THE IMPACT OF PARTICLE SIZE OF INGREDIENTS IN COMPOUNDED DIETS ON PELLET STABILITY AND PERFORMANCE IN *PENAEUS INDICUS* H. MILNE EDWARDS

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ABSTRACT

The impact of particle size of ingredients in a research diet and a practical feed in the water stability of pellets, their digestibility, growth, and food conversion ratio in the prawn *Penaeus indicus* were investigated. The research diet consisted of casein, cod-liver oil, sucrose, starch, cellulose, and other additives while the practical feed was made up of prawn waste, mantis shrimp (*Squilla*), fish meal, groundnut oilcake and tapioca. Casein in the research diet and prawn waste, mantis shrimp, and groundnut oilcake in the practical feed were prepared into particles of 500, 420, 300, 250, 210, 100, and 50 μm and dry pellets were prepared with ingredients in each size. The pellets of the diet compounded with the ingredients of 212 μm exhibited the highest water stability ($P < 0.05$) both in the research diet and in the practical feed. These pellets fed to *P. indicus* showed high digestibility, superior growth ($P < 0.05$) and the best food conversion ratio compared to the diets prepared with all the other particle sizes. The significance of grinding the ingredients to specific particle size in compounded diets is discussed.

The water stability of an aquatic feed plays an important role in determining the overall performance of the feed (Forster and Gabbot, 1971; Farmanfarmaian and Lauterio, 1982). Feed pellets which disintegrate faster facilitate rapid leaching of nutrients, especially the micronutrients, leading to non-availability to the animal. This leads to pollution of the water and also results in economic loss. The water stability of the feed depends primarily on the binding material used (New, 1976; Ahmad Ali, 1988). However, the method of preparation of the feed also contributes considerably to its stability. Invariably, in formulating research diets and practical feeds, a variety of ingredients with different properties are used. Grinding the raw materials to a uniform particle size is essential for preparing a homogeneous feed mixture. The impact of particle size of these ingredients on the stability and digestibility of the feed is not known. In this context, the effect of particle size of ingredients on the pellet stability in the water and the digestibility of a research (purified) diet and a practical prawn

J. Aqua. Trop., **6** (1991) 119–127
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feed was evaluated for the prawn *Penaeus indicus* in the present study and the results obtained are discussed.

MATERIALS AND METHODS

To study the impact of particle size of ingredients on the pellet stability, food conversion ratio, digestibility, and growth of prawns, a research diet and practical prawn feed were selected.

Research diet

The research diet consisted of the purified ingredients—casein, sucrose, starch, cod-liver oil, cellulose, vitamins and minerals, and other additives, the composition of which is given in Table 1. Chromium oxide was included for digestibility determination and sodium alginate was used as the binder. Among the solid ingredients obtained, only casein was in granular form and all the others were fine powder. Hence only casein was prepared into different particle sizes. It was first dried in the oven at 60 ± 2°C for 12 hours and powdered in a micro-pulverizer, using 1.0 mm mesh sieve. The powdered material was sieved through seven different standard sieves of 500, 420, 300, 250, 212, 100, and 50 µm mesh sizes with the help of a mechanical sieve shaker. The particles passing through 500 µm sieve, but retained by 420 µm sieve were taken as 500 µm particles. The particles passing through 420 µm sieve and retained by 300 µm sieve were taken as 420 µm particles. Particles of all other sizes were similarly obtained. Thus, casein was prepared into samples of particle sizes 500, 420, 300, 250, 212, 100, and 50 µm.

Practical feed

The practical feed consisted of prawn waste, mantis shrimp (*Oratosquilla nepa)*, fish meal, groundnut oilcake, and tapioca, the proximate composition of which is given in Table 2. Among the ingredients, prawn waste, mantis shrimp, and groundnut oilcake were separately prepared into six samples of particle sizes 500, 420, 300, 250, 212, and 100 µm as described for the research diet. Since fishmeal and tapioca were available in fine powder form, they could not be prepared into different particle sizes.

Preparation of diet and feed

In the case of research diet, seven diets (1–7) were prepared into dry pellets of 3 mm diameter having 500, 420, 300, 250, 210, 100, and 50 µm particles of casein respectively, whereas in the case of practical feed, seven feeds (8–14); mixed particle sizes obtained without sieving) were prepared as dry pellets (3 mm diameter) having similar descending order of particles. Starch in the tapioca served as binder in practical feed. The pellets were made with the aid of a hand pelletizer. They were cut into pieces of approximately 5 mm length.

