*Fishery Technology*
1995, Vol. 32 (1) pp : 19 - 24

# Formulation and Characterisation of Some Pelleted Feeds for *Penaeus monodon*

**P. Gokulakrishnan and S. Bandyopadhyay***
*Aquacultural Engineering Section*
*Department of Agricultural and Food Engineering*
*Indian Institute of Technology*
*Kharagpur - 721 302, India*

Three least cost feed formulae were designed with the help of linear programming model on the basis of nutritional and energy requirement of *Penaeus monodon* and processed through conventional meat mincer and cooking extruder. Four feeds developed from these formulae were characterised with respect to proximate composition, energy, pellet diameter, true and bulk densities, settling rate and water stability. Results showed that these feeds resemble some commercial shrimp feeds available in the market. Aquarium culture experiments with these feeds yielded feed conversion ratio similar to each other, but slightly higher than that of the commercial feed sample.

**Key words : Feed formulation, feed characterisation, *Penaeus monodon*, pelleted feed.**

Shrimp aquaculture technology has recently gained momentum in India and many South East Asian countries because of the favourable culture conditions. The increasing prices and the expanding world market for shrimps coupled with declining shrimp production from the marine sources make the aquaculture industry a major foreign exchange earner. At present modified extensive and semi-intensive culture systems which are being widely adopted in the country for shrimp culture depend primarily on steady supply of supplementary artificial feed. Supply of artificial feed, however, is dependent to a large extent on import and the technology of formulation and processing is not available in the country. Development of indigenously formulated and processed shrimp feeds is, therefore, imperative. The objective of the study was to develop cost-effective shrimp feeds for *Penaeus monodon* based on judicious selection of ingredients, nutritional needs of the species, and a suitable technology for processing.

## Materials and Methods

Raw ingredients commonly used for formulation of shrimp feeds were selected. Source, form and proximate composition of these ingredients are given in Table 1. Shrimp head meal, shrimp meal and mussel meat were processed in the laboratory from raw materials procured from the local market. Full fat soy flour was processed from the soy bean procured from the local market. Most of the ingredients were ground in hammer mill and sieved, and the fraction passing through 250 μm sieve were used for feed processing. The refined ingredients used for formulation were coated ascorbic acid, vitamin and mineral mix, cholesterol, sodium dihydrogen orthophosphate, cod liver oil and binder. These were of either animal feed grade or laboratory reagent grade quality.

Since the cost of raw ingredients contribute to a high proportion of the total operating cost, a least cost formula has to

* Corresponding author

be worked out by optimisation so that ingredients providing necessary nutrient levels may be changed according to availability, price and quality. Based on the nutritional requirements of a particular species, e.g. protein, fat, carbohydrate, ash, fibre and energy (dependent variables) a linear programming model can be formulated by adjusting the decision variables so as to minimise the cost (performance function).

If $x_1, x_2 \dots x_n$ be the ingredients and $c_1, c_2, \dots c_n$ be their costs, the objective function is to minimise

$$f(x) = c_1x_1 + c_2x_2 + \dots + c_nx_n \qquad \dots (1)$$

subject to the constraints

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \geq b_1 \qquad \dots (2)$$
$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \geq b_2$$
$$\dots\dots$$
$$\dots\dots$$
$$a_{n1}x_1 + a_{n2}x_2 + \dots + a_{nn}x_n \geq b_n,$$

where $x_1, x_2, \dots$ are the amounts of various ingredients; $c_1, c_2, \dots$ are the costs per unit weight of the ingredients; $a_{11}, a_{12} \dots$ are the nutritional contents of the ingredients; and $b_1, b_2, \dots$ are the recommended dietary intake of the nutrients for the species. Solution of the linear model was done using available software package.

Two different technologies were followed for processing of formulation, one by pelletisation through conventional meat mincer/grinder and the other by extrusion cooking. In both the methods dry ingredients of larger quantities were first mixed thoroughly and a premix of dry ingredients of smaller quantities was then mixed with the larger mix. For pelletisation through meat mincer about 55% v/w of hot water and for extrusion through cooking extruder about 25-30% of water was mixed with the dry mix. Cod liver oil was added just before pelletisation. A single screw variable length cooking extruder designed and developed in the laboratory (Rout, 1991) was used for extrusion cooking of feeds. Operating conditions of the extruder was : temperature 80°C, speed = 90 rpm, and length/diameter ratio = 16. Wet pellets extruded from either equipment were first cooled under a fan and then dried in a tray dryer at 60-70°C to a moisture content of below 10%. Feed samples were stored in a refrigerator in sealed packets before testing.

