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A Comparison of Proximate Composition and Water Stability of Three Selected Shrimp Feeds Used in Sri Lanka

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Abstract

Feed is considered as the major expense in shrimp farming, accounting for about 50 – 60% of the total variable costs. Feed is also a major input affecting water quality and subsequently effluent quality in shrimp culture ponds. Therefore, it is important to evaluate feeds to enhance the economical and environmental sustainability of the industry. Two imported feeds from Thailand (B1) and Taiwan (B2) and one local (B3) feed used in shrimp farms were analysed for moisture, protein, lipid, ash, and energy. Pellet stability tests were conducted in salinity adjusted sea water (20 ppt) in plastic tanks (100 L) with flow (treatment) and with out flow (control). Three feed brands used in this study are available in five different sizes corresponding to stock size. Feed sizes were not significantly different ($p > 0.05$) among different feeds. There was a significant ($p < 0.05$) linear relationship between length and diameter in feeds B1 and B2 ($y = 2.78x – 0.9$ and $y = 3.2x – 1.32$, respectively) but not in the local feed. The levels of moisture, crude protein, crude lipid, ash and energy content in shrimp feeds varied from 6.1 – 11.4%, 37.4 – 46.2%, 4.5 – 11.1%, 11.0 – 13.4% and 16.6 – 24.8 kjg^{-1}, respectively. Moisture content was significantly higher ($p < 0.05$) in B3 than B1 and B2 with means of 10.3, 7.9 and 7.7%, respectively. Mean energy content in B3 (17.5 kjg^{-1}) was significantly lower ($p > 0.05$) than B1 (22.8) and B2 (21.3 kjg^{-1}).

Water stability of feeds with flow (treatment) and the control (with out flow) were not significantly different ($p > 0.05$) among feeds. Mean dry matter, protein and ash retention in crumbles after four hours of immersion varied from 81.2 – 84.3%, 59.8 – 63.8% and 64.5 – 66.2%, respectively. Same parameters in the pellets ranged from 79.1 – 83.1%, 53.7 – 65.0% and 68.4 – 71.5%, respectively. Significant differences in water stability between crumble and pellet feeds were observed in all the feed brands except protein in the imported feeds and ash in the local feed. Dry matter retention of pellets in B3 was significantly lower

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($p < 0.05$) than B2 and protein retention in B3 was significantly lower than B1 ($p < 0.1$; $p = 0.08$). Ash retention did not significantly vary among feeds. Among the three shrimp feeds, B1 had the highest water stability followed by B2 and B3 in dry matter and protein retention.

Introduction

Penaeid shrimps are the most important group of crustaceans used in aquaculture (Taboada et al. 1998). Shrimp exports have become one of Sri Lanka's major foreign exchange earners and account for nearly 90% of total aquaculture exports. Cultured shrimp production increased from 3329 mt in 1995 to 5820 mt in 2000. Shrimp culture exports earned US$ 41,593,500 in 1996 and increased up to US$ 78,34,2800 in 2000 (FAO 2002).

Feed is considered as the major expense in shrimp farming, accounting for about 50–60% of the total variable costs (Hardman et al. 1991; Meyers 1991; Kutty 1995; Flores and Martinez 1993; Ling et al. 1997; Mohanty 2001). These costs can be minimised by improving the nutritional quality and the ability of pellets to remain intact in water and through the use of appropriate feeding rates (Meyers 1991; Flores and Martinez 1993; Jorry 1996). Even if a feed has an ideal composition, its nutritional value is uncertain if it rapidly leaches after immersion. Major causes of feed induced water quality problems are: fines included with the feed, nutrients which leach from the feed and poor water stability (Cook and Clifford 1997; Obaldo et al. 2002). Pellet water stability is defined as the retention of pellet physical integrity with minimal disintegration and nutrient leaching while in the water until consumed by the animal (Obaldo et al. 2002). Adequate water stability enhances feed efficiency and prevents it from being wasted and thus polluting the culture medium.

Because of the nature of the buccal appendices and mouth, the shrimp can hardly swallow whole feed particles presented. It dissects and swallows them progressively, which inevitably leads to leaching. Exposure to water currents and aeration systems can also hasten pellet disintegration and nutrient loss in to the medium. The duration of pellet water stability required is dependant on the time required by the shrimp to consume its ration. Pellet quality therefore refers to appropriate size, resistance to crumbling and stability in water. Determination of water stability of shrimp feeds is important because they provide a means of estimating nutrient availability with time for cultured species.

