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Aquaculture 252 (2006) 494–502

Aquaculture

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Effects of feeding frequency on feed leaching loss and grow-out patterns of the white shrimp *Litopenaeus vannamei* fed under a diurnal feeding regime in pond enclosures

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Received 22 June 2005; received in revised form 18 July 2005; accepted 18 July 2005

Abstract

Feed management plays a major role in the economical and environmental status of shrimp farms. It involves basic aspects such as when, where and how much to feed. Studies were conducted under pond conditions in order to determine the effects of feeding frequency on the grow-out patterns of *Litopenaeus vannamei*. Feed loss of crude protein (CP), lipid and dry matter (DM) over different water exposure periods were also investigated. In a commercial shrimp farm, 25 open-bottom enclosures (5 treatments and 5 replicates) of 50 m^2 each were installed in a 7.43-ha grow-out pond and stocked at 80 shrimp/m^2 (2.7 ± 1.52 g body weight). Shrimp were fed a commercial pelleted feed, delivered exclusively in feeding trays 2 (at 0700 and 1700 hours), 3 (at 0700, 1100 and 1500 hours), 4 (at 0700, 1000, 1300 and 1500 hours), 5 (at 0700, 0900, 1200, 1500 and 1700 hours) and 6 times/day (at 0700, 0900, 1100, 1300, 1500 and 1700 hours). Feed was made available over continuous 24-h periods and remains were collected at next feeding. After 8 h of water immersion, feed CP and lipid level dropped from 39.58% to 34.07% and from 9.25% to 7.88%, respectively. Leaching of feed CP and lipid was not statistically different over the study period. Long feed water exposure generated significant losses in DM. Leaching of DM reached 4.65 ± 0.34% after the first hour of water immersion, peaking at 8 h (10.20 ± 0.48%). Shrimp were harvested at day 84 of grow-out, when average body weight ranged from 9.7 ± 1.75 to 10.9 ± 1.90 g. No shrimp performance benefit could be detected by adopting higher diurnal feeding frequencies. Although shrimp fed five times/day showed superior grow-out performance indices, at harvest no statistical differences were detected in shrimp survival (64.1 ± 11.7%), shrimp yield (0.46 ± 0.08 kg/m^2) and feed conversion ratio (2.85 ± 1.42) between feeding treatments. Also, no consistent growth pattern could be detected in relation to feeding treatments over the rearing cycle. The present study demonstrated that when feed rations are only adjusted at a weekly basis, using as the only criteria shrimp estimated biomass, delivering feed more than twice per day is not advantageous in the grow-out of *L. vannamei*.

Keywords: Shrimp; Feeding; Frequency; *Litopenaeus*

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doi:10.1016/j.aquaculture.2005.07.013

1. Introduction

Production of farm-reared shrimp has increased significantly in tropical and subtropical areas of the world. In 2002, a total of 1,292,476 Mt of shrimp were harvested from aquaculture farms, accounting for more than US$ 7.3 billion in revenue (FAO, 2004). This rapid expansion has raised environmental concerns (Naylor et al., 2000), leading to a series of studies ranging from static and integrated farming systems (Burford et al., 2003; Wang, 2003), treatment of farm effluents (Tilley et al., 2002; Jackson et al., 2003) to the use of alternative ingredients in shrimp feeds (Smith et al., 2000; Forster et al., 2003).

Contradictorily, little attention has been given to the improvement of feed management practices, despite their potential to reduce economical and environmental pressure in shrimp farms. The tripod of traditional shrimp feed management combines population sampling to estimate gains of stocked shrimp biomass, the use of feeding tables to adjust weekly feed rations, and, sometimes, the daily monitoring of feed remains from feeding trays to serve as an indicator of feed consumption and population survival. Feeding rates, times of feed delivery, feeding frequency and feed dispersal method vary considerably depending on the farmed species, shrimp body weight, farm size, intensification level and water and feed quality. Although some countries have adopted more complex feeding protocols (Nunes and Suresh, 2001; Nunes, 2003, 2004), most feed management technologies have remained practically unchanged since the mid 1980s.

