New Technologies in Extrusion Process for Shrimp Feed

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Summary

The permanent increase in the costs of raw materials and the difficult secure supply, such as fish meal, has led to the industry to seek more flexible and low-cost processes that will allow a sustainable business in time. In addition a limited availability of water for the sustainable farming of shrimp, has routed this business to intensive raise where the levels of pollution play a very important role. This is why the feed must also generate lower levels of waste.

It is well known that the extrusion process compared with the pelleting process, produce better nutritional quality feed, but in the particular case of shrimp, where a feed of high density and stable in the water is required, the extrusion by itself is not able to achieve these levels of desired density.

The main characteristics of the shrimp feed are:
- Water Stability, Digestibility, Quick sinking, Smaller size of the pellet, Reduces pollution in the water, - Lowering costs in the feed and Other

Although the extrusion process requires a highest investment and also the operational costs are higher than the pelleting process, if the extrusion process has the appropriate technology for densification, it would be much cheaper with a much greater profit than the pelleting process and most importantly, with a better quality feed as a result.

In this work we show the latest technological advances in this direction to achieve a feed for shrimp in high quality and low cost through the extrusion process.

Keywords: extrusion, shrimp feed, pelleting process

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Introduction

This work shows the latest technological advances in the extrusion process for the production of shrimp feed in high quality at lower cost compared to the process of pelleting.

The shrimp industry, despite of its ups and downs in time, it is one of the most important aquaculture business in the world.

It is this fact, which should move us to think about how to maintain and care for this industry and make it every day more sustainable and profitable.

General aspects

The shrimp feed is quite difficult to produce through just the extrusion process since it must have a high density to achieve its sinking and have a high water stability. This last condition is the one that complicates the operation.

Since the beginning, the shrimp feed has been manufactured in pelletizing machines, which have been able to provide a good quality feed, which has boosted this industry throughout the world.

However, the increase in the cost of raw materials has been forced into this industry to look for new alternatives of technological processes to lower costs and improve the feed conversion.

Another important factor where producers of feed have been focused has been on the pollution of the water, which directly affects the mortality of individuals and the sustainability of the business over time.

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Finally, within the most important factors in the feed industry for shrimps, it is necessary to mention the water stability of the feed. Unlike other species, shrimp locates their food through the smell and taste, more than by the view and could take minutes or hours to eat it.

Importance of water stability

Some investigations have shown that approximately 20% of the crude protein, 50% of the carbohydrates and 50% of the content of vitamins from the feed of shrimps may be lost before ingestion. Therefore, improving the water stability of the pellet is not only a physical issue, but nutritional of great importance, it affects on the levels of feed conversion and of course in the cost of the feed.

In pelletized feed for shrimp are used different types of binders. There are nutritive and non nutritive, being both widely used. Binders include nutritious starches from grains such as wheat or rice, crude protein of plants or animals such as gelatin, casein, blood plasma and wheat gluten. Within the non nutritious binders there are hydrocolloids, gels as alginates and carragenines, mixtures of lignin, polymers, etc.

Role of the gelatinization of starch

The starch, which must be cooked to activate its functionality, it is the main binder used in shrimp feed. In the presence of water and heat, the starch is swollen; it loses its structure of crystals and hydrates in a process called gelatinization. In 1995 the survey "Physiochemical properties of shrimp feed with several Wheat Flour" led by G. H. Ryu and co-authors from the University of Kansas, KS, USA, showed a 89% correlation between the degree of starch gelatinization and the stability of 10 shrimp feeds from Asia.

In the presence of moisture by about 63%, most of the starches gelatinize completely to a temperature of 55 - 85 °C (131 - 185 °F). However, with the moisture level and cooking

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time of feed manufacturers, the complete gelatinization does not occur within this temperature range. Then, it requires greater temperature, pressure or friction in order to obtain this. These conditions are the ones that achieve the extrusion process easily.

Pelletizing process

The process of pelletizing in simple terms consist in taking raw materials finely ground, which, through the application of heat, moisture and mechanical pressure can be transformed into larger particles and stable nature.