There is one commercial shrimp feed producing company in Sri Lanka, which caters to the local market. The statistics of locally produced shrimp feeds are not available. Shrimp feeds are exported to Sri Lanka from India, Thailand, Taiwan and China. Comparisons of the nutrient composition and other desired feed characteristics in different shrimp feeds could be useful for farmers in the complex process of feed selection. This study was designed to investigate the variations among three commercial shrimp feeds with respect to size, proximate composition and water stability.

Materials and Methods

Two imported and one locally produced shrimp feeds used in commercial shrimp farms in Sri Lanka were compared for crumble/pellet size, proximate composition, energy content and water stability. Imported shrimp feeds from CP Aquaculture Limited, Thailand (CP shrimp feed, B1) and Tairoun Products Company Limited, Taiwan (Tairoun shrimp feed, B2) were purchased from a local feed distributor in Chilaw, Sri Lanka. The locally produced feed (Jaysons shrimp feed, B3) was obtained from the manufacturer, Jaysons Aqua Feed (Pvt) Ltd., Thoduwawa.

Pellet size

Each feed was measured for length and diameter (±0.01 mm) using a digital calliper (Aldrich, Australia). In crumbles, the highest diameter was measured for this purpose, more than 100 unbroken pellets were measured and means were calculated.

Feed quality

Samples of each feed type were analysed to determine its proximate composition; moisture, protein, lipid, ash and energy content. The moisture content and protein of feed samples were determined using standard techniques (AOAC 1990) and lipid content was determined by the method of Folch et al. (1957). All determinations were done in triplicates.

Water stability of feeds

Water stability of feeds were conducted in plastic tanks (100 L) using salinity adjusted (20 ppt) sea water at 27 ±2 °C. The tests were designed as much as possible to correspond with the conditions in the brackish water shrimp ponds where these feeds were used. Approximately 3.0 g of each feed type was placed in an empty tea bag made from oxygen bleached filter paper and suspended randomly in tanks with a flow rate of 1 L min^{-1}. Each feed type was triplicated for 1, 2, 3, and 4 h exposures. After exposure, the tea bags and feed contents were dried in an oven at 60ºC for 12 h. The amount of each diet (wet weight) and the full tea bag before and after immersion were weighed. The experiment was repeated with each diet for 1, 2, 3 and 4 h exposure with no flow. This was regarded as the control.

Dry matter retention was determined using the following formula:

$$\% \text{ DMR} = \frac{W_0 \times (1 - M) - W_t}{W_0 \times (1 - M)} \times 100$$

Where,

W_t = dry weight (g) after immersion; W_0 = pellet weight (g) before immersion (i.e. as feed); M = moisture content of pellet (%)/100

The dried samples after immersion in water were also analysed for changes in protein and ash using the same methods mentioned earlier.

Statistical analysis

Proximate composition of each feed was compared using one way ANOVA. Difference in water stability among treatment and control and differences among the feed types were compared using one way ANOVA followed by Tukey’s pair wise comparison. All the analysis were performed using MINITAB 12 for windows.

Results

Pellet size

Three feed brands (B1, B2 and B3) used in this study had two crumble feed types (L1 and L2) for the larvae and three pelleted feed types (G1, G2 and G3) for the juveniles and adult shrimp. Local feed (B3) had the smallest larval (0.3 x 0.8) feed size. However, feed sizes were not significantly different ($p > 0.05$) among the different feeds. There was a significant ($p < 0.05$) linear relationship between length and diameter in B1 and B2 feeds while it was not observed in B3 (Fig. 1).