In shrimp grow-out, it has always been thought that a higher number of daily rations led to a faster shrimp growth, a better feed conversion efficiency and an improved water quality (Sedgwick, 1979; Robertson et al., 1993; Jaime et al., 1996). However, more recently, opposing data have suggested no benefit in multiple feed rations in *Litopenaeus vannamei* and *Penaeus monodon* culture (Velasco et al., 1999; Smith et al., 2002). Different from most Latin American countries, in Brazilian grow-out farms, shrimp are fed three to four times daily exclusively in feeding trays. In such conditions, feed delivery is conditioned to a diurnal feeding schedule to allow collection and visual accounting of feed remains and immediate adjustment of next meal. In general, feeding more than twice per day is not desirable in shrimp farming as it represents a more labor-intensive method. The present study aimed at evaluating the effect of feeding frequency on feed leaching loss and grow-out patterns of the white shrimp *L. vannamei* fed under a diurnal feeding regime in pond enclosures.

2. Material and methods

2.1. Study site and experimental design

The study was conducted in a 7.43-ha shrimp grow-out pond located in a commercial shrimp farm CEAQUA Ceará Aquacultura Ltda. The farm is situated in the northeastern region of Brazil at the latitude 04°09′7.8″ S and longitude 38°09′2.8″ W. The study consisted of five diurnal feeding frequencies 2, 3, 4, 5 and 6 times/day. Five replicates were assigned for each treatment, arranged in a Latin square design. Experimental units consisted of 25 open-bottom enclosures, with 50 m^2 (5 m in width and 10 m in length) internal area. Enclosures were built with a blue polyethylene 4.0-mm diameter mesh net with 1.90-m height (Tecelagem Roma Ltda., Tatuí, São Paulo, Brazil). They were spaced 11 m apart and placed 30 and 27 m from the pond walls and paddle-wheel aerators, respectively. Enclosure set-up followed the methodology described by Nunes and Parsons (1999).

2.2. Pond preparation

Enclosures were installed in the pond prior to water filling, but after soil drying, tilling and liming. Soil treatment started with sun-drying during a 30-day period. This was followed by liming with the application of 40 and 120 kg/ha of calcium hydroxide ($Ca(OH)_2$) in the internal water drainage canals and pond plateau, respectively. After 5 days, all remainder water puddles were sterilized with a total of 35 kg of liquid calcium hypochlorite. The following day, 7.4 kg/ha of 15–0–0 inorganic fertilizer with 3.5% SiO_2 and 25% Na (Nutrilake®, SQM Brasil, São Paulo, Brazil) were distributed over the pond internal water drainage canals. The pond bottom was then sun-dried for 15 more days and filled with water to 60% of its holding capacity. Over the next 10 days, 19.2 kg/ha of Nutrilake®, 0.9 l/ha of silicate and 3.5 kg/ha of urea were spread over the water, following complete pond filling.

2.3. Shrimp stocking

Eleven-day-old postlarvae (PL11) of *L. vannamei* were transported from a hatchery 200 km away from the study site. In the farm, shrimp were acclimated to water salinity and temperature prior to pond stocking at a density of 38 PL/m^2. After 46 days of grow-out, juveniles of 2.7 ± 1.52 g (average ± standard deviation; n = 200) were captured with a cast net and transferred to the pond enclosures at 80 shrimp/m^2, totaling 4000 animals/enclosure. Shrimp biomass was used to determine the initial number of stocked animals in each enclosure, following the equation: $S_{pop} = t_n \times (W_s / c_n)$, where: S_{pop} = shrimp stocked biomass (g); t_n = number of shrimp to be stocked in each enclosure; W_s = total weight of sampled shrimp (g); and, c_n = number of shrimp sampled.