The pellets are usually made cylindrically and vary its diameter from 3/32" (2.38 mm). Normally the length of the pellet is greater than the diameter, ranging from $1^{1/2}$ to $2^{1/2}$ times the diameter.

The basic components of a pelletizing system are:

1. Feeder variable-speed
2. Conditioner
3. Area of die and rollers

Advances in pelletized food of shrimp

The manufacturers of shrimp feed increase the water stability using mostly wheat flour as a binder, because wheat starch has a lower gelatinization temperature than corn, rice or other grains. The gluten content and size of fine particles of wheat flour also assist in the process of ligament. In addition, the system of pelletizing process for shrimp feed uses advanced techniques of manufacturing such as a fine milling of the raw materials (pulverizer), multiple steam conditioners, high levels of moisture, pelletizing dies with high compression ratio, conditioners post-pelletizing process and drying. These techniques increase the levels of starch gelatinization to 50-60 %, but there is a limit potential for further improvements. Also existing systems are inherently expensive, because of their dependence on wheat flour of high quality.

Size of the extruded pellets vs pelletized

The ideal size in the diameter of shrimp feed is 1.0; 1.5; 2.0 and 2.3 mm. The reason for the smaller sizes is due to the diet based in biomass in the ponds. In the case of pelletized feed it is common to see the smaller sizes pellets at 2 - 2.3 mm in diameter. It is very difficult to be able to produce pellets under the 2 mm.

While smaller, greater amount of pellets will be given per shrimp and will promote less competition between individuals while feeding.

A pond with 500,000 post larvae and a survival that is estimated at 80% provides 400,000 shrimp aprox. With an average of 12 grams per animal. This calculation leads us to 4.800 kg of shrimp, which must be fed with an equivalent of 2% to 4% of the biomass per day. This should be between 96 to 192 kg of feed, with an average of 144 kg/day. If fed 4 times a day, means 36 kg of feed at a time.

This table shows the number of pellets available for each shrimp depending on the size of the pellet, for the case mentioned.

Table No. 1 Number of Pellets by Shrimp

Process	Size of the Pellet (mm x mm)	Nbr. of Pellets per each 36 kg	Nbr. Of Pellets/shrimp (400.000 shrimps)
Pelletized	2 x 6	818,200	2.04
Pelletized	2.3 x 7	857,000	2.14
Extruded	1.8 x 6	1,286,000	3.22
Extruded	1.5 x 4	2,250,000	5.62
Extruded	1 x 7	3,000,000	7.50

Therefore, the smaller the pellet, the greater number of pellets available by shrimp.

Assuming a proper technique of feeding, it allows each shrimp to have a greater choice to feed itself and therefore growth is more uniform.

Extrusion process

In recent years there has been much progress in the development of extrusion systems to improve the food shrimp from the point of view of the physical characteristics, starch gelatinization, sink rate, pasteurization, water stability and in general, critical properties that have a nutritional and environmental impact.

Gelatinization of starch in shrimp feed is important because it affects digestibility and contributes to stability in the water. The feed that is not immediately consumed should be stable to protect water quality. The shrimp feed requires a quick sinking. There are many factors that influence the flotation and these include the surface tension at the interface between the pelletized feed and the water, displacement of the pellet, temperature and salinity of the water.

For the control of the density, multiple parameters of extrusion process can be set, but they adversely affect other parameters such as the capacity of the system and mainly the quality of the shrimp feed.

However, there are currently some technologies and equipment available for the manufacture of shrimp feed to the desired density while maintaining optimum process parameters.

New technologies and equipment via extrusion

For an adequate control of the density of the feed, there are several technologies:

- extruder with Pressure Control Chamber
- extruder with CSR or special densification cone
- extruder with Product Densification Unit (PDU) (separate equipments)
- extruder with OTD (Oblique Tube Die)

Extruder with pressure control chamber

This system consists of two elements, the Back pressure valve (BPV) (see fig. Nº1) and the external pressure chamber. This complete system is called EDMS (External Density Management System) (see fig Nº2).