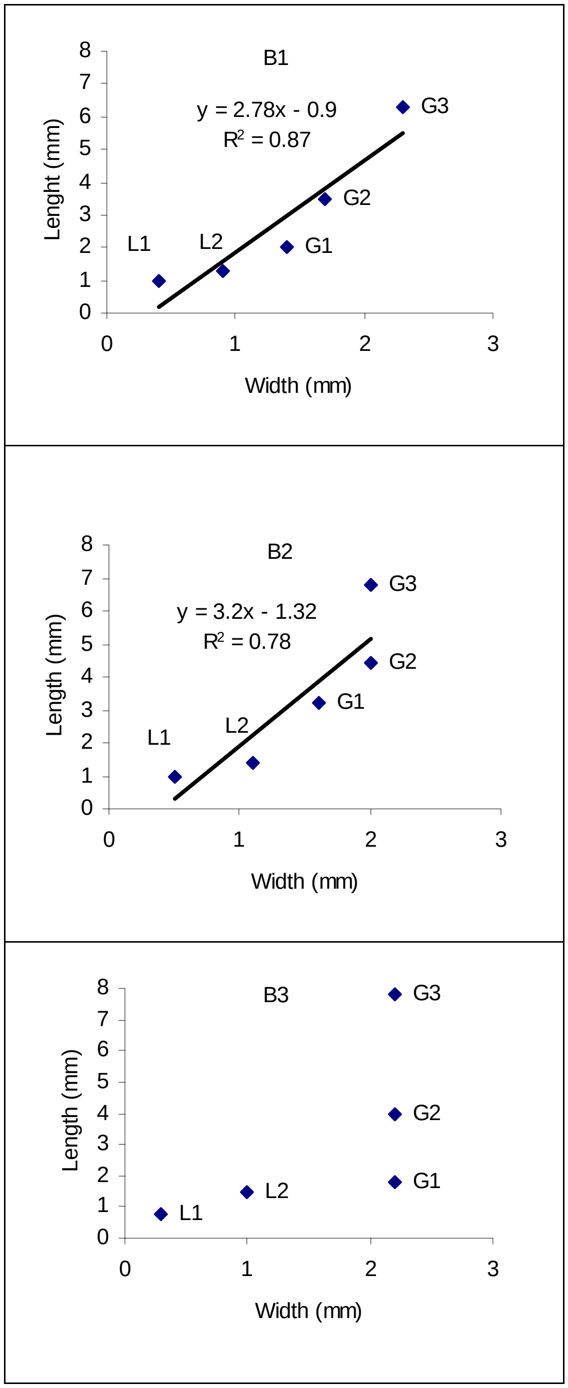


Fig. 1. Relation of width (diameter) to particle (pellet) length of imported feeds (B1, B2) and a local feed (B3) used in shrimp farms (L1 & L2 larval feed types, G1 to G3 grower feeds)

Proximate composition of shrimp feeds

Table 1 summarizes the protein, lipid, moisture and energy content of shrimp feeds. The levels of moisture, crude protein, crude lipid, ash and energy content in shrimp feeds varied from 6.1 – 11.4%, 37.4 – 46.2%, 4.5 – 11.1%, 11.0 – 13.4% and 16.6 – 24.8 kj g^{-1}, respectively. Moisture content was significantly higher ($p < 0.05$) in B3 than B1 and B2 with means of 10.3, 7.9 and 7.7%, respectively. The mean protein contents among three feed brands varied in a narrow range of 39.5 – 42.6%.

Comparatively higher lipid contents were recorded in B1 and B2 with ranges from 5.5 – 10.1% and 7.6 – 11.1%, respectively. Lipid content in B3 ranged from 4.5 – 5.8%. Lipid content in B3 was significantly lower than B1 and B2 ($p < 0.05$). Contents of ash in shrimp feeds varied between 11.0 – 13.4% with the highest mean value recorded in B2 (12.8%). Mean energy content in B3 (17.5 Kj g^{-1}) was significantly lower ($p < 0.05$) than in B1 (22.8 Kj g^{-1}) and B2 (21.3 Kj g^{-1}).

Table 1. Mean ± sd proximate composition and energy content of shrimp feeds (L1, L2 – larval feeds; G1, G2, G3 – grower feeds)

Feed type	% Moisture	% Protein	% Lipid	% Ash	Energy (Kj g^{-1})
B1:L1	7.5 ± 0.2	41.3 ± 0.1	9.4 ± 0.4	12.3 ± 0.2	24.2 ± 0.6
L2	10.0 ± 0.1	41.1 ± 0.2	5.5 ± 0.8	11.2 ± 0.9	19.1 ± 1.5
G1	7.7 ± 0.4	40.0 ± 0.7	8.6 ± 0.0	11.0 ± 0.2	23.6 ± 2.2
G2	7.3 ± 0.2	43.3 ± 0.6	10.1 ± 0.8	11.3 ± 1.0	24.8 ± 1.5
G3	7.1 ± 0.5	44.3 ± 0.2	9.5 ± 0.8	13.4 ± 0.3	22.0 ± 1.0
Mean	7.9^{a} ± 1.2	42.0^{a} ± 1.8	8.6^{a} ± 1.8	11.9^{a} ± 1.0	22.8^{a} ± 2.2
B2:L1	8.0 ± 0.1	40.6 ± 0.3	10.8 ± 0.9	13.3 ± 1.1	21.9 ± 0.9
L2	7.4 ± 0.1	42.9 ± 0.2	9.8 ± 0.4	12.3 ± 0.9	22.0 ± 2.1
G1	6.1 ± 0.3	46.2 ± 0.7	11.1 ± 0.7	12.2 ± 0.2	21.3 ± 1.5
G2	7.8 ± 0.0	42.4 ± 0.1	9.9 ± 0.8	12.8 ± 0.1	20.5 ± 1.5
G3	9.6 ± 0.2	40.9 ± 0.3	7.6 ± 0.5	13.4 ± 0.2	21.3 ± 1.1
Mean	7.7^{a} ± 1.3	42.6^{a} ± 2.3	9.8^{a} ± 1.4	12.8^{a} ± 0.6	21.4^{a} ± 0.6
B3:L1	10.0 ± 0.2	41.3 ± 0.3	5.8 ± 0.2	11.4 ± 0.6	18.3 ± 0.9
L2	11.4 ± 0.4	40.5 ± 0.6	5.2 ± 0.0	12.4 ± 0.1	16.7 ± 0.7
G1	10.5 ± 0.2	40.2 ± 0.8	4.9 ± 0.8	12.2 ± 0.2	18.0 ± 0.5
G2	9.5 ± 0.1	38.2 ± 0.1	5.5 ± 0.5	11.4 ± 0.0	17.9 ± 0.7
G3	10.4 ± 0.2	37.4 ± 0.4	4.5 ± 0.7	11.0 ± 0.1	16.6 ± 0.6
Mean	10.3^{b} ± 0.7	39.5^{a} ± 1.7	5.1^{b} ± 0.5	11.6^{a} ± 0.6	17.5^{b} ± 0.8

