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Aquafeeds

A look at the SME controlled extrusion process

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Evaluating the production of high water stability feeds

Feeding the best available aquafeed is a key factor in the success of any aquaculture operation. Photo by Darryl Jory.

Today, most shrimp feed manufacturers use the traditional pellet press equipped with long residence time preconditioners and post pellet cooking units. Starch gelatinization in these units can be between 40 to 55 percent using a short residence time pre-conditioner, and as high as 68 percent when a double or triple pass pre conditioner is used in conjunction with a post cooking unit.

Increasing starch gelatinization improves water stability; however, the degree of starch gelatinization has been assumed to be the sole reason for improvements in pellet water stability.

Extruded shrimp feeds

Many investigators and shrimp feed manufacturing companies have used high shear extruders with the understanding that the high degree of gelatinization obtained would improve pellet water stability. This resulted in the use of expanders, combinations of expanders and pelleting, and even double pelleting setups. The fact is that a lot of money was spent in these technologies with limited results. We believe the industry should have paid a closer look at other extrusion technologies that use high moisture, very low shear and low temperature drying. The pasta industry provides a good example: a spaghetti is basically a long pellet and, if broken into pieces and placed in water at ambient temperature, it exhibits very long water stability.

However, the cold extrusion process is at the low end of the scale and for the reasons explained in the previous column, an optimum range of energy input is required to produce a shrimp feed with the desirable characteristics, including a soft enough pellet that shrimp can shred (spongy texture), yet a pellet that can remain stable for 4 or more hours after it has been submerged. Therefore, a pellet designed for shrimp feeds should be one that has the perfect balance of Water Absorption Index (WAI) and Water Solubility Index (WSI), or high WAI and low WSI, respectively.

Studying effect of SME on water stability

A study carried out at the Buhler Extrusion Research facility in Uzwil, Switzerland to determine the effect of SME (Specific Mechanical Energy) on the water stability of shrimp feeds. An Eco-Twin, Twin-Screw Extruder (Figure 1) equipped with SME and Density Control valves were used. No artificial binder was included in the formula we used in the extrusion process contains, but a commercial binder was included in the same formula used for the pelleting conditions. In the traditional pelleting process, the formula was subjected to a long residence pass pre-conditioner (minimum 2.5 min at 90˚C) and the pellets to post conditioning (PPC) for 15 min at 90˚C, and long residence time pre-conditioner and pelleting without the post pellet cooking (PPO).

The study targeted two SME conditions: low (LSME or 90 Kj/kg) and medium (MSME or 126 Kj/kg). The extruded pellets were immediately cooled, therefore not subjected to any post-cooking. The pellets were analyzed for starch gelatinization using the Amylase Method.

The experimental feeds were produced using a twin-screw extruder equipped with SME and density control valves. Courtesy of Bühler AG.

The pellets produced in each cell were subjected to a 30 min water stability test using an orbital shaker at 250 rpm. Once the cycle was completed, the remaining pellets were placed in a Tyler 10 screen and thoroughly washed to remove any fine particles. The screens with the remaining material were later placed in a forced air oven at 100˚C for 3 h. At the end of the drying period the dried pellets were weighed and the amount remaining (corrected for the pellet moisture content) divided by initial weight and multiplied by 100 to obtain the percent water stability.

A pellet durability test was also done to determine if there was a difference in pellet hardness between regular pellets and extruded pellets.

Water stability

Test results are shown in Table 1. The data indicated that the pellets produced with the Eco-Twin extruder at low shear (LSME) and medium shear (MSME) had better water stability than pellets produced with the pellet mill for either treatment (PPC and PPO). The PPC pellets had acceptable water stability – above 80percent after the 30 min test – which correlates well with 4 h water stability. However, the PPO pellets had the lowest water stability, which can be mainly attributed to the lack of the post cooking treatment and not to the binder. Pellets subjected to post-cooking showed a considerable improvement in water stability when compared to pelleting alone, even in formulas that contain a commercial binder.

Item	PPC	PPO	LSME	MSME
Water stability %	82.1	67.5	89.7	85.3
PDI %	97.2	97.1	97.4	97.2
Starch gelatinization %	67.1	53.4	82.7	87.5

Gelatinization of starches

The starch gelatinization of pellets produced under treatment MSME was higher than for the low shear conditions; however, water stability appeared to decrease with increasing SME. This can be attributed to higher shear of the former treatment, which increases the water solubility of pellets. In this trial, however, the energy input at the MSME conditions was not as high as to cause a considerable reduction in water stability, which could have been expected when the energy input is above 250 kj/kg, or roughly 70 Wh/kg. The energy input in the material is controlled by the moisture content added, the screw configuration (in this study the SME valve), the screw speed, and the feed rate. All these have a direct impact on the amount of work that is done to the meal.

Another way to assess the amount of work done to the starch fraction is via Rapid Visco Analyzer or RVA. With the RVA, the viscosity of the starch phase can be measured when it is cold, and when it is heated and again allowed to cool (set back viscosity). This measurement of degree of cook can be used in extrusion processes to correlate the amount of starch gelatinization as it relates to the amount of thermomechanical cooking, and this can be in turn correlated to WAI, WSI and Pellet Water Stability. A study done by Lefuevrell, where RVA was used to measure starch damage, showed that low shear screw profiles (forward conveying, no reverse elements, low screw speed) produced less starch damage than screw profiles with reverse elements running at higher screw speeds.

Physical integrity and hardness of pellets

There was not difference in Pellet Durability Index (PDI, a measure of pellet hardness) for any of the pellets produced. Therefore, the pellet hardness cannot be directly correlated with pellet water stability.

a – Pellets produced under low shear held their physical integrity after water immersion.
b – Pellets produced under medium shear had longitudinal cracks after four hours of immersion.
c – Extruded pellets (E) produced under low energy input had better water stability than those pelleted using a pellet mill (P). Credit: Eugenio Bortone.

Figure 2a shows that pellets produced under the LSME conditions were still holding its physical integrity after being submerged in water after 4 hours. In Figure 2b it can be observed that the pellets produced in treatment MSME had a longitudinal crack after 4 hours. When compared (LSME vs. PPC) as shown in Figure 2b, it is clear that the extruded (Left E) pellets produced under low energy input exhibit better water stability than those pelleted using a pellet mill (Right P) after 4 h of immersion.

Our results show that pellets produced with an extruder with an SME control valve have improved water stability. However, other aspects remain to be evaluated, including what is the effect of the extrusion process using the SME control valve on Feed Conversion Ratios (FCR), on nutrient leaching, and on the digestibility of some less traditional ingredients. The environmental impact of low leaching, high-water stability extruded feeds should also be evaluated.

Perspectives

Low mechanical energy input improves water stability of shrimp formulas that do not contain a binder. Using a twin screw extruder with SME control valve improves water stability of pellets, and in addition, the versatility of the equipment allows the operator to dial optimal processing conditions at star up in a few seconds. Therefore, shrimp feeds can be produced at target quality attributes in a shorter time, thus improving feed production efficiencies.

Because twin screw extruders are efficient pumps, the surging and blockages observed in pelleting at high moistures is non-existent – this improves production efficiencies due to less down time. The twin screw technology with SME control also permits the production of more uniform pellet lengths, and the production of smaller pellet diameters that do not require particle size classification, or better yet, the need to reprocess fines produced as pellets are ground up with the braking rolls. In the extrusion process, fines are almost non-existent. And extruded feeds are produced at higher temperatures and pressures that will destroy any pathogenic organism.

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