMS), as shown in Figure 6, is a device that also mounts on the end of an extruder barrel and assists in controlling the density of sinking feeds. In the photo, the extruder barrel feeds a back-pressure valve with a pressure vessel mounted above a discharge airlock. There are a few designs available, but the one discussed utilizes this combination of BPV technology mounted on the extruder barrel before the pressure vessel. The BPV allows independent adjustment of the energy input and cook level before passing through the actual die enclosed inside a small pressure device with a rotary vane discharge and controls to maintain a selected pressure. The basis of this design is the fact that water does not boil at elevated pressures. Expansion occurs when the product with superheated water exits the extruder die. The water immediately changes phase from a liquid to a gas inside the pellet causing expansion. The increase in pressure around the die keeps the water from changing into steam and, thus, expansion is controlled and the pellet is formed and set before exit from this area. The result is a higher capacity sinking feed with lower moisture levels out of the extrusion cooker than what occur without this device. The technology is used mainly for pellets such shrimp feeds that require long water stability. Additional technology for even higher production levels of extruded shrimp feed exists and approaches 10 to 15 t per hour. This requires the use of a PDU or product densification unit.

Methods to control density and specific mechanical energy inputs also result in cell structure development as well as cell size control. The comparison of the four photographs seen in Figure 7 shows the effect of increasing the specific mechanical energy in a feed formulation. Notice that as the energy input increases as shown on a percentage increase basis from 0 to 40 percent, the size of the cells themselves decrease and cell numbers increase.

The use of twin-screw extruders with increased power and torque capabilities are becoming popular with aquatic feed producers for the range in diameters, ingredient flexibility, increased rpm and horsepower inputs that can lead to significant increases in production capacity. The production range with four extruder sizes start at 300-7,500 kg/hr and the same models have expanded the range to achieve 1,700-22,000 kg/hr. This allows the cost for use of twin-screw extruders to come down inasmuch as a smaller model can be used to provide the production of what larger models formerly produced.

Additions to extruders as described, combined with balanced extrusion systems in terms of preconditioning and extruder barrel designs, have greatly reduced the change over time in multiple use feed productions facilities. These factors also can greatly increase the production capabilities of single product production facilities. Various methods exist to perform many of the same functions as outlined above. Matching the production method consumer requirements results in greater tonnages produced more efficiently with lower waste over a broader product variety.

Notes

1Skretting Australasian Aquaculture Conference, Adelaide, South Australia, 2006
2Wenger Manufacturing, Inc., Sabetha Kansas, USA

References


Gulf of Mexico plan delayed

The Gulf of Mexico Fishery Management Council’s plan for development of a management plan for aquaculture in the Gulf of Mexico still awaits approval from the National Oceanic and Atmospheric Administration (NOAA), a situation that has gone on for several months. The effort may be delayed further now that opponents to the plan have enticed several Congressmen to write NOAA expressing their concerns that approval of the plan will lead to degradation of the environment in the Gulf.