New Developments in Aquafeed Production by Extrusion

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Aquafeed industry developments continues with trends towards the use of alternate ingredients, with new protein sources of the most interest. The specification of these ingredients can be important based on the overall formula with grinding and sifting closely behind. In most cases the industry is interested in flexibility of the production line, equipment which is versatile and can make many kinds of aquatic feeds. There are special cases where the aquatic feed is more commodity driven and thus specialized high capacity equipment is preferred. High capacity aquatic feed production is greatly enhanced with improved end of the extruder die designs. If the goal is to be specific in production of product characteristics then the use of improved ancillary devices which allow for fine adjustments or control of the operating conditions should be considered. In-Line data gathering and the use of this information greatly assists in the control of the operation as well as data logging of the results.

Ingredients are not all alike and variations can occur within a given ingredient classification. Functional ingredients are of interest, ones that are extruder friendly, allow binding and other characteristics when extruded. The industry is looking for ingredients with lower cost and a nutritional benefit. It might also be said that a good predicable filler is of interest for the lower protein level feeds. An example would be wheat middlings with a constant starch level. Insect meal, single cell proteins, local indigenous ingredients and by products usage is growing and developing. Actually you could say the above ingredient topics are centered around simply using the extruder as a tool with its ability to handle a wide range of ingredients while achieving a profitable feed for you and your clients.

Protein, fat, fiber, vitamins and minerals are in all basic feed formulas. Proteins specifically have characteristics and can be modified during their processing prior to being received at the feed mill. In some cases, these modifications are not fully desirable, depends on the total formulation. Proteins with a higher PDI, Protein Dispersibility Index, are extruder user friendly. The formula might not need all premium proteins but the degree of need will be dependent of the balance of the formula if you desire a formula that is easier to produce. Easier is defined as higher capacity at lower energy usage but the cost needs to be evaluated as the easier to produce proteins are usually also higher in cost. Does the reduction in energy or increase in capacity justify a review of ingredient quality?

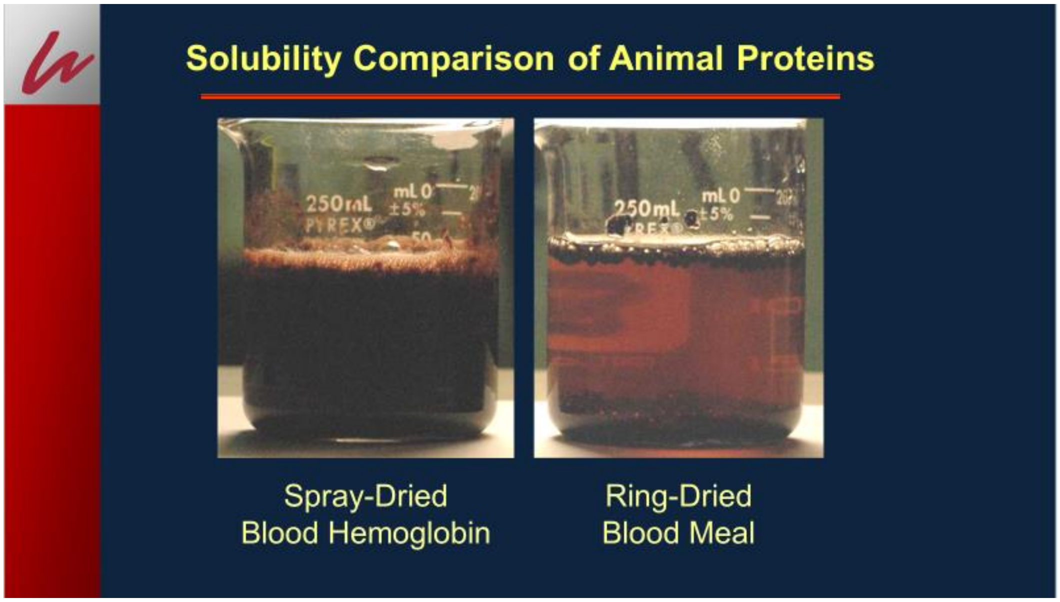

Photo 1: Example of protein quality, spray dried is more soluble or functional.

