Evaluation of selected binders in a ring-die pellet mill for processing shrimp feed pellets

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ABSTRACT
Polymethylolcarbamide (PMC), gura gum and wheat gluten were evaluated as feed binders in a ring-die (R–D) pellet mill at 0.5, 2.0 and 5.0% levels using a shrimp feed formulation. Pelleting of feeds was carried out at three different temperatures of 70, 80 and 90 °C. Highest increase in moisture level was recorded in the case of feed mix with wheat gluten as binder (20.9 – 26.0%), followed by the feed mix with guar gum (16.2 - 17.2%) and least increase in feed mix with PMC (11.4 – 12.6%). The results indicated that wheat gluten has the highest moisture absorbing capacity followed by guar gum and PMC has the least moisture absorbing property. The turbidity of water in which pellets with binder PMC were soaked resulted in lowest nephelometer reading (10.6 maximum). Pellets with wheat gluten resulted in higher values of turbidity (18.6 nephelometric units maximum) while those with guar gum as binder resulted in intermediate values of turbidity (15.3 nephelometric units maximum) between PMC and wheat gluten. Pelleting temperature of 70, 80 and 90 °C improved hydrostability of pellets for all the three binders from 79.5 to 82% in the case of PMC, 80.5 to 81.5% in the case of wheat gluten and from 77.9 to 80.5% for guar gum. Pelleting temperature had no influence on water turbidity (10.6 – 10.8 nephelometric units) for pellets with binder PMC. Increase in pelleting temperature from 70 to 90 °C reduced the turbidity of water from 18.6 to 17.0 and from 15.3 to 14.9 nephelometer readings, in the case of wheat gluten and guar gum respectively. The drop in turbidity meter reading was more pronounced for wheat gluten than for guar gum. The results of the study indicates that PMC like synthetic binders are more suitable for processing shrimp feeds in ring-die pellet mill, which is required at very low level (0.5%), imparts good water stability to pellets and is also cost effective.

Keywords : Binder, Guar gum, Polymethylolcarbamide, Ring-die pellet mill, Shrimp feed, Wheat gluten

One of the important quality criteria of shrimp feeds is the pellet stability in water known as aqua-stability. Shrimp feeds contain different types of binders (Myers, 1991; Myers and Zein – Eldin, 1972; Myers et al., 1972; Anon., 1987) and are generally processed in various types of pellet mills under different moisture and temperature combinations. Several materials have been evaluated as binders in aqua-feeds (Forster, 1972; Ahamad Ali, 1988). Although feed formulations include sufficient levels of starch, some of the processing conditions do not adequately gelatinize starch in feed. Hence additional binders are used in shrimp feed formulations for achieving the desired water stability under specific processing conditions. Commercially, shrimp feeds are mostly made with ring-die pellet mill (Bortone, 2003) using different materials as binders (Huang, 1989; Hetramf, 1992). With a view to find out a most suitable binder for processing shrimp feed in a ring-die pellet mill, three binders were evaluated and the aqua-stability of pellets was studied.

A shrimp feed formulation consisting of fishmeal, prawn meal, squid meal, mantis shrimp meal, soybean meal, wheat flour and other feed additives (fish oil, lecithin, vitamin and mineral mixture) was selected for evaluating wheat gluten, polymethylolcarbamide, PMC (a urea-formaldehyde polymer) and guar gum as binders. They were individually incorporated at the suggested levels of inclusion, Hetramf, (1992) at 3, 0.5 and 2% respectively in the feed formulation.