2.4. Feed and feeding

Shrimp were fed a commercial pelleted feed (Camaronina 35 hp, Purina do Brasil, São Lourenço da Mata, Pernambuco, Brazil) during the complete study period. Feed was delivered 2 (at 0700 and 1700 hours), 3 (at 0700, 1100 and 1500 hours), 4 (at 0700, 1000, 1300 and 1500 hours), 5 (at 0700, 0900, 1200, 1500 and 1700 hours) and 6 times/day (at 0700, 0900, 1100, 1300, 1500 and 1700 hours), made available at continuous 24-h periods. No feeding occurred on Sundays, following local commercial feeding practices. To minimize feed loss during delivery, all feed was distributed in circular feeding trays, equipped with a retractable cover (Plastsan Plásticos do Nordeste Ltda., Caucaia, Ceará, Brazil) which opened in contact to the pond bottom (Nunes, 2004). Trays were allocated at one unit per enclosure and positioned 80 cm from its internal boarder. Daily at each feeding time, trays were rinsed, brushed clean and inspected for uneaten feed, which was then collected for weighing. Although all feed remains were accounted at each feeding, modifications in feed ration did not follow the amount of feed consumption from feeding trays. Feed rations were adjusted weekly, according to shrimp stocked biomass and estimated population survival. Feeding rates per average shrimp body weight dropped progressively as animals grew, from 3.4% for a 2.5-g shrimp to 2.6% for a 10.5-g animal. Rations were adjusted for each replicate, regardless of the feeding treatment. Feed quantities were always in excess to estimated feed consumption in order to avoid the possibility of underfeeding.

2.5. Shrimp sampling and water quality

A total of 40 animals or 1.0% to 1.2% of all remaining estimated shrimp stocked population were sampled weekly for body weight gains. Shrimp were always sampled between 1800 and 2000 hours with a cast net, weighed and discarded. The total number of sampled shrimp during the study was deducted from the initial stocked population to determine final shrimp survival. For each treatment, final survival was calculated based on harvested shrimp biomass and final shrimp weight. Shrimp survival throughout the rearing cycle was estimated using a commercial table with modifications (Nunes, 2000). Pond water temperature and dissolved oxygen were monitored daily at 0900, 1400, 2000 and 0400 hours. Water salinity and pH were evaluated once daily. Water transparency was determined through Secchi disk readings at 1300 hours.

2.6. Feed assessments

To assess the effect of feeding frequency on feed leaching losses of crude protein (CP) and lipid, 1.0 kg of feed was individually immersed in water (35.3 ± 2.9‰ salinity and 26.97 ± 0.46 °C) in eight feeding trays over three consecutive days. Trays were placed simultaneously in the pond near enclosures, with covers locked to prevent shrimp feeding. Feed recovery occurred hourly up to an 8-h period. Collected feed was kept frozen at −18 °C until proximate analysis. For CP and lipid, feed samples were pooled and evaluated in duplicates. Proximate chemical analyses followed the methodology described by AOAC (1990). Crude protein was analyzed by the Kjeldahl method [calculated as nitrogen (N) × 6.25], while lipid was determined gravimetrically following Soxhlet extraction using acetone as the solvent.

Feed dry matter leaching (DM*i*) and feed water absorption (WA*i*) were determined in 500-l tanks without stocked shrimp (36.5 ± 0.7‰ salinity). Feed was administered in PVC feeding trays measuring 14.3 cm in diameter and boarders at 3.5 cm in height. A total of 5 g of feed was distributed in each feeding tray and collected hourly up to an 8-h period. The percentage of dry matter leaching (DM*i*) at its respective immersion interval was calculated by the formula: DM*i* = [1 − (Wd*i* / Wf)] × 100, where: DM*i* = percentage of dry matter leaching at time *i* (%); Wf = dry feed weight before immersion in seawater (g), and; Wd*i* = dry feed weight after immersion in seawater at time *i* (g). Dry feed weight refers to the feed weight after drying at 105 °C for 24 h. Water feed absorption (WA*i*) in its respective immersion interval was given as: WA*i* = [(Wmi − Wf)/Wf] × 100, where: WA*i* = percentage of feed water absorption at time *i*, and Wm*i* = wet feed weight after immersion in seawater at time *i*.