Fat is an ingredient to watch in extrusion processing. The level in the extruder during processing either added or indigenous can alter density and increase the need for energy for proper production. In some examples, salmon feed, extreme levels of fat or oil are added after extrusion. 20 to 50% as an example and this range of fat levels require the extruder to be able to handle densities and cell structure to hold the various levels of fat and sink slowly.

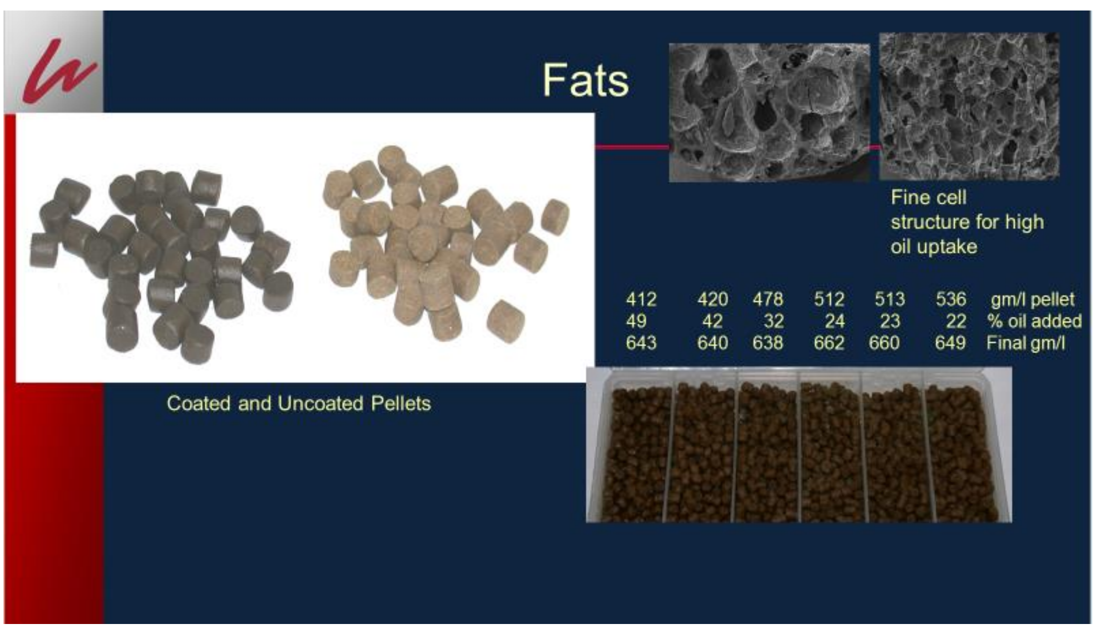

Photo 2: Pellets coated and uncoated, cell structure example for high oil uptake and various density raw pellets with correct cell structure can pick up various oil levels and all be sinking densities.

Ingredient processing post mixing is usually some sort of grinding. Hammermills and or micro grinders are usually the selection. The idea is to have a fine enough grind for the animal or its age and appropriate pellet size. This might not only be for the animal but the farmer as well as the homogenous appearance when fine grinding is used is obvious. Hammermills can and are used very effectively in the industry for various species. In fact, hammermills usually are used before a micro grinding step for the micro feeds and for the smaller diameter feed requirements. Sifting is an additional step highly recommended for the micro feed categories.

Photo 3: Difference in finer grinding, product on right looks better and is of lighter density. Finer grinding give versatility in running for desired densities.