The solid feed ingredients were finely powdered in a micropulverizer and passed through 0.5 mm screen. The ingredients along with the binder were mixed in horizontal ribbon mixer and thoroughly homogenized after adding 3 l of water for 100 kg feed mix.
The feed was pelletized in a ring-die pellet mill having three stage steam conditioners using 2.5 mm die. Steam produced in a modern light diesel oil boiler at 10 kg cm\(^{-2}\) pressure was used for conditioning the feed mixture. In the first conditioner, steam was passed through an outer jacket as the feed mix slowly passed through the inner chamber with the help of a screw conveyer. In the second conditioner, steam was directly injected into the feed mix. Finally the feed enters the third conditioner with direct steam injection and then passes on to the pelleting die-roller assembly. The temperature of the feed mix at this stage depends upon the quantity of the steam injected and the speed of the screw conveyer of the conditioning chamber. By adjusting these factors, pelleting was carried out at three temperatures namely, 70, 80 and 90 °C for each binder. Conditions of steaming, temperatures and pelleting process were uniform for all the binders. At each pelleting temperature, samples of feed mix just before it enters the die-roller assembly were taken, quickly weighed, transferred to hot air oven in aluminum containers and dried at 100 °C for 6 h for estimation of moisture. As the pellets emerged from the die, samples were collected and moisture was estimated as described above. After the pellets emerged from the die, they were further conditioned at the same temperature for 10 min, dried and cooled. These pellets were used for determination of water stability.

Water stability of feed pellets was determined by following methods described by Ahamad Ali (1988) and Rani and Ahamad Ali (1991) with necessary modifications. For determining the aqua-stability of feed pellets, fine galvanized wire mesh was molded into cubes of 5x5x5 cm for holding pellets in water (cubes closed on one end and open on the other end). Before use, the mesh cubes were thoroughly washed, dried in oven at 100 °C and weighed. About 5 g of feed pellets (pre-dried at 100 °C) were exactly weighed into the cubes and lowered into a beaker of 400 ml water. After soaking feed pellets for 2 h, the water in the beaker was gently stirred with a glass rod for ten seconds, the mesh cube was removed from water and dried in the oven at 100 °C for 6 h. All the treatments were carried out in duplicate. The turbidity of water in the beaker was also measured at the end of 2 h using a nephelometer. The water stability of pellets was calculated as percentage of dry matter left after soaking in water for 2 h.

The results of the experiments conducted with three binders namely, polymethylolcarbamide (PMC), guar gum and wheat gluten in the ring-die (R-D) pellet mill led to interesting results. For increasing the temperature of feed mix at the time of actual pelleting (entry of feed mix into the pelleting die), the quantum of steam injected was manipulated, which resulted in the variation of moisture content of feed mix (Table 1). As the feed mix emerged from the pelleting die, the post-pelleting moisture levels of the emerging pellets dropped from 2 – 4%. The highest increase in moisture level was recorded in the case of feed mix with wheat gluten as binder (20.9 – 26.0%), followed by the feed mix with guar gum (16.2 - 17.2%) with least increase in feed mix with PMC (11.4 - 12.6%). The results indicated that wheat gluten had the highest moisture absorbing capacity followed by guar gum and PMC had the least moisture absorbing property. The pelleting temperature of 70, 80 and 90 °C influenced the water stability of pellets in all the three binders. Water stability of pellets improved with increase in pelleting temperature (Fig.1). In the case of PMC, the pellet stability improved from 79.5 to 82.0%, and for wheat gluten the improvement was from 80.5 to 81.5%. The highest improvement in pellet stability from 77.9 to 80.5% was noticed in the case of guar gum. The binding properties of a material depend upon its dissolution, adhesive property and interaction with other ingredients forming complex matrix (Hertramf, 1991; Huang, 1989; Meyers, 1991). The improvement in water stability of pellets with increase in temperature noticed in the present study may be due to increase in dissolution of the binder at higher temperature, increased gelatinization of starch present in the formulation and also improved ingredient-binder matrix formation.

