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Aquatic Feed Production Technology

Vijayagopal, P.
Marine Biotechnology Division, CMFRI, Cochin - 682 018, vgcochin@hotmail.com

Introduction

Aquaculture feed technology evolved with the intensification of this food production system. There are wide varieties of methods that can be used to process aquatic feeds. For example, in early days the most common method to feed the fish was hand feeding of mixed, home- blended diets and trash fish. Then fish farmers started using cold forming of moist diets. Pelleting presses then became popular and a majority of the fish feed were processed using pellet mill technology. Shown below is the traditional method of dough ball making practiced in India.

Pelleting

In order to understand the pelleting presses the figure given below is self explanatory. The ingredient mixture falls on to a continuous spiral. A screw forces the feed against a knife and this knife rotates against a fixed die plate. Feed this forced through the die comes out as a compact pellet.

The components of a wet feed mincer/grinder/pelletizer are shown below.

Thus, pelleting is defined as an extrusion type thermoplastic moulding operation wherein finely divided particles of feed are packed into a compact pellet. It is thermoplastic because the protein and sugar of feed ingredients become plastic when heated and diluted with water (moisture). Extrusion is versatility inbuilt into the pelletizer which involves a cooking process where the major macronutrients viz., protein and starch gets cooked in such a way to from an inflatable gel.

Extrusion

Extruders are basically screw pumps through which feed mix forced is subjected to heat, pressure and shear forces. Extrusion is a process, which combines several unit operations including mixing; cooking, kneading, shearing, shaping and forming. The two factors that most influence the nature of the extruded product are the operating conditions of the extruder and the rheological properties of the food. The most important operating parameters are the temperature, pressure, diameter of the die apertures and shear rate.

The array of machines available is mind boggling due to their applications in food industry in general; and the array of value added food products produced are limitless.

Extrusion with steam preconditioning is known as wet extrusion and extrusion without steam preconditioning is called dry extrusion. Dry extruders were solely designed for processing soybeans, which inherently had sufficient oil to act as a lubricant during extrusion. Later, steam preconditioning

prior to extrusion was shown to improve the processing efficiency and product versatility. This lead to what is technically called 'retro-fitting' of dry extruders with steam conditioners. Thus, a clear distinction between dry and wet extrusion is absent today.

Extruders can also be classified according to the method of operation (cold extruders or extruder cookers) and the method of construction (single- or twin-screw extruders).

Twin screw extruders Twin screw extruder is a better design where one screw wipes out the cavity of the other screw thus ensuring positive displacement of feed materials though the barrel preventing burning out of products prevalent in single screw extruders. Moreover, a single screw extruder requires more moisture in the feed mix to make it move through the extruder barrel which results in residual moisture in the extruded product requiring elaborate drying utilizing higher energy. In a twin-screw extruder, lower moisture content in feed ensures less moisture in the extrudate requiring no or short drying.

Current aquatic feed manufacturing practices seem to fit into two simple categories; floating and sinking. Today 100 percent floating feed is extruded and nearly 60 percent sinking feed is extruded. Whereas, the rest of the 40 percent sinking feed is still pelleted. This is just simply because extrusion cooking offers several benefits to the aquatic feed manufactures. Following is the brief description of the advantages of the extruded feed.

Hygienic quality of extruded feed

Ingredients are cooked at high temperatures and pressures. Therefore, extrusion cooking provides hygienic processing of feed destroying the pathogens and most viruses and reducing the toxin levels in the feed ingredients. Growth inhibitors, allergens and other anti-nutritional factors largely inactivated during extrusion cooking.

Option of producing floating or sinking feed

There are many aquatic species that are cultured today. Some of them prefer to eat the pellet on the bottom of the pound where as some of species like to come on the surface to control of the density of the products and thus buoyancy properties are managed.