Water stability of pellets

Thirty pellets of each diet and feed were taken into previously dried and weighed pouches of bolting cloth (no. 30) and the weight of the pellets was recorded. The pouches were slowly immersed in troughs containing 25 l of water having 8 cm depth, and placed in a Petri dish at the bottom of the trough. For each diet, nine pouches were simultaneously lowered in the trough. At the end of one hour the Petri dish along with the pouch was gently taken out, the physical shape of the pellets was noted, the adhering salt was carefully washed away, and the pellets were dried in the oven at 60°C for 24 hrs.

The loss in weight of the pellets was recorded. Similarly, the pellets remained in water for 2, 3, 4, 5, 6, 8, 12, and 24 hr intervals and were treated and the loss in weight was calculated. The experiment was repeated thrice and the average loss in weight in each case was determined. The salinity, temperature, and pH of the water used in the troughs are the same as reported for the feeding experiments.

Feeding experiments

For determining the digestibility, growth, and food conversion ratio of each group of pellets, hatchery-reared juveniles of the prawn *P. indicus* with an average length and weight of 33 mm and 0.331 gm respectively were stocked at the rate of six animals in a circular trough of 30 l capacity. There were three replicates for each treatment. The prawns were fed at the rate of 20% body weight initially and feeding was regulated according to the left-over food, each day. The animals were fed twice daily, the feed being divided in equal portions. Water management in the troughs was carried out by removing the sediments, providing aeration, and changing the water completely once in five days. The salinity of the water was maintained at 15 ± 1‰, temperature at 28 ± 1°C, oxygen at 4.1 mg/l and pH at 8.2 ± 0.2. The duration of the feeding experiment was 30 days. Separate feeding experiments were conducted with research diets and practical feeds.

For determining the digestibility, faeces were carefully collected and pipetted on bolting cloth and gently washed with distilled water. The samples were dried in the oven at 60°C for 12 hrs. Faeces accumulated over the period of feeding experiments were analysed for chromium oxide content.

Growth was calculated by the following formula:

$$\frac{\text{Final average weight} - \text{initial average weight}}{\text{Initial average weight}} \times 100$$

Food conversion ratio was determined by the following formula:

$$\frac{\text{Quantity of food consumed (in dry weight)}}{\text{Increase in live weight}}$$

The chromium oxide content in diets and faeces was determined by the method of McGinnis and Kastings (1964) and the total digestibility was determined as follows:

$$\text{Digestibility (\%)} = 100 \frac{\%\ Cr_2O_3 \text{ in faeces}}{\%\ Cr_2O_3 \text{ in feed}}$$

Statistical analysis

The data obtained in the different experiments were subjected to analysis of variance following the method of Snedecor and Cochran (1971).

RESULTS AND DISCUSSION

The results of the present study clearly indicate that in the purified diet, the weight loss of pellets became lesser with the increase in particle size of casein (Fig. 1) from 50 µm to 212 µm and the same was increased as the particle size increased from 212 to 500 µm (Fig. 1). Minimum loss was exhibited by diet 5 having 212 µm casein particles ($P < 0.05$). The changes

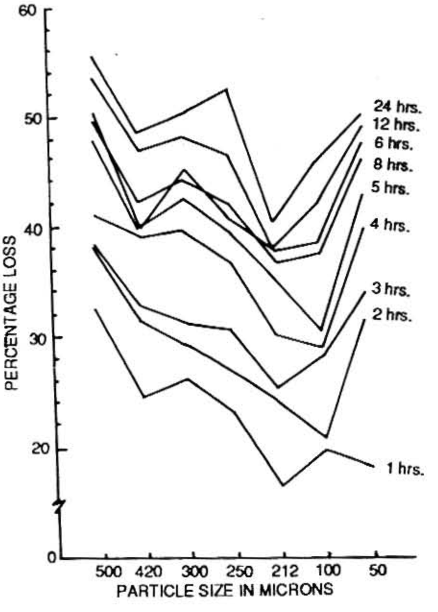

Fig. 1. Relationship between loss of weight (pellet stability) and particle size of casein in the diet 1–7

occurring in the external shape of the pellets with time revealed that the smaller the particle size of the ingredients the more stable the pellet. Only the pellets of diets 5, 6, and 7 could retain the original shape for six hours in the increasing order of stability. The results were similar in practical feeds. The loss of weight in pellets (Fig. 2) of the feeds gradually decreased with the decrease in particle size from 500 to 212 µm, the weight loss being the minimum at this point. It again increased as the particle size of the ingredients further decreased from 212 to 100 µm. It is of interest to note that the weight loss was maximum in feed 14 (unassorted). However, the difference in the loss of pellets of different feeds was not statistically significant ($P < 0.05$) except in feed 14.