Physical characteristics of the feed pellets like diameter, true and bulk densities, and settling rate were determined following standard methods. Water stability of the pellets following modified Hasting's method (Hepher, 1968) was carried out at 2, 4, 6 and 12 h of immersion in water and the values were reported as % pellets retained on 2.36 mm BIS sieve after 'n' hours immersion and drying the retained pellets at 110°C for 3h. Proximate composition and fibre content of ingredients and feeds were analysed following AOAC (1984) procedures.

Culture experiments with the pelleted feeds in aquarium tanks were done in 60x60x37 cm aquaria, fabricated from acrylic sheets. *P. monodon* juveniles of size 5.2-5.3 g at a stocking density of 22 $m^{-2}$ were cultured for a period of 20 days. An initial period of acclimatisation of the animals for three days was followed during which they were fed with fresh shrimp and marine snail meat and 100% water exchanged daily. About 15% water exchange was carried out in each tank throughout the culture period by maintaining a continuous flow of water through the top of the tank and siphoning of water from the bottom of the tank. Initially the feeding rate was 5% of the biomass which was decreased to

4.5% after first moulting and finally to 4% after second moulting. The whole day's ration was distributed over four times. Aeration was provided by air pumps at each tank. Range of salinity, pH and temperature was 12.5 - 14 ppt, 7.0 - 7.5 and 17 - 26°C, respectively. Salinity was measured by a salinometer (YSI model 33 of Yellow Spring Instruments, USA).

**Results and Discussion**

Three formulae were designed from the list of ingredients given in Table 1 with the help of linear programming model. The three formulae varied basically with the content and quality of fish meal such as (a) Formula I with imported fish meal ($F_1$), (b) Formula II with 30% replacement of fish meal with full fat soy flour ($F_2$ & $F_3$), and (c) Formula III with indigenous fish meal ($F_4$). In Formulae I and II 1.5% binder was used, but in Formula III 2% binder was included. In these formulae the recommended dietary intake of the *P. monodon* juveniles which constituted the constraints 'b's in Eq. (2) were set as follows:

$$44.44 \leq b_1 \geq 38.99$$
$$11.11 \leq b_2 \geq 6.66$$
$$17.78 \leq b_3$$
$$3.35 \leq b_4$$
$$411.11 \leq b_5 \geq 316.67,$$

where $b_1$ to $b_4$ are protein, fat, ash and fibre, respectively, in % and $b_5$ is digestible energy, in kcal $100g^{-1}$. The dietary nutrient levels and the energy were arrived at on the basis of practical data available for the particular species.

The other constraints were:

$$x_5 + x_6 + x_7 \geq 40$$
$$x_2 \leq 10$$
$$33.33 \leq x \geq 6,$$

where all the values are in %. The vegetable protein ingredients were kept at a minimum of 40% to restrict the cost of the ingredients. The inclusion level of shrimp head meal ($x_2$) was limited to 10% on a trial

Table 1. Raw ingredients, their source, form and proximate composition

| Code No. | Ingredient | Source/form | Proximate composition, % dry basis | | | | |
|---|---|---|---|---|---|---|---|
| | | | Protein | Fat | Ash | Carbohydrate | Fibre |
| $X_1$ | Fish meal | Imported, Aquaculture feed grade | 76.18 | 10.82 | 12.64 | 0.36 | 0.21 |
| $X_{11}$ | Fish meal | Indigenous, mixed size | 58.31 | 1.81 | 35.70 | 4.18 | 1.03 |
| $X_2$ | Shrimp head meal | Processed in the lab | 46.49 | 5.30 | 36.69 | 11.52 | 8.39 |
| $X_3$ | Mussel meat | Processed in the lab | 47.42 | 16.61 | 27.86 | 8.11 | 4.72 |
| $X_4$ | Shrimp meal | Processed in the lab | 51.26 | 1.79 | 40.20 | 6.75 | 5.17 |
| $X_5$ | Wheat flour | Local purchase | 11.78 | 0.97 | 0.71 | 86.54 | 0.42 |
| $X_6$ | Full fat soy flour | Processed from beans | 49.11 | 24.48 | 4.79 | 21.62 | 3.46 |
| $X_7$ | Deoiled rice bran | Local purchase | 17.18 | 0.51 | 18.81 | 63.50 | 15.45 |