Flexibility in extrusion equipment is a topic in many areas. There are many different types of aquatic feed based on species, pellet size, the formulation and buoyance in general. These coupled with throughput, energy input needs, desired quality and versatility require a specially designed extruder if this is your goal or make all the required feed styles with one machine. Extruders can be optimized for individual products or built for flexibility. The investment for one machine to make all feeds can be justified in many areas but often the cost advantage is to use designed machines for a specific product for maximum production. Four examples of styles of machines. Large single screw extruders are quite accepted in the floating carp, catfish, tilapia, sea bass and sea bream areas based on volumes needed and the business model of that area. Thermal twin extruders are designed for high level moisture feed ingredients. High levels of added slurries from aqua and or terrestrial animals and other liquids as well.   Conical co rotating extruders have shown that their specialty is making small diameter floating and sinking feeds, as in 0.5mm and above. Specifically designed large twins have been effective in the areas where several different styles of feeds are required. From high capacity, small diameter floating and sinking as well as shrimp feeds and a range of other marine aquatic species. The conditioner, barrel design, cutting and shaping as well as all the controls give the range of operations generating the flexibility.

Ancillary items coupled with extrusion cookers are devices where the added benefit justifies the use. In aquatic feed production one of the most important characteristics is the product density. The use or development of density control devices such as the back-pressure valve have been very successful in its use to change product density as the machine is running. The device quickly allows pressure to be developed inside the barrel directly behind the die. Initially this device was manually operated and is still today on manual style machines. Advancements with In-Line measuring devices of product specifications with practically instantaneous information allow the connection of the devices to computers for added control. Density can be computer controlled with a feedback control loop greatly effecting production as reduced rework from constant density monitoring with feedback control loops to maintain the set point. Additional devices also effecting profits is the Waste Recovery System (WRS) and optionally a tank and pump for adding liquid additives, for nutritional reasons and or operational assistance. The WRS system is designed to allow the operator to take the startup and shut down waste and reintroduce it into the system in a controllable flow liquid stream. At approximately 500.00 US per ton ingredient cost, it is estimated in a normal aquatic plant changing products multiple times a day running at 20 tons per hour will have around 3 to 4,000 kg of wet product to handle daily. This is 1500.00 to 2,000.00 USD value in ingredients returned to conditioner and back into the product at the site of the waste development, the extruder, instead of other more costly waste product handling systems.

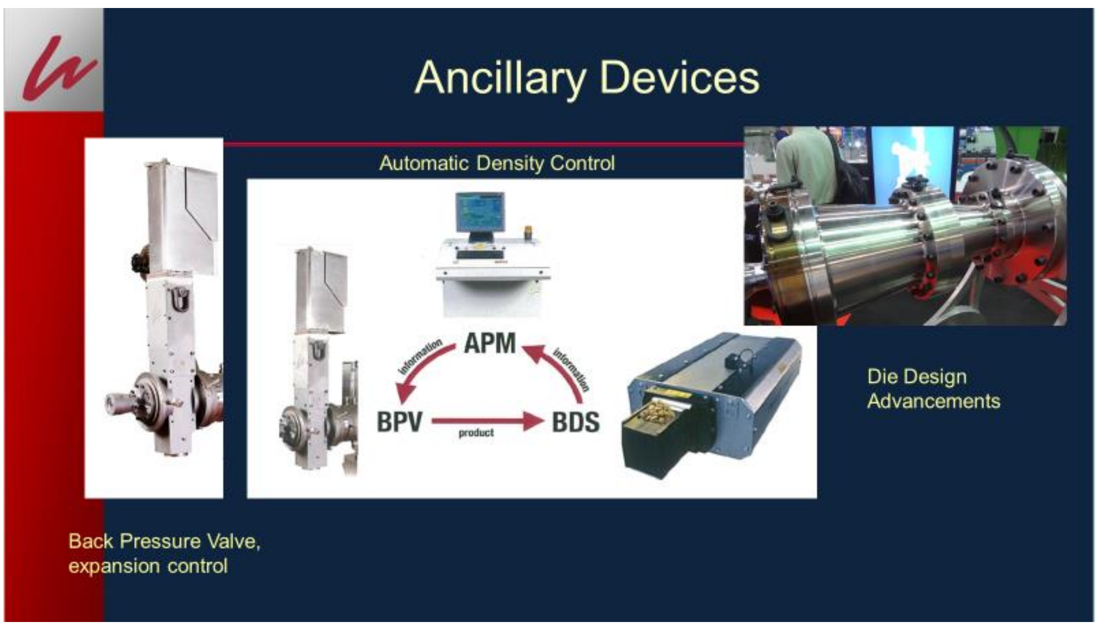

Photo 4: Ancillary devices of great importance for density control.

