CONSIDERATIONS IN SHRIMP AQUA FEED EXTRUSION PROCESSING- THE LATEST TECHNOLOGY AND PROCESSES

by Mian N. Riaz

Food Diversity Food Science and Technology Department
Texas A&M University, USA

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U.S. Soybean Export Council (Southeast Asia) Ltd
541 Orchard Road, #11-03 Liat Towers, Singapore 238881
Tel: +65 6737 6233, Fax: +65 6737 5849
Email: Singapore@ussec.org, Website: www.ussec.org

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Introduction

In recent years advances in feed extrusion, changes in the availability and quality of ingredients used in feeds, development of new feed ingredients, and advances in our knowledge of shrimp nutritional requirements have resulted in improved and better quality feed production. Historically baby shrimps were produced in the hatchery and later stocked in outdoor nurseries and grow-out ponds. In the initial days of grow-out, they were fed crumbled feed. Increasingly, the nursery phase has been moved indoors for the following benefits; higher survival rates in intensive systems, production predictability, biosecurity, mitigate disease threats, more optimal production conditions to ensure faster growth, and the ability to use the benefits of compensatory growth. Why is the feed program so important for shrimp? It is the gas that runs the engine; it represent the largest variable cost, and it is a source of pollution. Currently, there are two way to process shrimp feed; pelleting and extrusion.

Pelleting vs Extruded Shrimp Aquatic Feeds

In extrusion, entire pellets are used for feeding the shrimp and they are not crumbled. These pellets have a smooth surface, less fines (fines pollute the water), and are uniform size in both pellet diameter and length. In extrusion, we have formulation flexibility which means we can produce nutrient dense feeds with better cooking and digestibility. Based on the desired requirement we can produce floating, slow sinking, and fast sinking pellets. These pellets are better suited for use on auto feeders. There are three different ways we can produce shrimp feed with extrusion technology; 1) large pellet extrusion followed by crumbling 2) spherizer process (SAS) and 3) direct extrusion. In this paper, the focus will be on direct extrusion of shrimp feed. There are several bottlenecks for producing shrimp feed with direct extrusion. Some of these hurdles are mixing, grinding, conveying, extrusion and the drying capacities of the feed mills. Other challenges can be sifting and dust control, pneumatic system changes, sanitation, HACCP requirements, and having a dedicated line.

Considerations in Shrimp Aqua Feed Extrusion

There are four main factors a feed mill need to pay attention to 1) raw material 2) system configuration (hardware) 3) processing conditions (software) and 4) final product specification.

1. Raw Material

The raw materials used for the production of extruded shrimp feed are both the most expensive and important consideration of the process. There are several important raw material characteristics that require attention. These include the protein, starch, oil, fiber content and particle size of each ingredient. In any extrusion process, the particle size of the raw material is important. Large particles are difficult to hydrate and may require additional preconditioning or additional mechanical energy input in order to plasticize and disperse the entire particle.

2. Hardware

Feeding Devices (Feed Delivery System)

The live bin/feeder provides a means of uniformly metering the raw materials into the preconditioner and subsequently into the extruder. This flow of raw material must be

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uninterrupted and rate controllable. The live bin/feeder controls the product rate or throughput of the entire system. The live bin/feeder system can be controlled in a volumetric or gravimetric manner. In a volumetric setup, the feeder delivers a constant volume of feed to the preconditioner. When operating under gravimetric or loss-in-weight (LIW) conditions the feeder delivers a set mass flow rate of raw material to the preconditioner.

Preconditioner

The preconditioning step initiates the heating process through the addition of steam and water into the dry mash. Complete and uniform moisture penetration of the raw ingredients significantly improves the stability of the extruder and enhances the final product quality. The objectives of a preconditioning step are to continuously hydrate, heat, and uniformly mix all of the additive streams together with the dry recipe. After preconditioning, the material is discharged into the extruder barrel. Here the major transformation of the raw preconditioned material occurs which ultimately determines the final product characteristics. For making shrimp feed, the industry uses a high shear conditioner that allow almost 48,000 mixing contact per minutes. This results in better gelatinization (85-90% of the starch cooked in micro shrimp formulation with a higher rate of up to 5 tons/hours.

Extruder Barrel

Extruders used for the manufacture of shrimp feed are most commonly twin screw in design. The impact on final product characteristics such as texture and density is produced by the screw and barrel profile, screw speed, processing conditions (temperature, moisture and retention time), raw material characteristics and die selection. As the moistened and partially cooked material leaves the preconditioner, it directly enters the extruder assembly consisting of the barrel and screw configuration. The initial section of the extruder barrel is designed to act as a feeding or metering zone to convey the preconditioned material away from the inlet zone of the extruder. The material then enters a processing zone where the amorphous, free flowing material is worked into elastic material. The compression ratio of the screw profile is increased in this stage to assist in blending water or steam with the raw material. For making shrimp feed, conical co-rotating screws are used for de-aeration of the feed mix and maximum product densities for sinking feed.