<table>
<thead>
<tr>
<th>Binder</th>
<th>Inclusion level (%)</th>
<th>Pelleting Temperature (°C)</th>
<th>Moisture level in feed % Pre-pelleting</th>
<th>Moisture level in feed % Post-pelleting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymethylolcarbamide (PMC)</td>
<td>0.5</td>
<td>70</td>
<td>13.9</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>14.5</td>
<td>12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>16.9</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>Guar gum</td>
<td>2.0</td>
<td>70</td>
<td>16.5</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>16.2</td>
<td>12.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>17.2</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>Wheat gluten</td>
<td>3.0</td>
<td>70</td>
<td>26.0</td>
<td>23.2</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>24.6</td>
<td>22.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>20.9</td>
<td>16.9</td>
<td></td>
</tr>
</tbody>
</table>
The measurement of turbidity of water after soaking pellets with different binders for 2h also helped in understanding the effect of binder and the pelleting temperature on stability. As the leaching and disintegration of pellets progressed, the turbidity of water in which they were soaked increased. The turbidity of water in which pellets with PMC were soaked, recorded lowest nephelometer reading (10.6 maximum) (Fig. 2). Pellets with wheat gluten as binder resulted in higher values of turbidity (18.6 units maximum). Pellets with guar gum as binder resulted in intermediate values of turbidity (15.3 maximum) between that of PMC and wheat gluten.

Pelleting temperatures of 70, 80 and 90 °C appeared to have very little influence on water turbidity (Fig. 2) of pellets with binder PMC giving nephelometer readings in the range of 10.6 – 10.8. However, in the case of wheat gluten and guar gum, increase in pelleting temperature from 70 to 90 °C marginally reduced the turbidity of water, showing a decrease from 18.6 to 17.0 and from 15.3 to 14.9 nephelometer readings for wheat gluten and guar gum respectively. The drop in turbidity meter reading was more pronounced in the case of wheat gluten than in guar gum. These data indicate that increase in pelleting temperature reduces leaching and disintegration of pellets when guar gum and wheat gluten are used as binders. Polymethylolcarbamide (PMC) appeared superior among the three binders tested, followed by guar gum and wheat gluten, in the present study.

Ring-die (R-D) pellet mill is extensively used in shrimp feed pellet manufacturing, as these machines efficiently operate at low moisture (16-17%) and low temperature (70–90 °C) (Bortone, 2003) and give continuous output, that can be cooled and packed directly. Higher moisture levels create problems of feed mash sticking to the die and the rollers, resulting in choking. Polymethylolcarbamide (PMC) seems to be the most preferable binder for the R-D pellet mill as it has low moisture uptake (13.9 to 16.9%) and imparts good aqua-stability to pellets at low inclusion level (Hertramf, 1991) and at low temperatures (70-90 °C), which are the most desirable conditions for smooth working of R-D pellet mill. Victor and Shivanandamurthy (2003) made similar observations while comparing synthetic binder and wheat gluten. As wheat gluten absorbs more moisture (20.9 to 26.0%) and could impart improved pellet stability only at higher pelleting temperature (90 °C), wheat gluten can be preferred as binder only next to PMC in R-D pellet mills. While analysing the use of wheat flour as binder in shrimp feeds, Ryu et al. (1995) observed that higher moisture is required for gelatinization of wheat flour starch. Further, wheat gluten is a more expensive binder as opined by Victor and Shivanandamurthy (2003), even though it contributes protein to the diet.

Guar gum also showed higher absorption of moisture (16.2 to 17.2%), which is however, within the desirable limits required for the R-D pellet mill. However, the pellets containing guar gum bulge and develop cracks when put in water. Like wheat gluten, guar gum is also expensive; hence use of guar gum as binder has no advantage over PMC. The cost of PMC is Rs. 150/- per kg and that of both guar gum and wheat gluten is Rs. 80/- per kg. At an inclusion level of 0.5%, the cost of PMC per tonne of feed will be Rs. 950/-. For guar gum, the cost for tonne of feed is Rs. 1050/- at the inclusion level of 2% and for wheat gluten, the cost
will be Rs. 240/- for tonne of feed at the inclusion level of 3%. Thus PMC works out to be less expensive among the three.

The results of the present study demonstrated that PMC like synthetic binders are more suitable for processing shrimp feeds in ring-die pellet mill. It is required only at low inclusion levels and has the advantage of providing more space for the inclusion of other essential ingredients in the feed formulation in addition to being less expensive.

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References