Other major developments have been in the die area. Multiple dies on the same extruder coupled with the hole design developments allow for the main advantage of increased capacity per extruder on die limited style products, normally the smaller diameter ranges and shrimp feed or sinking style feeds.

Dryers also have or are undergoing advancements to keep pace with developments. The major development in recent years has been the Source Technologies In-Line devices allowing, directly before the dyer, measurement of product quality characteristics. The advantage is the prediction of what you will get out of the dryer and not waste 20 to 30 minutes and the cost of drying to find out after the fact. Dryer improvements include improved spreader designs with electronic spreader controls for improved accuracy. An even bead depth is the major control point yielding even moisture levels at the end of the dryer, in the range of +/- 0.5% variation being the end goal. Dryer bed screens also have advances as smaller diameter pellets off the extruder are possible thus finer screen mesh of high temperature designs became necessary. Generally, a 0.6mm product practically all stays on a 1.0 mm opening screen. 0.5 mm products fall straight through a 1.0 mm screen but smaller screens are now available for pellets down to about 300 microns. Extruders can now produce 0.5 mm pellets while some system can approach 150 microns using agglomeration technology.

Basically, the above is a necessary review as all the above has allowed for and was used in the development of being able to make a neutral buoyant feed. To define neutral buoyant, in this case some pellets floated, some sank and some were in the water column. The challenge was to make a feed that would be available in the entire water column for aquatic animals. Time will tell if this technology theoretically assumed which could possibly change the FCR, feed conversion ratio, of fish. Dominate fish will no longer in some cases control the feed area. The feed will be in other areas allowing all fish a more even chance during feeding time. It is suspected this will have a big advantage for RAS, recirculating aquatic systems where floating feeds are used a feed for the water column might be more appropriate?

Final Product Bulk Density Correlation with Float/Sink Properties

Pellet Characteristic	In sea water @ 20°C (3% salinity)	In fresh water @ 20°C
Fast sinking	> 640 g/l	> 600 g/l
Slow sinking	580-600 g/l	540-560 g/l
Neutral buoyancy	520-540 g/l	480-520 g/l
Floating	< 480 g/l	< 440 g/l

Photo 5: Densities and Sinking Properties.

Using a formula with a functional vegetable protein the feed was made to float, adjustments in extruder operation with computer controls allowed for the feed to sink, float and to remain in the water column. Minute computer control changes with all the tools reviewed above allowed for adjusted density to 100% sinking and then back to all floating showing the system was under control and modulating the density up and down as desired in a finite range. Buoyance tests in fresh water, and 1, 2 and 3% salt water made it easy to see the difference in density as it changed. Results confirm the density chart where the feeds were in the neutral buoyant range. This was accomplished on a research scalable extruder so it is expected to be possible at higher production rates but this needs confirmation.

Photo 6: Neutral Buoyant Feed test 3% salt water and products made at less then 80°C.

Additional studies with the same research formulation was designed to determine the lowest possible temperature the system could be operated at and achieve floating, sinking and neutral buoyant feed densities. All the same control devices were used including automatic temperature control on the extruder barrel resulted in feeds produced under 80°C at the extruder exit. Immediate collection of the feed in an insulated mug with thermometer was used for verification. The goal was to see if such feed could be made in the area of above 77°C for a sanitary feed, no salmonella, but produced cool enough for the prebiotic and probiotic and other heat sensitive ingredients usage. Tests will be needed with these ingredients to determine the level of survival. At least the technology now exists for feed production at lower temperature levels in an extrusion cooker also capable of pushing the cook and energy levels for higher inputs.