Die and Knife

The extrusion chamber is capped with a final die which serves two major functions. It provides restriction to product flow causing the extruder to develop the required pressure and shear. In addition, the final die shapes the extrudate as the product exits the extruder. A face cutter is used in conjunction with the die, which involves cutting knives revolving in a plane parallel to the face of the die. The relative speed of the knives and the linear speed of the extrudate results in the desired product length. For shrimp feed there are special dual dies that can increase the extruder capacity. These new dies can have a hole population almost three times than the normal die opening. In this die design, long tubes increase cooking and decrease expansion through pressure drop and retention time whereas having a small tube diameter gives uniform cross-sectional flow to the pellet. These dies can be used to achieve a higher rate, more uniform sizes, and a higher density for sinking and increase water stability.

3. Processing Conditions (Software)

Once the hardware is selected based on the above discussion, the extrusion system can be operated under various processing conditions to achieve a multitude of final product qualities. Following is a list of independent variables that an extruder operator can directly manipulate;

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1) Incoming recipe - the actual recipe, particle size, and moisture and temperature resulting from preconditioning
2) Capacity - the rate at which the recipe is introduced into the extruder
3) Steam addition - steam at 6-9 bar can be injected directly into the material in the extruder barrel
4) Water addition - water at various temperatures and 3 bar can be injected directly into the material in the extruder barrel
5) Liquid addition - other liquids and/or gasses can also be introduced into the extruder barrel
6) Extruder and die configuration
7) Temperature and flow rate of thermal fluid to barrel jackets
8) Extruder speed - requires a variable speed drive

When changes from the above list are made, they will in turn affect the following operating variables (referred to as dependent variables);

1) Material retention time in the extruder barrel
2) Product temperature in the extruder barrel
3) Product moisture in the extruder barrel
4) Pressure in the extruder barrel
5) Mechanical energy developed

Density Control of the Extruded Aquatic Feed

Pellet density can be changed by following three tools;

1) Recipe/ingredients adjustment and composition
2) Process Variables (not including recipe changes)
3) Hardware tools

Density Control with Ingredients:

Proteins, lipids, fiber and their interactions with starches are factors that complicate the estimates of density. All of these factors will play a role in the density of the finished pellet.

Density Control with Process Variables

Density can be manipulated by the following changes in the process:

- Changes in the energy input
- RPM of the extruder shaft
- Feed rate of material into the extruder
- Temperature and moisture (added water and steam)

Hardware Tools to Control Product Density

Other hardware tools that can be used to control product bulk density. Four tools that are available to the industry include the following:

- Vented extruder barrel, with or without vacuum assist
- Separate cooking and forming extruders where the product is vented between the two units
- Restriction device at the discharge end of the extruder
- Pressure chamber at extruder die

Vented Extruder Barrel, With or Without Vacuum Assist

In certain shrimp feed where higher product densities are required, the extruder barrel can be configured to include a vent which releases process pressure and reduces product temperature through evaporative cooling. A vacuum assist can be added to the vented barrel to increase the product density even further through more evaporative cooling and de-aeration of the extrudate. Vacuum assist (up to 0.7 bar) will improve pellet durability, increase piece density, and reduce extrudate moisture.

Separate Cooking and Forming Extruders

Another hardware tool utilized by the feed manufacturers to control product bulk density is a dual extrusion process. In this process, the first extruder is used in solo for the production of expanded feeds or it can be used as a cooking extruder for the two-stage

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cooking/forming process. The second forming extruder (PDU or Product Densification Unit) is used only when processing very dense feeds such as fast-sinking aquafeeds.

Mid-Barrel Valve

A "mid-barrel valve" (MBV) can be installed within the extruder barrel to serve as an adjustable restriction device for controlling shear stress and specific mechanical energy (SME) during operation of the system. 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.

Back Pressure Valve

Final product characteristics such as density can be controlled by extruder die restriction. One device commonly used by feed manufacturers is termed a "back pressure valve" (BPV) which is used to adjust die restriction while the extrusion system is in operation. By changing the restriction at the discharge of the extruder during operation, the product 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 assembly. Specific mechanical energy (SME) and extrusion pressure are process parameters controlled by valve positioning.

Post Extrusion Pressure Chamber

Another device available in the industry is an enclosed chamber which surrounds the die/knife assembly and permits control of pressure external to the extruder and die (often referred to as an EDMS or External Density Management System). Desired pressures are maintained in the knife enclosure by a special airlock through which the product discharges. Compressed air or steam can be used to generate the required pressure in the chamber. As pressure increases, the water vapor point increases which reduces product "flash-off expansion" and thus increases density.

Conclusion

Shrimp feed can be directly extruded using new and improved extrusion technology, which provide several benefits as compared to pelleting and other methods. Extruded feed has an internal matrix system, which tends to increase resistance to mechanical handling of feed. Extruded feed produces approximately 1-2% fine, whereas pelleted feed normally generates between 5-8% fines during handling in bulk or bag forms. This means extrusion decreases the amount of fines which normally enters the water and ends up decaying on the bottom of the pound by 75%. Less fines means, increased water stability, clearer ponds, lower fatality rates, less undesirable bacteria growth, increased conversion rates (10 - 20%), higher production yields and improved digestibility. Extrusion cooking provides and increased pellet durability index (PDI), better pasteurization of feed, destruction of insect eggs, improved feed conversion ratio (FCR), starch gelatinization and a reduced feed cost.