The final feature of the product can be controlled by the restriction of the dies of the extruder. The Back Pressure Valve (BPV) allows to adjust the restriction of the die, while the extruder is in operation. This BPV is mounted at the end of the extruder and prior to the die, as shown in fig N°1.

The BPV allows controlling the specific mechanical energy and the pressure of the process. In this way it achieves a control of the density in line. Also the BPV provides an internal control of sheer, which improves the properties to the product, such as:

- Density of the pellet
- Size and uniformity of the cell structure in the pellet
- Starch gelatinization
- Better shape definition
- Water and fat absorption

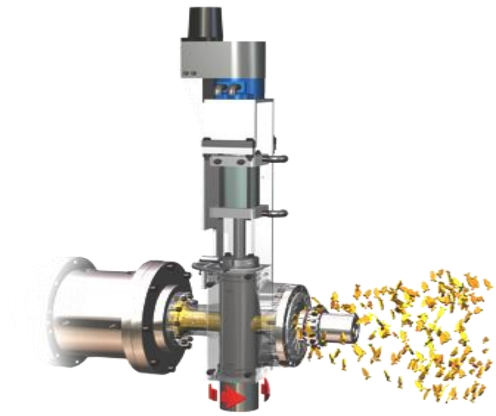

Figure 1. Back Pressure Valve (BPV)

A chamber can be added to this BPV to control the pressure. Within the die and the knives are hermetically sealed. In this way the external pressure can be controlled immediately at the exit of the extruder. This increase in the external pressure allows to raise the boiling point of water and therefore, to reduce the "Flash-off". This can achieved to increase the density of the pellet. In Table Nº2 shows the effect of pressure on the flash-off.

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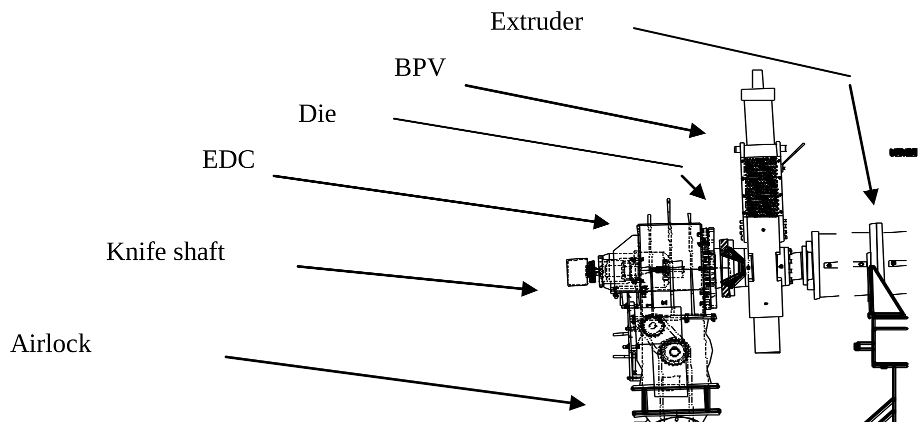

Figure 2. External Density Management System (EDMS)

Extruder with External Density Management System (EDMS)

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Table 2. Effect of Increased pressure in the EDMS

Pressure in the chamber (bar)	Boiling point of water (ºC)	Extra expected density of the product (%)
0	100	0
0.5	112	10.0
1.0	121	18.3
1.5	128	25.0
2.0	134	28.3

This system operates very well and the quality of the shrimp feed is excellent with a very good water stability. However, the only limitation to this system is that in sizes of pellet very small capacity of production is reduced.

Extruder with CSR (Conical Screw Retainer)

This system is composed of a special cone to increase the density and is located at the end of the extruder.

The density of the product can be controlled directly in the extrusion process. This is an economic system for producing shrimp feed but its limitation is given by the production capacity that in the case of pellets under 3mm, its capacity will be very similar to that of the extruder working with pellets in those sizes. The layout below shows the process line complete.

This is a good solution when the customer wants to test the market without big investments in extrusion process or increase the dryer capacity.