The use of wet material in the pellet

Extrusion allows raw aquaculture wastes and undercooked waste to be used in final feed without any problem. There are closed loop systems designed for recycling wet product with extruders. These systems allow us to use wet slurries at levels ranging from 22 to 42 percent (as a percentage of the dry recipe) depending upon the moisture contents of the slurries in single screw extruders. In a twin-screw extruder, addition of wet slurries can be as high as 60 percent depending upon the final moisture contents of the wet slurry. Extrusion allows raw aquaculture wastes and undercooked waste to be used in final feed without any problem. A reclamation system to recover wet, under-processed product that cannot be recycled through the dryer as dry rework are available to be used in extrusion processing. These are closed loop systems designed for recycling wet product with extruders. These systems allow us to use wet slurries at levels ranging from 22 to 42 percent (as a percentage of the dry recipe) depending upon the moisture contents of the slurries in single screw extruders. In a twin-screw extruder, addition of wet slurries can be as high as 60 percent depending upon the final moisture contents of the wet slurry.

High fat pellets

Extrusion processes allow feed manufacturers to produce high fat feed. With twin screw extruder a 20 percent fat can be added during extrusion of feed. Whereas, in a single screw extruder, it is limited to around 12 percent fat addition during extrusion. Additional fat is added to the pellet using different coating systems (vacuum or atmospheric). Extruded feed can absorb more fat externally in the coating steps as compared to pelleted feed. Nowadays aquatic feed is processed to contain almost 50 percent fat which is only possible by using extrusion technology. The main purpose of lipids (fats and oils) in feeds are as an energy source; to increase palatability; provide essential fatty acids; carrier for fat soluble vitamins; modified texture; density control and dust reduction. Fat level in fish diets can vary depending upon the species of the fish.

The buoyancy properties required in the feed for common aquatic species cultured is shown in the Table below. And their bulk density indices are also shown

Buoyancy Properties of Feed for Common Aquatic Species (Modified from Riaz 2009)

Floating	Slow-sinking	Sinking
Carp	Seabass	shrimp
Catfish	Grouper	crab
Koi	Cobia	
Tilapia		
Milkfish		

Final Product Bulk Density Correlation with Buoyancy

Properties

Pellet buoyancy Sea water @ 20ºC (3% salinity)
Fast sinking > 640 g/l
Slow sinking 580-600 g/l
Neutral buoyancy 520-540 g/l
Floating <480 g/l

Size of the pellets and water stability

Through extrusion pellets of sizes varying from less than 1 mm to 10 mm in diameter can be produced. Extrusion moisture content during processing can be controlled over a wide range, which helps to increase the water stability of the final feed. These pellets absorb more water, retains shapes for longer time and results in reduced losses of nutrients. Water Absorption and integrity after hydration is very important. It benefits pellet technical qualities and fish health.

Mechanical resistance of pellets

Feed made using extrusion technology is more resistant to mechanical durability and produces fewer fines in the finished feed during transportation. Extruded feed has an internal matrix system which tends to increase resistance to mechanical handling of feed. Extruded feed produces approx one-to-two percent fines in the finished products during bulk handling, where as pelleted feed normally generates five-to-eight percent fines during handling in bulk or bag form. Extrusion reduces 75

percent of the amount of fines which normally enters the water and ends up decaying on the bottom of the pond. In other words, fewer fines means: increased water stability; clearer ponds; lower fatality rates; less unde- sirable bacteria growth; increased is not going to eat 10mm pellet since the size of the pellet is bigger than the mouth.

Water stable pellet

Pellets that break down quickly in water will lose nutrients. Some farmers hydrate feed in water and nutrient solution prior to feeding and require rapid and excellent water stability for handling and feeding purposes. Pellets that breakdown quickly in the stomach of fish loses nutrients (during regurgitation) and may contribute to GDAS (Gastric dilation and air sacculitis) in certain species.

Manufacturing soft aquatic pellets

Some species like blue fin tuna prefer very soft pellet. Extrusion processing allows us to make a very soft pellet (moisture content up to 30 percent in finished feed), which is not possible by pelleting or other methods. This is accomplished using a preservation system in aquatic feeds (final product moisture of 16-28 percent) during extrusion processing. Lower Aw, (water activity) below 0.70 can be controlled with humectants at 10-12 percent levels and by reducing pH to 4.0-4.5 with acids at 1-2 percent levels or with fish silage/solubles. Mould inhibitors are also added at 0.2- 0.5 percent level in the formulation. Recent developments indicate that soft, gel-like aquatic pellets can be processed by coupling alkaline extrusion with a post- extrusion acid bath to adjust ph and set or 'firm up' the texture and pellet integrity.