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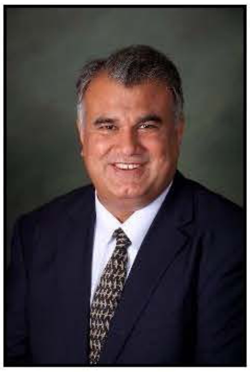
About the Author



Dr. Mian N. Riaz is Holder of the Professorship in Food Diversity Food Science and Technology Dept. at Texas A&M University, USA. He joined Texas A&M University 27 years ago after completing his Ph.D in Food Science from the University of Maine at Orono, Maine. His first academic appointment was in 1992 at Texas A&M University, Food Protein R&D Center, where he was put in charge of the Food and Feed Extrusion Program and went on to become the head of the Extrusion Program and a member of the Graduate Faculty in the Food Science and Technology Program. He served as Director of the Process Engineering R&D Center (formally Food Protein R&D Centre) from 2005 to March 31, 2020. He organizes 5 courses every year in the area of extrusion. Three of these courses are in the area of feed and two of them are in the area of food extrusion. Currently, he is offering these courses through Professional & Continuing Education program, Texas A&M Engineering Experiment Station (TEES), Extrusion Technology Program. He has published seven books (three of them are in the area of extrusion technology) 25 chapters and more than 143 papers on extrusion and other related topics.

Soy In Aquaculture Program

This technical paper was created through the USSEC Soy In Aquaculture (SIA) program and the USSEC Southeast Asian Regional Program. USSEC works with target audiences in Southeast Asia and globally to show the utility and benefits of using United States soybean products in aquaculture diets.

The SIA program replaces the Managed Aquaculture Marketing and Research Program (the AquaSoy Initiative, funded and supported by the United Soybean Board and American Soybean Association) which was designed to remove the barrier to soybean meal use in diets fed to aquaculture species.

The objective of the SIA is to optimize soy product use in aquaculture diets and to create a preference for U.S. soy products in particular, including but not limited to U.S. soybean meal, soybean oil, soybean lecithin, and "advanced soy proteins" such as fermented soy and soybean protein concentrate.

This paper follows the tradition of USSEC to provide useful technical materials to target audiences in the aquaculture industry.

For more information on soybean use in aquaculture and to view additional technical papers, please visit the Soy-In-Aquaculture website at www.soyaqua.org.

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U.S. Soybean Export Council Headquarters

16305 Swingley Ridge Road, Suite 200
Chesterfield, MO 63017, USA
TEL: +1 636 449 6400
FAX: +1 636 449 1292
www.ussec.org

USSEC INTERNATIONAL OFFICES

USSEC AMERICAS
Carlos Salinas
REGIONAL DIRECTOR – AMERICAS (AM)
U.S. Soybean Export Council
16305 Swingley Ridge Road, Suite 200
Chesterfield, MO 63017-USA
CSalinas@ussec.org
TEL: +52 331 057 9900

USSEC GREATER CHINA
Xiaoping Zhang
REGIONAL DIRECTOR - GREATER CHINA
U.S. Soybean Export Council
Suite 1016
China World Office #1
China World Trade Center
No. 1 Jianguomenwai Avenue
Beijing 100004
People's Republic of China
XPZhang@ussec.org
TEL: +86 106 505 1830
FAX: +86 106 505 2201

USSEC NORTH ASIA
Rosalind Leeck
SENIOR DIRECTOR - MARKET ACCESS AND REGIONAL DIRECTOR - NORTH ASIA
16305 Swingley Ridge Road, Suite 200
Chesterfield, MO 63017
RLeeck@ussec.org
TEL: +1 314 304 7014
FAX: +1 636 449 1292

USSEC SOUTH ASIA
Kevin Roepke
REGIONAL DIRECTOR - SOUTH ASIA
16305 Swingley Ridge Road, Suite 200
Chesterfield, MO 63017-USA
KRoepke@ussec.org
TEL: +1 314 703 1805

USSEC GREATER EUROPE, MIDDLE EAST/NORTH AFRICA
Brent Babb
REGIONAL DIRECTOR - GREATER EUROPE AND MIDDLE EAST/NORTH AFRICA (MENA)
16305 Swingley Ridge Road, Suite 200
Chesterfield, MO 63017
BBabb@ussec.org
TEL: +1 636 449 6020
FAX: +1 636 449 1292

USSEC SOUTHEAST ASIA AND OCEANIA
Timothy Loh
REGIONAL DIRECTOR - SOUTHEAST ASIA
U.S. Soybean Export Council
541 Orchard Road
#11-03 Liat Towers
Republic of Singapore 238881
TLoh@ussec.org
TEL: +65 6737 6233
FAX: +65 737 5849

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