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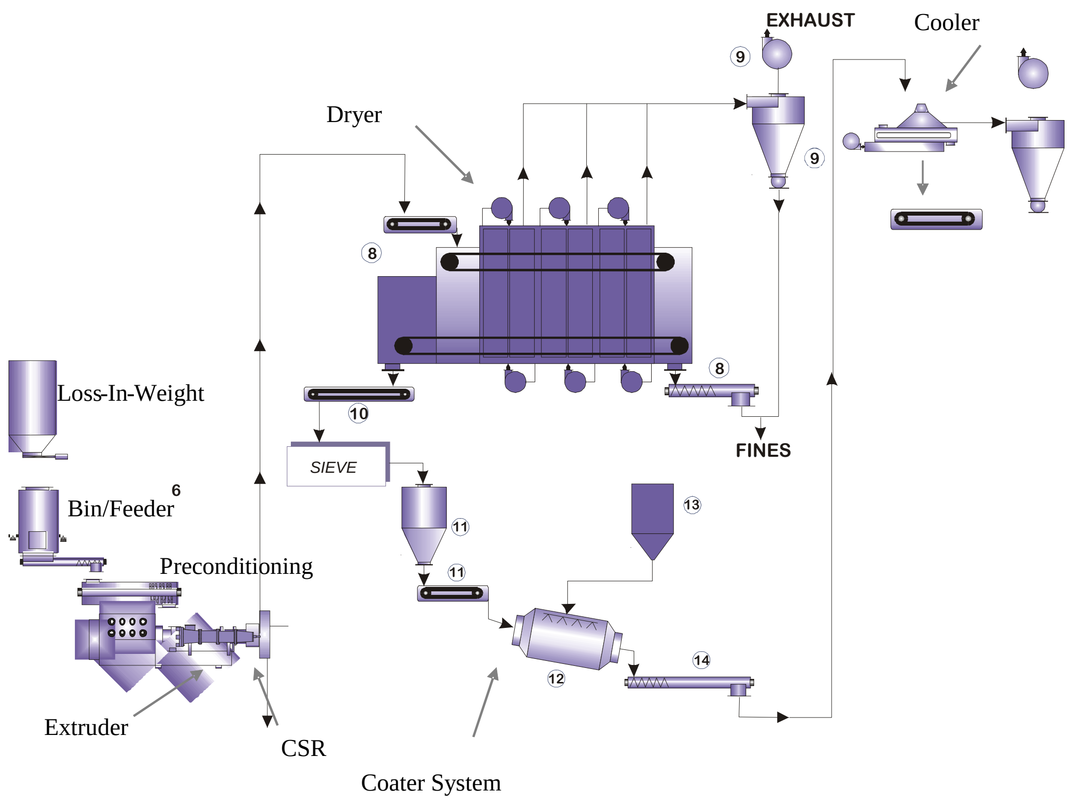
Layout Extrusion Line of Shrimps with CSR



Extruder with Product Densification Unit (PDU)

Another system that is used to manufacture high density sinking feed is a dual system consisting of an extruder and a PDU. See figure No. 3

