Producing micro aquafeed via extrusion cooking technology

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Micro aquafeed production has been a historical challenge in terms of consistent product quality, low throughput, and energy sustainability. However, recent advancements in continuous extrusion cooking technology and recipe development are now enabling feed producers to accomplish these aspects.

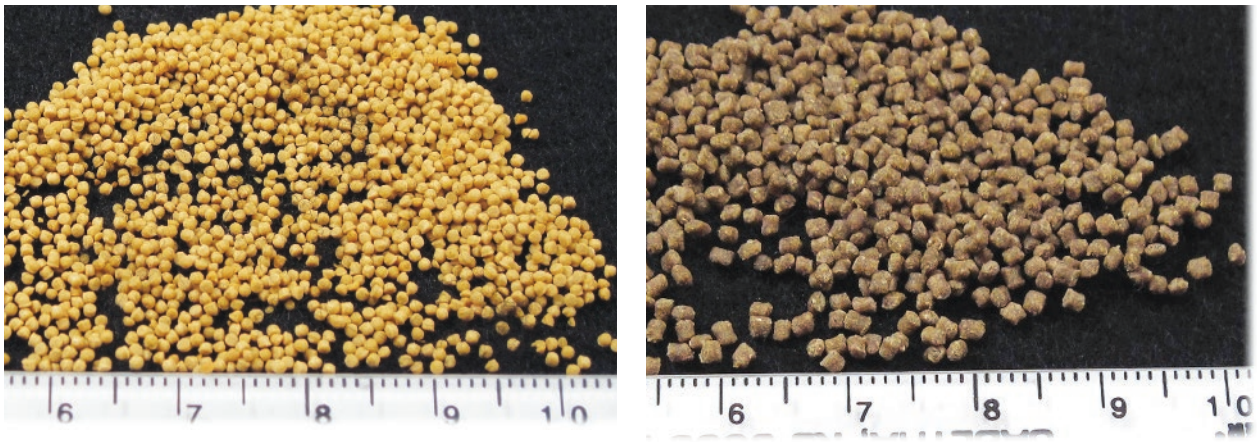
Micro aquafeeds are products in which the final product is 1,000 microns and smaller in size. Continuous extrusion cooking, which includes single and twin screw technologies, along with appropriate preconditioning and precise feed control to the process, has become a proven method for consistently producing high-quality and high-capacity micro feeds. The difference in the extrusion technologies involves processing and recipe flexibility. Both single screw and twin screw systems utilize mechanical and thermal energy inputs, through direct and indirect steam and water, under pressure, to gelatinize ("cook"), shape, and size the product to a specific density for the targeted aquatic species. By design, a continuous extrusion cooking system, versus traditional pellet milling, provides control of the specific recipe phase transition through compression, kneading, melting, and texturization prior to the final shaping – allowing for optimized starch gelatinization to yield a uniform product with long water stability. The flexibility in today's extrusion technology provides many tools to manage this phase transition control including:

- accurate metering of the recipe and preconditioning control
- adjusting extruder barrel fill through modern variable speed controls
- unique extruder screw and barrel configurations
- sophisticated screw element design

These innovations provide more process control across a broad range of ingredients and recipes than alternate methods of aquafeed production. Extrusion process controls provide the ability to impart differing levels of specific mechanical energy (SME or "shear") and specific thermal energy (STE or "heat") into the recipe to effectively manage the process whether producing floating, fast sinking, or slow sinking micro products. Equally important is the control of the upstream systems to deliver accurate recipe metering control and preconditioning prior to the extrusion process. With today's technology, the metering control of the dry feed recipe – through sophisticated loss-in-weight systems – can consistently deliver accuracies down to 1.0%. Additionally, new preconditioning technology is available to effectively blend, with even distributive and dispersive continuous mixing, the dry recipe with water, steam, and fats or oils. Using automated controls, the preconditioning process can be adjusted for retention time, differential shaft speed, and mixing impacts to dial in the process parameters specific to the requirements of the recipe or product. This can be done while in production without the need to shut down and make mechanical adjustments. Given this level of control, current preconditioning technology can deliver a reduced coefficient of variation down to 2.0%.

Reducing variability in the metering and delivery systems of the dry feed recipe and preconditioning to the extrusion process will result in a more stable process, with reduced external factors influencing performance, and enhancing product quality attributes such as uniformity, density, moisture content, and starch gelatinization which directly impacts the associated water stability. The improved level of control and variability reduction is important for all aquatic feed production, however, it is critical when the target product is micro aquafeed, given the inherent challenges of producing small diameter products at high capacities.