In this set, the feed consisting of 212 µm particles showed the highest stability in terms of weight loss and physical shape confirming the results obtained with the research diets. While the water stability of aquatic feeds, especially of the prawn feeds, had been studied

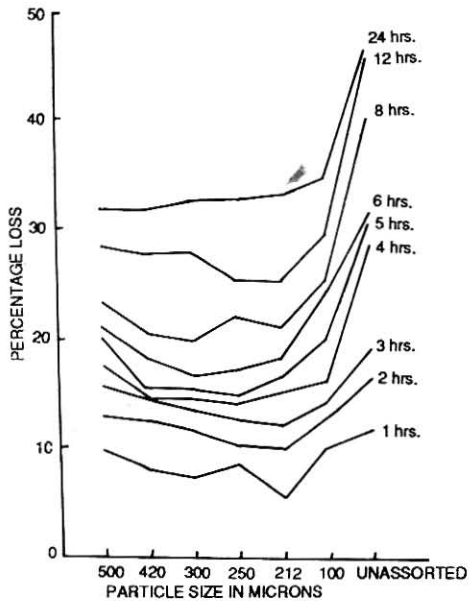

Fig. 2. Relationship between loss of weight (pellet stability) and particle size of ingredients in the feed 8–14

(Meyers and Zein-Eldin, 1972; Goswamy and Goswamy, 1979; Farmanfarmaian and Lauterio, 1982; Ahmad Ali, 1988) in relation to different binders, the studies on the water stability of feed pellets in relation to the particle size of constituent ingredients could not be

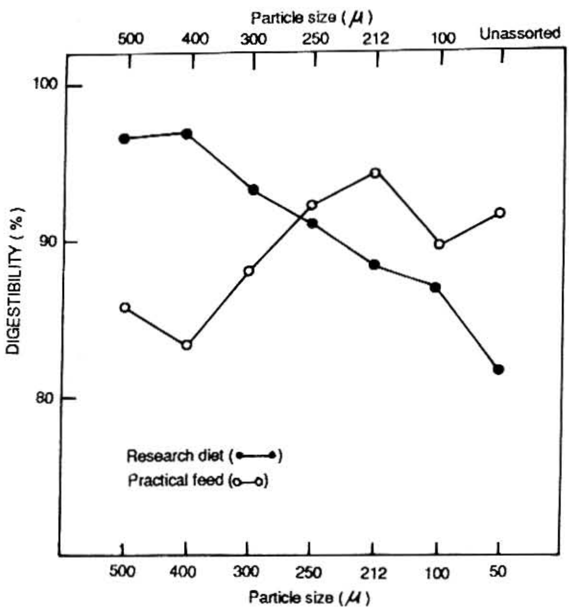

Fig. 3. Relationship between size of the ingredient particles of the feed 1–14 and digestibility of the recipient prawn

Table 1. Composition of the research diet

Ingredients	Quantity
Casein	40 gm
Cod-liver oil	5 gm
Sucrose	10 gm
Starch	30 gm
Sodium succinate	0.3 gm
Sodium eitrate	0.3 gm
Ascorbic acid	0.5 gm
Choline chloride	0.6 gm
Inositol	0.2 gm
Cholesterol	0.5 gm
Glucosamine HCl	0.8 gm
Sodium carbonate	1.0 gm
Cellulose	7.8 gm
Cr_2O_3	0.5 gm
Sodium alginate	3.0 gm
Tap water	60 ml

Table 2. The proximate composition of the research diet and practical feed

	Research diet	Practical feed
Crude protein	40%	38.5%
Lipid	5%	6%
Carbohydrate (nitrogen-free extract)	36.7%	24.4%
Ash	4.5%	19.9%
Crude fibre	7.8%	6.2%
Moisture	6%	5%

traced in the literature. In the present study, grinding the ingredients to bigger and smaller particles resulted in poor stability of the pellets in the water. More space between the larger particles of the ingredients might be responsible for lesser stability of the pellets prepared with larger particles. As the particle size becomes smaller, feed becomes more compact, which improves the durability of the pellets. On the other hand, the finer particles below 200 μm may facilitate leaching of the nutrients, though their physical shape is apparently stable.