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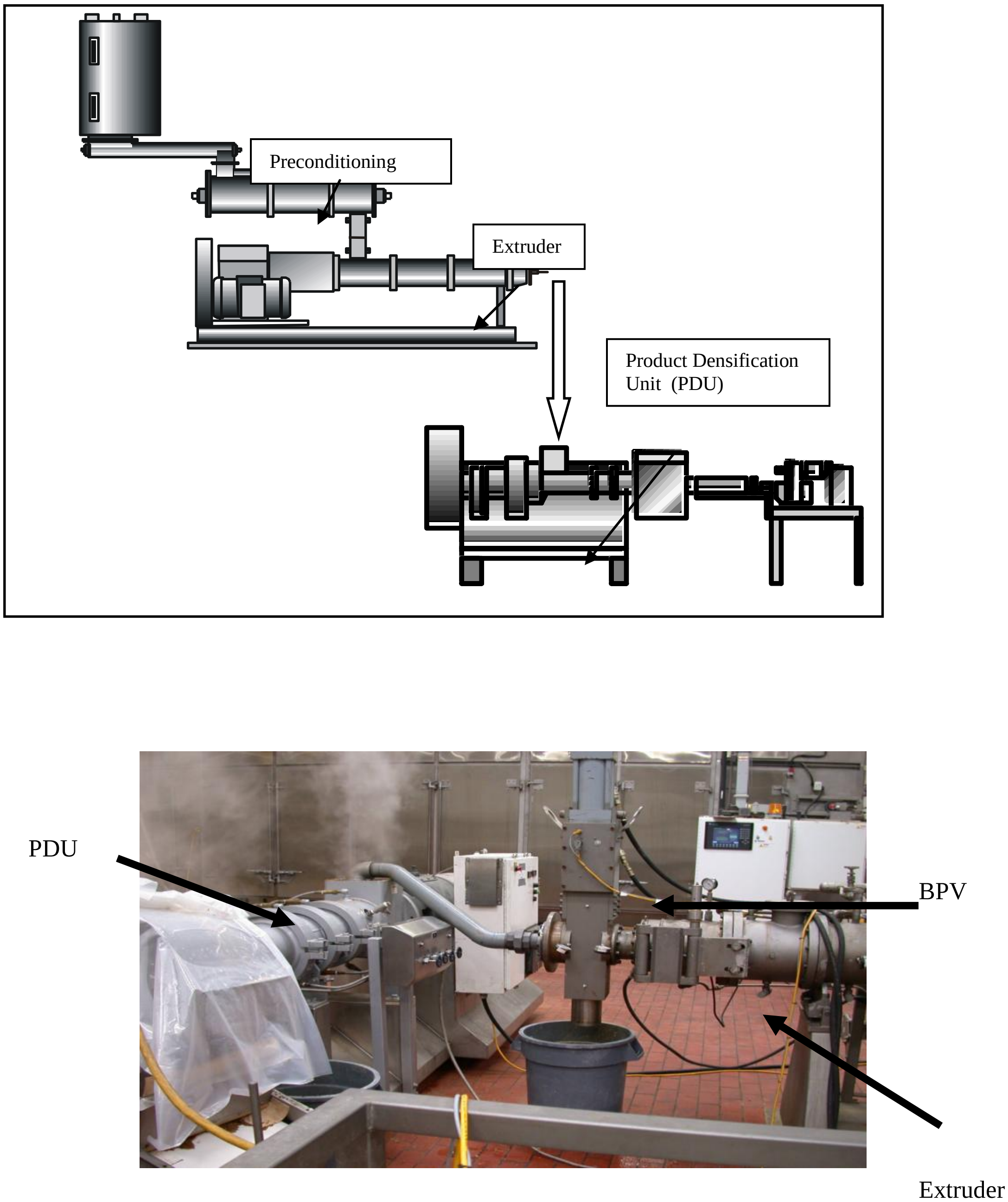

Figure 3. Extruder with Product Densification Unit or PDU

In this process the extruder can be used separately for the production of floating feed and/or slow sinking. But if it is combined with the PDU, can be on the one hand, to

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achieve complete cooking of the starches with the extruder and on the other hand, to increase the density to obtain a high water stability pellet with a high density enough to achieve a quick sinking.

As mentioned at the beginning of this work, a good stability in the water and a good digestibility or feed conversion, is achieved with a good level of cooking of starches. This can be done in an extruder that possesses a system of adequate preconditioning. It is for this reason that if we separate the two processes, we can take to their optimum level of quality and performance in each one of them.

One of the main advantages of this system is that the extruder works to its maximum production capacity and the PDU deliver a pellet with an excellent digestibility and water stability. If the extruder has a higher capacity rate, more than one PDU can achieve, a second PDU can be added to achieve maximum productivity.

Extruder with OTD (Oblique Tube Die)

Another of the latest developments in this field is the OTD (Oblique Tube Die) (patented by Wenger) which allows to increase the capacity of the extruder working with pellets minors to 3 mm in diameter, leading the extruder almost to reach its maximum capacity as if it were producing pellets of 5 mm or more. This OTD allows to intensify the feed on the 650 g/l achieved the production of an excellent shrimp feed directly from the extruder.