Table 2. Proximate composition and energy of the commercial feeds and the feeds processed in the laboratory

| Code No. | Type/Formula | Proximate composition, % dry basis | | | | | Energy, kcal $100g^{-1}$ |
|---|---|---|---|---|---|---|---|
| | | Protein ($b_1$) | Fat ($b_2$) | Ash ($b_3$) | Carbohydrate | Fibre ($b_4$) | ($b_5$) |
| Comm. | Grower-1 | 48.57 | 6.25 | 10.60 | 34.58 | 2.23 | 388.85 |
| Comm. | Grower-2 | 46.20 | 7.45 | 15.10 | 31.25 | 2.97 | 376.85 |
| $F_1$ | Formula I | | | | | | |
| | - Expt. | 40.08 | 8.47 | 15.62 | 35.83 | 1.73 | 379.87 |
| | - Calc. | 38.89 | 8.30 | 16.65 | 34.15 | 3.50 | 366.90 |
| $F_2$ | Formula II | | | | | | |
| | - Expt. | 42.45 | 11.23 | 15.05 | 31.27 | 2.44 | 395.95 |
| | - Calc. | 38.89 | 10.87 | 15.74 | 35.20 | 3.50 | 383.37 |
| $F_3$ | Formula II | | | | | | |
| | - Expt. | 41.66 | 11.16 | 15.09 | 32.09 | 2.69 | 395.44 |
| | - Calc. | 38.89 | 10.87 | 15.74 | 32.50 | 3.50 | 395.95 |
| $F_4$ | Formula III | | | | | | |
| | - Expt. | 38.20 | 10.94 | 17.91 | 32.95 | 2.11 | 383.06 |
| | - Calc. | 37.77 | 11.06 | 17.78 | 30.87 | 3.10 | 374.18 |

Expt. = values from proximate analysis; Calc. = values calculated from the formula

basis, due to its uncertain availability and high fibre content. The minimum and maximum inclusion levels of any ingredient were fixed within 6% and 33% considering the minimum and maximum values of most of the ingredients used for practical diet preparation for marine penaeid shrimps (Tacon, 1993).

In Formula III the minimum protein requirement was relaxed by 1% because of the high ash content and the minimum inclusion level for mussel meat and shrimp meal was not fixed in order to overcome the infeasible solution.

All the three formulae were processed through the meat mincer ($F_1$, $F_2$, $F_4$) and while Formula II was processed also through the cooking extruder ($F_3$). Proximate composition and energy of the four feeds processed in the laboratory ($F_1$, $F_2$, $F_3$ and $F_4$) and two commercial feeds available in the country (Grower-1 and Grower-2) are given in Table 2. Physical characteristics of feed pellets are given in Table 3 and Fig. 1, respectively. The commercial feeds acted as controls. Results showed that formulations arrived at by the linear programming model and processed in the laboratory by two different technologies closely resemble the commercial feeds in proximate composition and digestible energy but with a little lower protein and higher fat content. However, the nutrients were well within the range of recommended dietary intake of *P. monodon* juveniles. The bulk and true densities, and the settling rates of the commercial feeds were higher than the present feeds. Water stability of the commercial feeds was also higher, but stability of the feed with 2% binder ($F_4$) at 2, 4 and 6 h immersion was not statistically different (e.g., for 2 h immersion period, $F_{2,2}$ = 0.73 at p = 0.05) from that of the commercial feeds. The stability of the feed processed through extrusion cooking ($F_3$) was low and the difference was significant when compared with the feeds processed through meat mincer ($F_1$, $F_2$ and $F_4$). The low water stability of $F_3$ might have been due to the extruder operating conditions maintained below the optimum level (George, 1993).