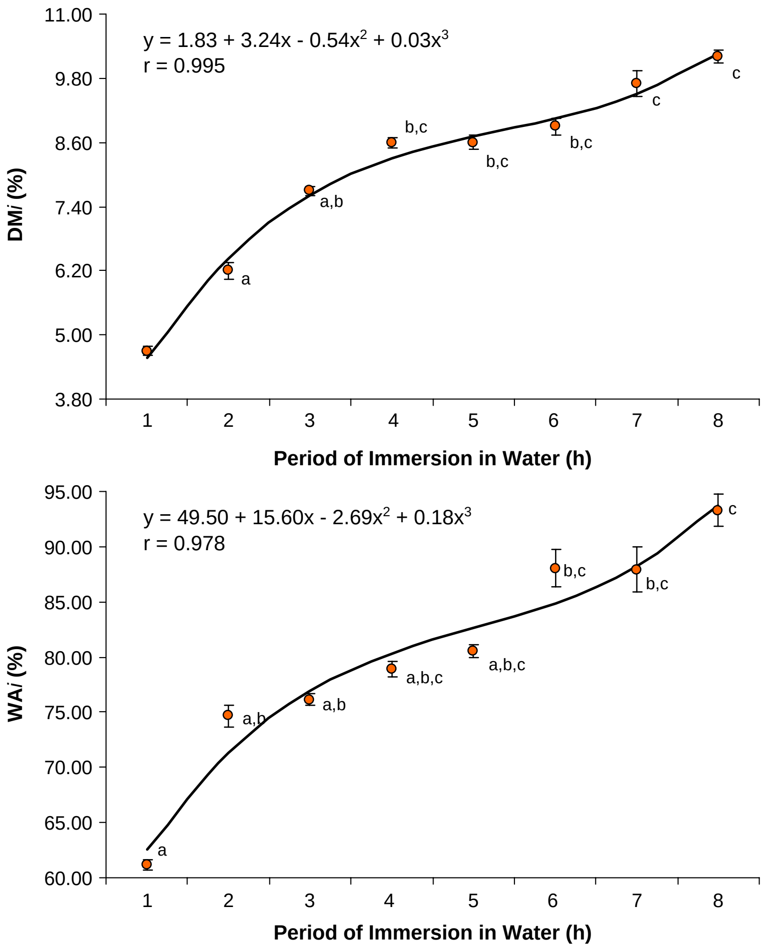

Fig. 1. Feed hourly leaching loss of dry matter (DM*i*, %) and water absorption (WA*i*, %) after immersion in seawater at eight interval periods in 500-l tanks. Each value represents the average ± standard error of four samples. Common letters denote non-significant differences between treatments at the $\alpha = 0.05$ level by Scheffé's multiple range. Thick curve indicates regression line expressed by the cubic equation on the left-hand side.

2.7. Shrimp grow-out performance indices

Shrimp were sampled weekly to determine weight gains. Final survival was calculated by subtracting the harvested shrimp biomass from the stocked shrimp biomass of each individual enclosure. Two enclosures from each treatment with final shrimp survival equal or below 40% were eliminated from all performance evaluations. Feed conversion ratio (FCR) was calculated based on apparent feed consumption (Cs). Daily at each feed delivery, all uneaten feed from previous feeding was collected from trays and weighed. Apparent feed consumption (Cs) was determined for each feeding treatment by the equation: $Cs = \sum[(F_d \times DMi) - (Fci \times WAi)]$, where: Cs = apparent feed consumption; F_d = amount of feed delivered, and; Fci = amount of feed that remains at time i.