According to Riaz (2009) the aquatic feed industry is further complicated by the presence of multi-national firms who will often know what extrusion process is required for their production strategies. Their requirements may not always fit the categories outlined above. Another group of aquatic feed producers that will have unique processes are those that manufacture starter feeds. These extrusion systems will be very specialized and often dedicated to the production of smalldiameter feeds. They also require several add-on's listed below.

- VFD (Variable Frequency Drive)
- DMS (Density Management System – vented head, stuffer, vacuum system)
- MBV (Mid-Barrel Valve)
- BPV (Back Pressure Valve)
- EDMS (External Density Management System)
- PDU (Product Densification Unit)
- SAS (Spherizing Agglomeration System)
- Some of these add-ons can help the feed industry make floating, sinking, and slow sinking feed on the same extruder. The following is detailed information for some of these add on equipments.

Back pressure valve

Final product characteristics such as density and texture can be controlled by extruder die restriction. The extrusion industry has developed the revolutionary back pressure valve (BPV) to adjust die restriction while the extrusion system is in operation. By changing the restriction at the discharge of the extruder during operation, the aqua feed density can be varied by up to 25% without changing the screw configuration or the final die. The variable opening BPV is mounted on

the end of the extruder prior to the final die. Specific Mechanical Energy (SME) and extrusion pressure are process parameters controlled by valve positioning. The BPV provides internal control of shear stress and SME for regulation of important product properties:

- Bulk density
- Size and uniformity of cell structure
- Starch gelatinization
- Shape definition
- Water and fat absorption

The BPV also reduces the need for altering the extruder configurations between different aquatic feed families. An integral part of the BPV is a by-pass feature to divert product from the die/knife assembly for service and start-up/shutdown procedures which also improves sanitation in this area.

Mid-barrel valve

Extrusion companies came up with the idea to install a valve in the middle of the extruder barrelto serve as an adjustable restriction device for controlling shear stress and SME during extrusion of aquatic feed. The name of this valve is mid-barrel valve (MBV). The MBV can be adjusted from a setting that adds little or no restriction to a setting that can almost completely restrict the passage of the extrudate, and has demonstrated SME increases of 100% or more. Insertion of this on-line valve can greatly enhance the flexibility of the extrusion process without the downtime associated with configuration changes. A mid-barrel valve can also be connected to the extruder control system to automatically adjusted and maintain the SME valve to its desired set-point in order to make pet food with a wide range of bulk densities.

SAS

In the sphereizer-agglomeration system (SAS); a uniformly mixed and pulverized formulation is passed through a low shear and low temperature extrusion process where it is conditioned with steam, water and other possible liquid additives and compressed through a special die to form extruded strands. These strands when transported into a sphereizer by cyclonic motion sizes and shape the strands into pellets with lengths about the size of the strand diameter. Through SAS™ feeds in the size range of 0.3 to 1.2 mm can be produced. Low processing temperature minimizes nutrient damage and favours production of medicated feeds and utilization of other temperature sensitive ingredients. However, the main disadvantages pointed out are, no pasteurization and capability to produce only sinking pellets.

According to experts, the global aquatic feed market is expected to grow by over six percent per year. This estimate is based on feed sales of 21,000,000 tonnes/year in 2005. The global aquatic feed market is expected to be 28,000,000 tonnes by 2010. (Form www.andritzsprout.com **andritzsprout@andritz.com)**

Suggested Reading

Riaz M.N. 2009 Advances in aquaculture feed extrusion. 17th Annual ASAIM SEA Feed Technology and Nutrition Workshop, June 15-19, 2009 f& Imperial Hotel f& Hue, Vietnam

Riaz, M. N. 2009 Benefits of using extruders to process aquatic feed. Interantional Aqua feed. March – April 2000