Means of each feed brand in different columns with different subscripts are significantly different determined by one way ANOVA following Tukey's pair wise comparison ($p < 0.05$).

Water stability of shrimp feeds

Shrimp feed crumble and pellet water stability results from the three feed brands used in shrimp farms, expressed in terms of percent dry matter, protein and ash retention are illustrated in figures 2, 3 and 4. There was a gradual loss of dry matter, protein and ash in all the feed types within four hours in the treatment and control studies. In general, a higher rate of dry matter, protein and ash loss was recorded within the first two hours of immersion than the last two hours.

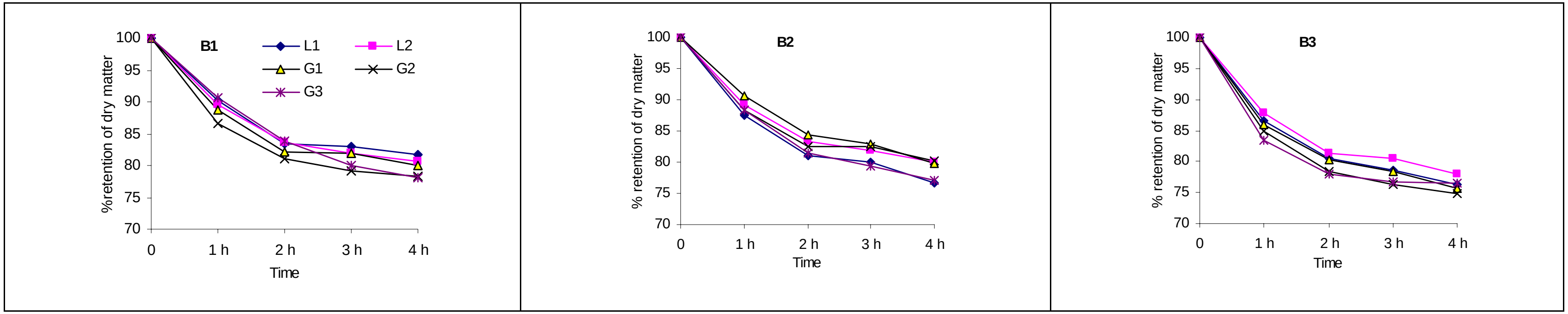
Dry matter, protein and ash retention with water flow (treatment) and the control (without water flow) were not significantly different ($p > 0.05$) among feeds. Significant differences in water stability were also not observed among different feed types of the same brand ($p > 0.05$). However, significant differences were detected between crumble and pellet feeds within same feed brand (Table 2). Water stability among the different feed brands was not significantly different except pellet dry matter retention between B2 and B3. Dry matter retention of pellets in B3 was significantly lower ($p < 0.05$) than in B2. Protein retention in B3 was significantly lower than in B1 at 0.1 level ($p < 0.1$; $p = 0.08$). Retention of ash did not significantly vary among feeds. Among the three shrimp feeds, B1 had the highest water stability followed by B2 and B3 in dry matter and protein retention (Table 3).