The minimum digestibility (81.4%) of diet 7 and the maximum digestibility of diet 2 (96.7%) were observed in the research diet. However, the digestibility steadily declined with the descending order of particle sizes from 500 to 50 μm (Fig. 3). The difference in the digestibility attained by the first four diets was not significant ($P < 0.05$), but the digestibility of diet 7 was significantly lower. Contrary to these results, the digestibility of practical feed gradually increased (Fig. 3) as the particle size declined from 500 to 212 μm. The digestibility of 94.23% of feed 12 (212 μm) was remarkably higher than that of all other feeds. The contrasting behaviour exhibited by the research diet and practical feed is clear

Table 3. Results of feeding experiment with research diets 1–7 fed to *P. indicus* for 30 days

	Diet number						
	1	2	3	4	5	6	7
No. of animals receiving the diet	18	18	18	18	18	18	18
Initial average length (mm)	37.36	37.1	37.1	37.1	37.7	37.7	37.9
Initial average live weight (g)	0.331	0.331	0.331	0.331	0.331	0.331	0.331
Initial average dry weight (g)	0.0785	0.0785	0.0785	0.0785	0.0785	0.0785	0.0785
Final average length (mm)	45.4	48.2	43.85	53.1	58.16	55	56.15
Final average live weight (g)	0.604	0.706	0.498	1.04	1.17	0.953	0.996
Final average dry weight (g)	0.168	0.19	0.1345	0.3685	0.33	0.28	0.256
% increase in length	22.17	29.63	17.7	42.6	54.23	45.6	49.7
% increase in live weight	82.37	113.42	50.5	212.18	254.8	187.6	209.3
% increase in dry weight	114.4	141.6	72.1	288.99	321.1	265.8	280.2
Food conversion ratio	13.86	12.5	13.12	6.11	4.7	6.06	5.73

Table 4. Results of feeding experiment with practical feeds 8–14 fed to *P. indicus* for 30 days

	Feed number						
	8	9	10	11	12	13	14
No. of animals stocked in each trough	18	18	18	18	18	18	18
Initial average length (mm)	30.0	29.9	29.1	29.2	30.4	29.5	30.63
Initial average live weight (g)	0.143	0.143	0.143	0.143	0.143	0.143	0.143
Initial average dry weight (g)	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336
Final average length (mm)	44.10	45.67	43.76	48.2	46.4	45.3	45.16
Final average live weight (g)	0.547	0.513	0.4161	0.602	0.645	0.566	0.387
Final average dry weight (g)	0.125	0.122	0.085	0.126	0.124	0.129	0.107
% increase in length	47.67	51.82	49.65	64.7	52.8	53.1	49.76
% increase in live weight	282.47	259.1	188.01	324.03	399.0	294.9	179.8
% increase in dry weight	280.7	264.3	154.2	272.2	314.9	284.4	223.0
Food conversion ratio	3.96	5.82	6.66	4.2	4.5	6.2	10.1

from the present experimental results. The reason for such behavior can be accounted for by the nature of the constituent ingredients, which are different in these diets and feeds. In practical feeds grinding the mantis shrimp and prawn waste, which are coarse in nature, to specific particle size favoured the efficient digestion of nutrients. This is clearly expressed by the better digestibility shown of feeds 8 to 12 with the decrease in the particle size. It appears there may be two reasons for the low digestibility of the feeds with less than 100 um particle size. First, the finer particles make the pellets very hard and, second, they accelerate leaching of a large quantity of digestible matter. This is further supported by the fact that feed 14 with mixed particle sizes having moderate stability had shown higher digestibility (91.8%) than that of the feeds with specifically finer particles. The same reasons can explain the decreasing tendency in the case of purified diets with finer particles.

Both the diet and the feed with 212 μm particles significantly enhanced the growth of prawns ($P < 0.05$). Similarly, the same particle size had shown the lowest food conversion ratio in the diet and feed, which is significantly better ($P < 0.05$) than that of the other diets and feeds. Excluding the diet and feed having 212 μm, all other diets and feeds (lower as well as higher) yielded insignificant growth and a high food conversion ratio. The importance of particle size of ingredients is further supported by the above result.

The present study shows the influence of particle size of ingredients in diets on the water stability of the pellets, digestibility, growth, and food conversion ratio. The results indicate that the ingredients should be powdered to a particle size of 200 μm to achieve maximum water stability of the pellets of aquatic feeds and for their efficient performance.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to Dr. E.G. Silas, Former Director and Dr. P.S.B.R. James, Director, Central Marine Fisheries Research Institute, Cochin, for their encouragement in carrying out this work. The first author wishes to thank the Indian Council of Agricultural Research for providing a Junior Research Fellowship.

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