Table 3. Pellet size, true and bulk densities and settling rate of different feeds

| Feed type | Pellet dia., mm | True density, kg $m^{-3}$ | Bulk density, kg $m^{-3}$ | Settling rate, m $s^{-1}$ |
|---|---|---|---|---|
| Comm. Grower-1 | 2.34 | 1284 | 710 | 0.088 |
| Comm. Grower-2 | 2.11 | 1328 | 800 | 0.102 |
| $F_1$ - Formula I | 2.50 | 1214 | 590 | 0.076 |
| $F_2$ - Formula II | 2.51 | 1232 | 640 | 0.075 |
| $F_3$ - Formula II | 2.82 | 1278 | 670 | 0.084 |
| $F_4$ - Formula III | 2.47 | 1240 | 670 | 0.067 |

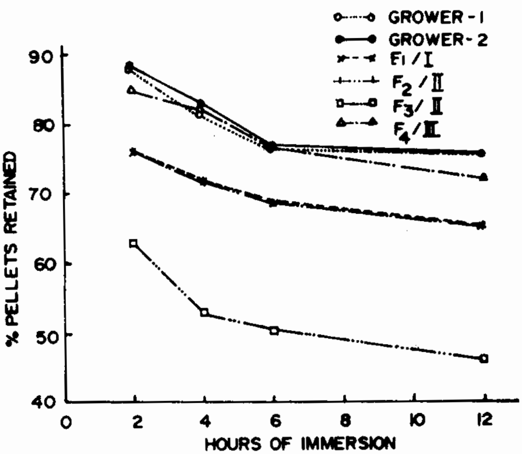


Fig. 1. Water stability of feed pellets

Results of aquarium culture experiments are shown in Table 4. The experiments were carried out with four different feeds ($F_1$, $F_2$, $F_3$ and $F_4$) processed in the laboratory along with a commercial feed sample (Grower-2) as control feed. (Number of replications was 2x8, i.e. each feed was given to 16 animals in 2 tanks). Growth of the shrimps fed with the control feed was the best followed by $F_3$, $F_2$, $F_1$ and $F_4$ but the difference between $F_4$ and control only was statistically significant ($F_{1,30}$ = 4.26 at p = 0.05). The difference in growth among the feeds processed in the laboratry was not statistically significant ($F_{2,30}$ = 0.49 at p = 0.05). Since the growth was similar with $F_1$ and $F_2$, 30% substitution of fish meal by soy flour did not appear to have any adverse effect on the growth rate. In case of $F_4$, level of inclusion of shrimp meal and mussel meat was made zero, and the feed was processed with indigenous fish meal. Performance of this feed was, therefore, not unsatisfactory, but the lower cost of indigenous fish meal would be counter balanced by the cost of the higher content of the binder.

Table 4. Results of culture experiments

| Feed types/ Formula | Comm. Grower-2 | Processed in the lab | | | |
|---|---|---|---|---|---|
| | | $F_1$/I | $F_2$/II | $F_3$/II | $F_4$/III |
| Av. initial weight, g | 5.28 | 5.23 | 5.24 | 5.25 | 5.21 |
| Av. final weight, g | 6.40 | 6.18 | 6.19 | 6.29 | 6.11 |
| Growth rate, % | 21.26 | 18.16 | 18.27 | 19.80 | 17.35 |
| Feed consumption, g | 29.11 | 29.11 | 29.11 | 29.11 | 29.11 |
| FCR | 3.24 | 3.83 | 3.80 | 3.51 | 4.03 |
| Mortality, % | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

FCR - Food conversion ratio

The authors are thankful to Mr. M.K. Behera for extending help and facilities to them for carrying out aquarium culture experiments at his farm at Chandipur road, Balasore, Orissa.

## References

AOAC (1984) *Official Methods of Analysis* 14th edn., Association of Official Analytical Chemists, Arlington, USA

George, K.O. (1993) *Studies on Extrusion Cooking Technology for Shrimp Feed Processing,* M. Tech Thesis, I.I.T. Kharagpur, India

Hepher, B. (1968) *General Report of the Working Party on Recent Developments in Fish Feed Technology* FAO FI/ EIFACC 68, Appendix 4, 48

Rout, R.K. (1991) *Studies on Extrusion Characteristics of Prawn Feed Formulations,* Unpublished Report, Agricultural Engineering Department, I.I.T., Kharagpur, India

Tacon, A.G.J. (1993) *Feed ingredients for crustaceans - natural foods and processed feed stuffs.* FAO Fisheries Circular No. 866, FAO, Rome