Table 2. Mean ± sd dry matter, protein and ash retention in crumble and pellet shrimp feeds after four hours of immersion in water (salinity – 20 ppt; temperature – 27 ± 2°C)

Parameter	Feed brand	Crumbles	Pellets
Dry matter	B1	$84.3^{a} \pm 3.9$	$82.6^{b} \pm 4.3$
	B2	$82.5^{a} \pm 4.3$	$83.1^{b} \pm 4.3$
	B3	$81.2^{a} \pm 4.3$	$79.1^{b} \pm 4.0$
Protein	B1	$63.0^{a} \pm 10.7$	$65.0^{a} \pm 12.2$
	B2	$63.8^{a} \pm 9.6$	$61.6^{a} \pm 9.6$
	B3	$59.8^{a} \pm 13.2$	$53.7^{b} \pm 13.6$
Ash	B1	$64.5^{a} \pm 4.3$	$68.4^{b} \pm 5.5$
	B2	$66.1^{a} \pm 4.4$	$71.5^{b} \pm 3.1$
	B3	$66.2^{a} \pm 3.9$	$69.5^{a} \pm 7.1$

Means of crumbles and pellets of each feed brand in different columns with different subscripts are significantly different determined by paired t-test ($p < 0.05$).

Treatment (With flow)



Control (With out flow)

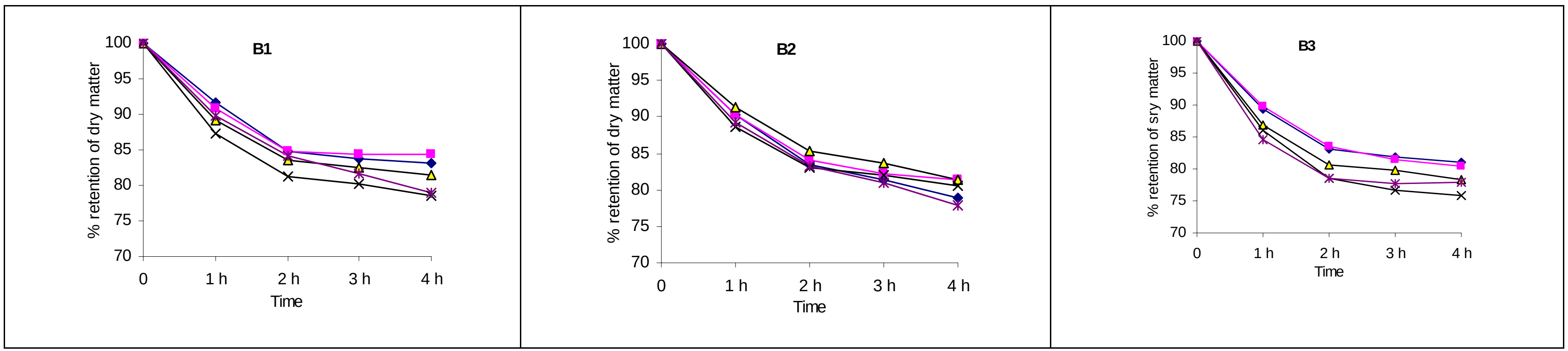
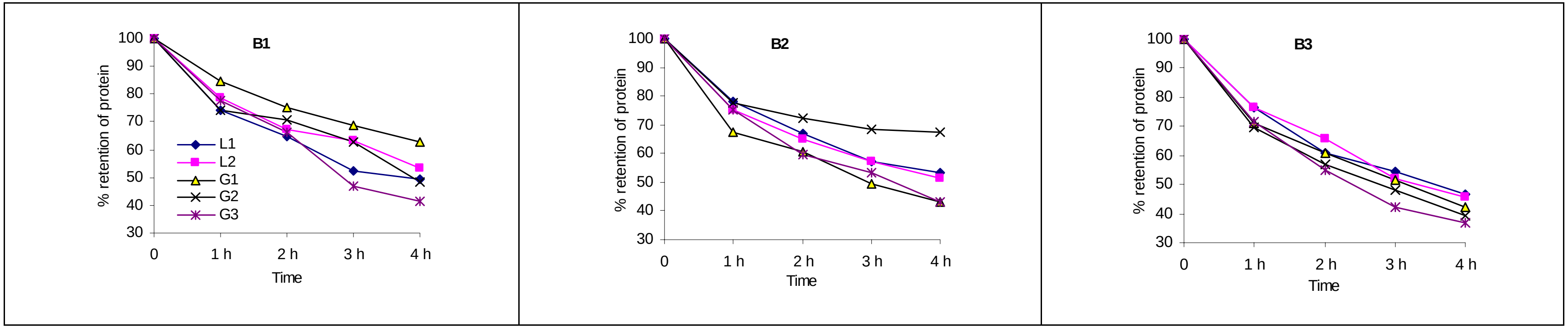


Fig. 2. Percentage dry matter retention in shrimp feeds (feeds B1, B2 & B3) after immersion in salinity (20 ppt) adjusted sea water (temperature – 27 ± 2º C) (L1 & L2 larval feed types, G1 to G3 grower feeds)