So, what is the correct extrusion system to produce micro aquafeed? This question is best answered



Floating micro feed (left) and sinking micro feed (right)

by considering the range of ingredients, recipes, throughputs, and final products desired. In short, how much flexibility is needed in the process?

Single screw extruders

Single screw extruders – as indicated in the name – have a single shaft, typically with a set of configurable screw elements to produce a classified range of products, either floating or sinking, with output ranging from 1,000 to 30,000 kg/hr. With modern additional components, such as variable screw speed control and in-line restriction devices, the flexibility of a single screw extrusion system has increased in recent years. However, changing from a floating to sinking product will typically require modification to the screw element configuration to optimize production. Additionally, some recipe or ingredient modifications may be required, such as the carbohydrate, protein, and inherent fats or oil sources and inclusion ratios, to provide the capability to produce the range of products desired. Generally, the operating and recipe window for single screw extruders is narrower than that of its twin screw counterpart.

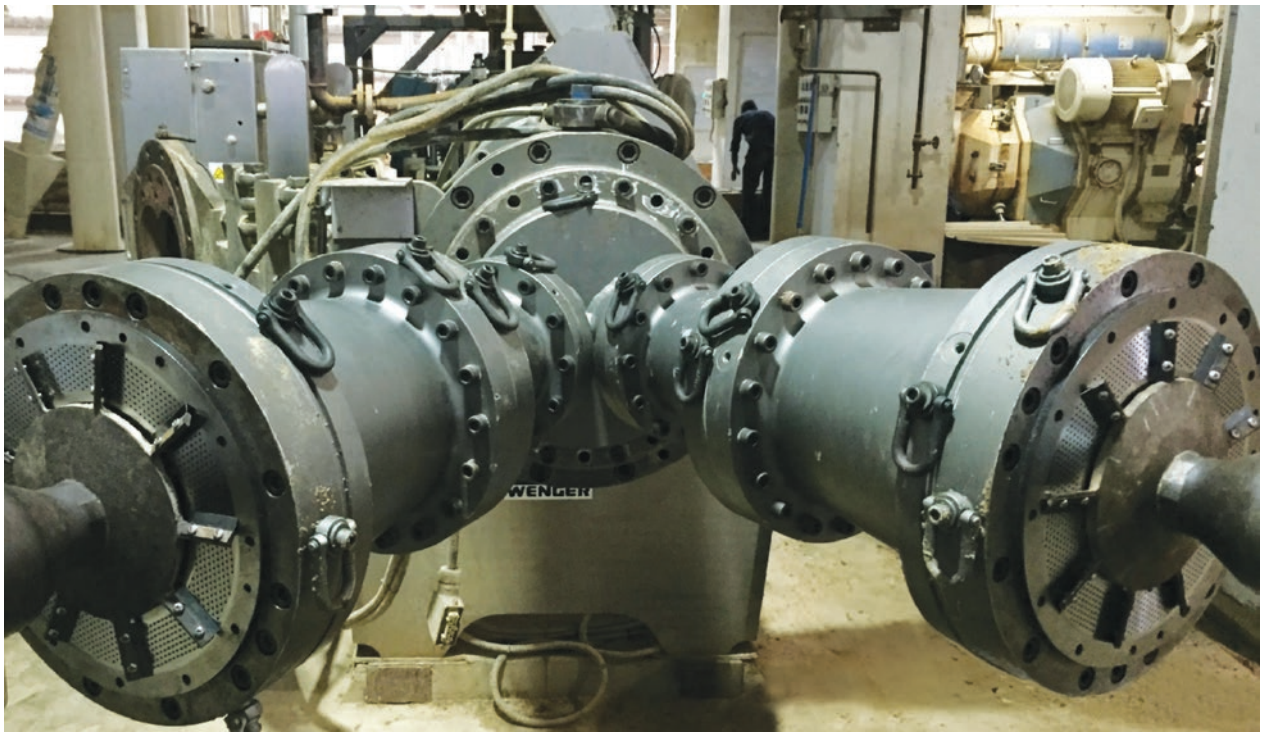
Twin-screw extruders

Twin-screw extrusion provides the ultimate flexibility in process and recipe control to produce the broadest range of micro aquafeed products without the need for changes in mechanical components or configuration – resulting in increased uptime. Simply changing the final die for the specific product diameter is usually all that needs to be done. Flexibility comes from utilizing unique screw element designs with longer specifically designed processing zones to enhance the kneading, mixing, and cooking while allowing for higher levels of specific thermal energy inputs to provide instantaneous adjustments to the SME to STE ratios specific to the recipe or product being produced.