In this process, the extruder can be used directly for the production of feed of high density. This special head allows the extruder on the one hand, to achieve complete cooking of the starches with the extruder and on the other hand, to increase the density in order to achieve a feed with an excellent stability in water and a density high enough to achieve a quick sinking.

Oblique tube die

US Patents 7,611,347 and 7,588,789

Main differences of the shrimp feed extruded v/s pelleting process

- In the extruded feed, the starch is highly cooked.
- The conversion of the feed is lower.
- Results shown by some companies with the diet tested shows between 15 to 20% reduction in feed used due to a better conversion to achieve the same biomass.
- Extruded feed is pasteurized, unlike the pelletized feed that carries with it the bacterial contamination from the raw materials such as salmonella, *E. coli*, listeria, etc. that are thrown into the water
- The smallest diameter of the extruded feed can be from 1mm. In the case of the pelletized, it can be from 2 to 2.3 mm. In this way, the availability of food extruded is greater for each shrimp.
- The extruded feed allows adding more soy in the diet and reducing the fish meal. And during the growing the shrimp can accept more soy in the diet.
- Also through the extrusion process almost unlimited raw material can be used.

- The wheat flour used in the pelleting process can be replaced, and any type of binder is not required, which leaves more space in the formula to use ingredients with lower protein levels, without changing the final nutritional contribution. This makes it possible to lower the costs of the formula considerably.
- Waste or feces of the shrimp fed with pelleted diets; contribute a significant amount of nitrogen, protein and amino acids that contaminate the ponds and this increase mortality. In the case of the extruded feed this contribution is significantly lower and therefore lower mortality.

Economical comparison between extrusion and pelleting process plant for shrimp feed

Resumen Comparación Económica Extrusión v/s Pelletizado

General Considerations:

- Plant to produce:
  - 5,000 kg/hr
  - 300 days/year
  - 16 hr/day

Total 24,000 Mton/year

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	Extrusion (US$/ton)	Pelletized (US$/ton)
Capital & and Amortization per year	22.00	14.83
Electricity Cost	11.22	10.42
Steam Cost	10.03	1.14
Water Cost	0.99	0.00
Formula Cost	466.00	606.00
Total	510.24	632.39
Total Cost (US$) For 24,000 Mton/year	12,245,760	15,177,360
Differences in 1 year (US$)	2,919,600	

This means that in an extrusion plant for shrimp feed in less than a year it is possible to safe around US$ 2,919,600. This plus the standard profitability of the business.

This difference does not include the saving when 15% or 20% of less shrimp feed is used. Neither the extra profit generated by less pollution, lower mortality grater water stability

Conclusions

While the extrusion system requires a higher investment and the operational cost are higher than the pelleting, the extrusion process in the medium and long terms is much more profitable.

In extrusion the main saving cost is achieved by lowering the formula cost. This occurs by having more space in the formula to use almost unlimited range of raw materials.

Shrimp feed can be made with a good amino acid profile with a very low fish meal content compared with pelleting.

The extruded feed has a better digestibility than the pellet (a 15% or 20% less feed can be used to achieve the same biomass).

At 24,000 ton/year of shrimp feed production at around US$ 632.39/ ton, if we safe 20% of feed for a better FCR about US$ 3,000,000.00 can be safe in capital cost.

The extruded feed has a better water stability than the pelleted feed. In some formulas the extrusion process can achieve 24 hrs of water stability without any problem, depending of the formula.

- Both feeds are 100% sinking.
- The extruded feed is pasteurized and free of pathogens. The pelleted feed carries most of the bacteria's and pathogens lead in the raw materials.
- The extruded feed provides a significant less level of waste from the feces, resulting in bacterial growth, diseases and mortality
- Through the extrusion process pellets can be smaller, reducing the competition for the feed and like a result allowing a more uniform growth

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Wenger Technical Center, in Sabetha, Kansas, USA. Gathering information from multiple testing with shrimp feed, made for many years of research and develop in conjunction with Dr. Addison Lawrence of Texas A&M University.