Treatment (With flow)



Control (With out flow)

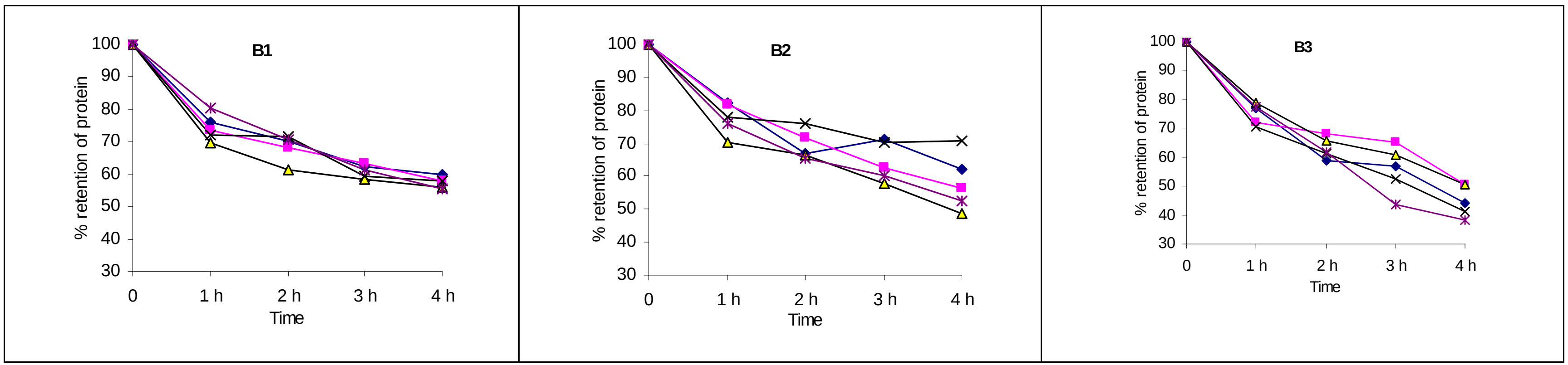
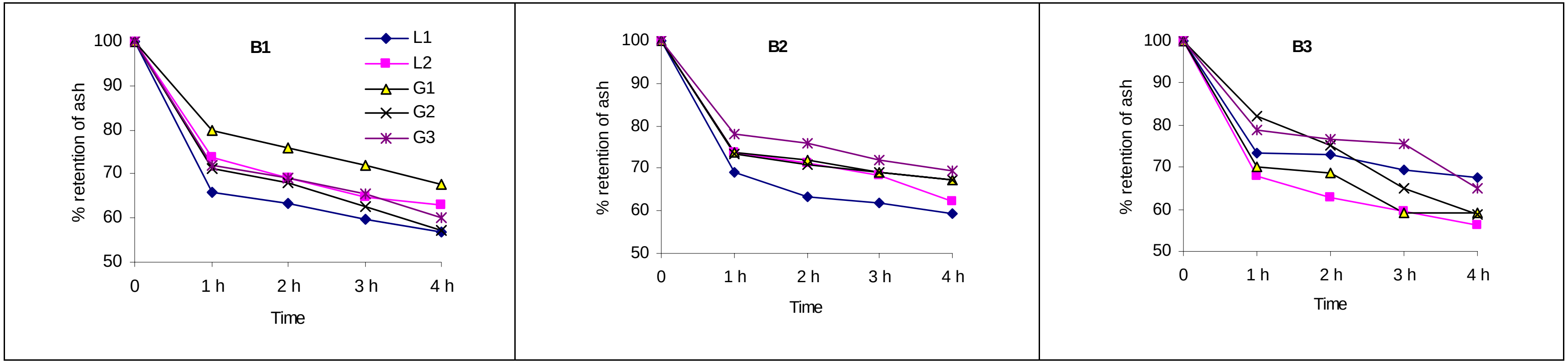


Fig. 3. Percentage retention of protein in shrimp feeds (feeds B1, B2 & B3) after immersion in salinity (20 ppt) adjusted sea water (temperature – 27 ± 2º C) (L1 & L2 larval feed types, G1 to G3 grower feeds)

Treatment (With flow)



Control (With out flow)