The ability to utilize higher thermal energy inputs and reduced mechanical energy inputs, or “shear”, not only reduces wear costs but also improves the final product texture – yielding a finer cellular structure that enhances water stability and nutrient retention. This is especially important in the production of micro feeds used in Recirculating Aquatic Systems (RAS) using complex filtration systems. The improved water stability and nutrient retention reduce the particulate and suspended oils that tend to be released from the product yielding cleaner water with less stress on the RAS filtration systems as well as delivering the intended nutrition to the fish (improving feed conversion ratios).

The twin screw extrusion process is further enhanced by the ability to adjust the screw speed to optimize barrel fill within the target cooking zone, providing a balanced process to increase uniform gelatinization. This is an important requirement to achieve consistent final product quality, especially in terms of size, water stability, nutrient retention, reduced leaching of oils and fine particulate, and density control reducing the prevalence of random off-specification floating or sinking product.

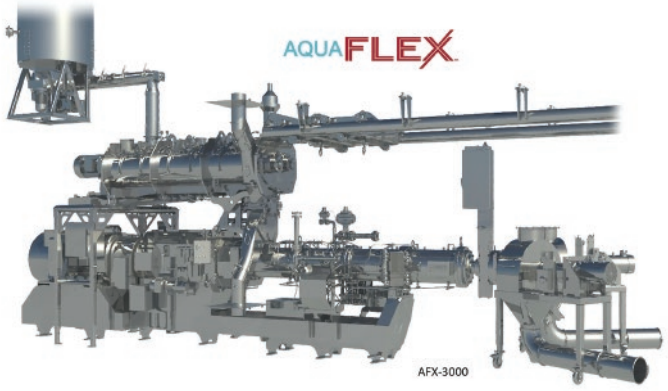
The basic characteristic of a twin screw extruder, utilizing two rotating shafts and screw elements, provides increased positive displacement and uniform pumping capability across a broader range of viscosities into the shaping, die, and cutting zone of the extruder.



Wenger dual die head assembly for the AFX-3000 enables high volume output of extruded micro feed

For micro feed extrusion, where it is typical for the final die to include a high quantity of die holes (upwards of 5,000) to increase total open area, controlling uniform flow and displacement into each die opening over the entire cross section of the die is even more important. Precisely controlling the flow provides the best opportunity to appropriately shape the final product at high throughputs while maintaining the required uniformity.

Given the industry's desire for increased throughputs, there is increased focus on the final die configuration, and associated total open area limitations. Especially true in producing micro aquafeeds, the limitation to throughput is not the volumetric capacity of the extrusion process but rather the available final die surface area to provide the necessary total open area. To address this challenge, newer die technologies have been developed to utilize multiple dies connected to the same twin screw extruder to significantly increase the production capacity of 300-1,000 micron-sized final products. This approach can yield production upwards of 8,000 kg/hr without the need for external density management chambers. The utilization of multiple dies at the extruder discharge further emphasizes the need for the referenced positive displacement that a



twin screw extrusion process can provide for uniform consistent extrudate flow to each set of dies and specific die openings.

The flexibility of twin screw extrusion for producing micro feeds goes beyond just the processing and production side. It also provides the opportunity to broaden ingredient and recipe options, opening the opportunity for utilization of sustainable ingredient sourcing and lower-cost ingredients while yielding high-quality products. A flexible process, with advanced controls in recipe delivery, preconditioning, and a broader cooking zone that the twin screw extrusion process provides, allows for the utilization of higher

A typical Wenger dryer for aquatic feed uses multiple horizontal passes to ensure proper air flow through the product bed.

inclusion of vegetable carbohydrates and proteins, fibrous ingredients, and increased utilization of internal fats and oils and without the need for special binders to control water stability, which can lower costs. Additionally, this flexibility provides the opportunity to adjust the recipes and substitute ingredients without significant research and development time when individual ingredient cost fluctuation is a challenge. Thus, extruder flexibility enables least cost formulation and reduced operating expenses, while still producing the same high-quality product.

Conclusion

Modern, continuous cooking extrusion technology has developed into an effective and efficient process for producing high-quality and high-capacity micro aquafeeds. When the correct extrusion technology is used (either single screw or twin screw), producers can meet market expectations for nutrition and performance, as well as their own throughput and product cost goals.

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