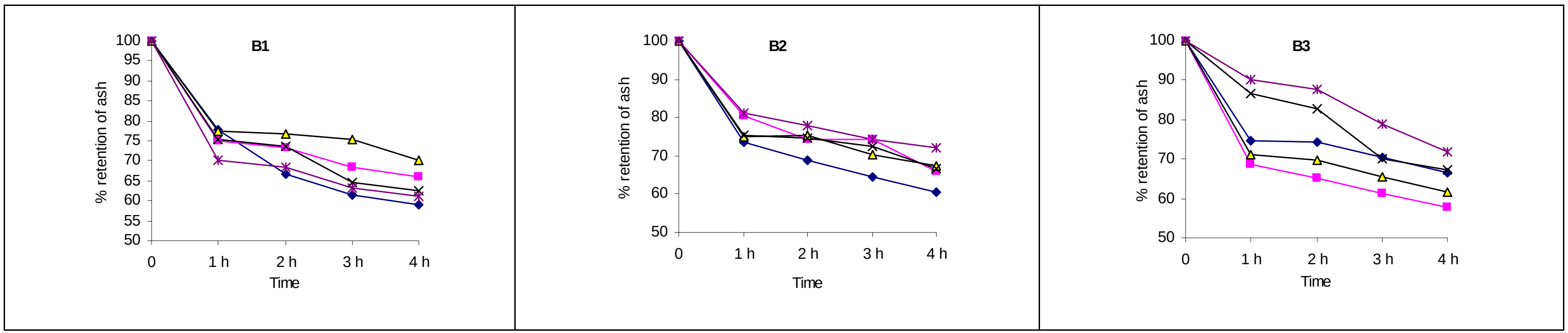


Fig. 4. Percentage retention of ash in shrimp feeds (feeds B1, B2 & B3) after immersion in salinity (20 ppt) adjusted sea water (temperature – 27 ± 2º C) (L1 & L2 larval feed types, G1 to G3 grower feeds)

Table 3. Water stability of shrimp feeds irrespective of types in relation to immersion for four hours in salinity adjusted sea water (20 ppt) with flow at a temperature of 27 ± 2 °C

Parameter	Time (h)	B1	B2	B3
Dry matter	1	89.2 ± 1.5	88.8 ± 1.2	85.8 ± 1.7
	2	82.8 ± 1.2	82.6 ± 1.3	79.7 ± 1.4
	3	81.2 ± 1.6	81.3 ± 1.6	78.1 ± 1.7
	4	79.7 ± 1.5	78.8 ± 1.8	76.2 ± 1.2
Protein	1	77.7 ± 4.3	74.7 ± 4.3	73.1 ± 3.1
	2	68.9 ± 4.1	65.0 ± 5.2	59.8 ± 4.2
	3	58.9 ± 9.0	57.1 ± 7.1	49.7 ± 4.8
	4	51.1 ± 7.9	51.7 ± 10.0	42.1 ± 4.1
Ash	1	72.5 ±5.0	73.6 ± 3.2	74.5 ± 5.9
	2	69.2 ± 4.5	70.5 ± 4.6	71.2 ± 5.7
	3	64.9 ± 4.5	68.1 ± 3.8	65.8 ± 6.9
	4	60.9 ± 4.6	65.1 ± 4.2	61.3 ± 4.8

Means of each feed brand in different columns are not significantly different determined by one way ANOVA following Tukey's pair wise comparison ($p < 0.05$).

Discussion

Our study showed significant size disparities between imported feeds and the local feed studied especially in the diameter of the grower feeds. The local feed had the same diameter (2.2 mm) for three grower feeds. On the other hand, mean feed length in B1 (2.8 mm) was considerably lower than in B2 (3.4 mm) and B3 (3.2 mm). Shepperd et al. (2002) showed that the handling and external maceration of pellets by juvenile spiny lobster (*Jasus edwardsii*) before ingestion can generate considerable food wastage of up to 50%. It was demonstrated that this wastage could be reduced by as much as 19% by providing the ideal size of the pellets for a specific size of lobsters. It is suggested that the local feed studied can be further developed by changing the feed diameter to suit the size of the shrimp.

The highest moisture content recorded in this study was 10.3% in the local feed. According to New (1990), six commercial shrimp feeds from different countries had 10.0–13.0% moisture. Comparatively lower moisture levels recorded in this study could be considered as a desired character for the shrimp feeds.

Optimum protein requirement for *P. monodon* varied from 36–40% (Shiau and Chou 1991). New (1990) recommended 35–42% protein for commercial shrimp feeds. Imported shrimp feeds (B1 and B2) used in this study had protein content from 40–46% while the local feed had 38–41.3%. The average level of protein recorded in this study (41.4%) is in the upper level of the range recommended for *P. monodon*. Higher protein contents in commercial shrimp feeds were also recorded in Australia ranging from 36.8–45.5% (Macguire et al. 1988; Sarac et al. 1993).

Akiyama et al. (1992) recommended the minimum three protein levels 40.0, 38.0 and 36.0% from larval to grower feeds. Feeds used in early stage of the culture cycle (commercial nursery production) contained 35–45% protein and were 10–30% higher in protein content than that of the grow-out diet (Samocha and Lawrence 1992). Local feed (B3) followed the same pattern proposed by Akiyama et al. (1992) and Samocha and Lawrence (1992) by giving higher protein content at early stages and gradually decreasing it at the latter part of the culture cycle. However, post larval feed (L1) in the three brands had very similar protein levels with a very narrow range of 40.6–41.3%.

Lipid level in imported shrimp feeds used in this study varied between 5 – 11%. In the local feed lipid level varied between 4 – 6%. Recommended lipid levels for commercial shrimp feeds range from 6 – 7.5% and a maximum of 10% has been suggested (Akiyama et al. 1992). There was a substantial difference in the crude lipid within different shrimp feeds used in Australia with the ranges of 3.9 - 13.9% (Macguire et al. 1988; Sarac et al. 1993). Lipid levels in Taiwanese and Indian shrimp feeds varied from 5.7 – 6.5% (Macguire et al. 1988) and 2.8 - 10.0% (Kutty 1995), respectively.

According to De Silva and Davy (1992), aquaculture feed pellet quality is influenced by the fat level. Very low (> 2%) or high (>10%) fat levels are not desirable. Other than that, oxidative rancidity is common in feeds with high lipid contents and occurs when lipids in feed spoil, causing feed rejection by animals (New 1990; Jorry 1996; Kongkeo 1997). Farmers stored imported feeds for more than 2–3 months in farm store rooms. Therefore, the probability of feed spoilage in imported feeds can be higher than in the local feed.

Ash content measured in this study which varied between 11.0–13.4% is comparable with the ash content in Australian shrimp feeds

(11.0-13.6%) (Macguire et al. 1988). New (1990) recorded 12-18% ash in six different commercial shrimp feeds from different countries.

At present there is very little useful information on the dietary energy requirement of shrimp. If the feed has an excess of dietary energy, this may result in decreased feed intake, hence intake of other nutrients is also lowered and this can affect growth. On the other hand, if the dietary energy is too low the shrimp utilizes other nutrients such as protein to fulfil its energy requirement rather than for growth (Kompiang 1990). Significantly higher dietary energy level was recorded in the imported feeds which ranged from 19.1 - 24.8 kj g^{-1} while that for the local feed (16.6 – 18.3 kj g^{-1}) was significantly lower.

Dry matter, protein and ash were lost from all the feed samples immersed in water for 1–4 h. Relatively lower water stability of feeds was observed within the first hour of immersion and after which, there was a gradual and relatively even rate of loss of dry matter, protein and ash. Within the first hour of immersion nearly 10–13% of dry matter loss was found in the crumble feeds while it was 11–15% in the pellet feeds. Highly ground fine particles tend to leach out rapidly at the initial stage of immersion while larger particles are still retained. Cuzon et al. (1982) found a dry matter loss of 19% of shrimp feed within one hour of immersion. According to Sarac et al. (1993) there was a higher than 15% loss of dry matter in shrimp feeds after 4 h of immersion. In the present study, dry matter loss after 4 hr ranged from 20–30%. Within 30 minutes, 26.4–48.4% dry matter loss was observed in commercial Tilapia feeds (Siddiqui et al. 1994). According to Muylder et al. (2003) dry matter loss from shrimp feeds is higher in fresh water than in seawater. Therefore, salt absorption during the submerged period by the shrimp feeds might have affected the results of dry matter retention in the present study. Water stability of these feeds should be tested at fresh water and at full strength seawater to standardize the results.

Higher loss of protein was detected within the first hour of immersion ranging from 15.6–28.7%. Cuzon et al. (1982) found 21% protein loss within 1 hour in commercial shrimp feed. Protein loss within two hours in the present study ranged from 24.9–45.1%. The high percentage leaching of protein might be attributed to the higher solubility of amino acids in the feeds. Comparatively higher water stability was observed in two imported shrimp feeds than the local feed tested in the present study. The stability of pellets is influenced by different factors like feed composition, nature of ingredients, type of processing and moisture content. The lower water stability in the local feed could be attributed to the lowest fat and the highest moisture levels detected. Higher fat content prevents water penetration leading to high water stability of aquaculture feeds (Das et al. 1994) while higher moisture levels increase water penetration. The lack of significant difference between water stability of feeds in the flowing water system (treatment) and the static water system (control) could be the result of low water flow rate in the treatment system.

According to the results, local feed can be further developed by changing the feed diameter according to shrimp size and by reducing the moisture level. Formulations of feed management strategies should consider the water stability of shrimp feeds to reduce the feed wastage observed in this study.

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