2.8. Statistical analyses

Statistical analyses were performed with the Statistical Package for Social Sciences Windows version, release 7.5.1. (SPSS Inc., Chicago, Illinois, USA). Analysis of variance (ANOVA) was applied to determine statistical differences between treatments. Scheffé's Multiple range test was used to examine individual statistical differences between treatments

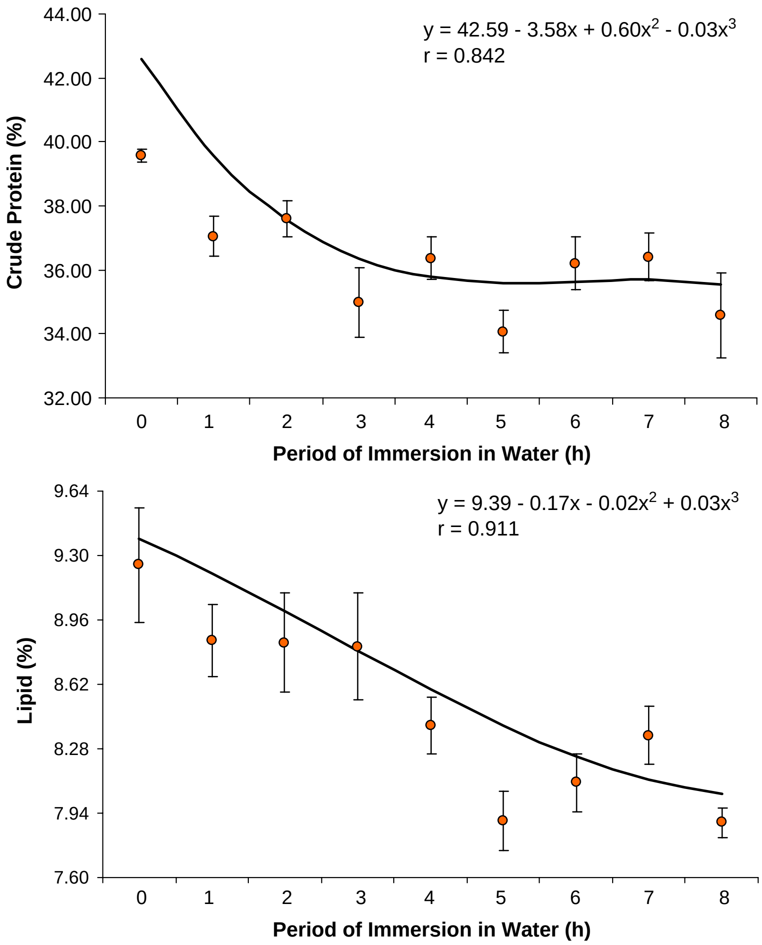

Fig. 2. Feed hourly leaching loss of crude protein (CP, % dry weight) and lipid (% dry weight) after immersion in pond water over eight interval periods. Each value represents the average ± standard error from two samples. Thick curve indicates regression line expressed by the cubic equation on the right-hand side.

whenever significant differences were detected by ANOVA at a probability level of $\alpha=0.05$.

3. Results

3.1. Water quality

A total of 924 individual readings of temperature, pH, salinity, dissolved oxygen and water transparency (Secchi disk) were conducted over the 84-day grow-out cycle of *L. vannamei*. Water temperature was kept constant during the study period, without any significant changes (27.69 ± 1.43 °C; $n=336$). Similarly, pH (8.59 ± 0.17; $n=84$), salinity (40.0 ± 5.1‰; $n=84$), dissolved oxygen (6.80 ± 2.15 mg/l; $n=336$) and water transparency (23.5 ± 4.8 cm; $n=84$) did not vary significantly.

3.2. Feed leaching

Percentage of water feed absorption (WA*i*) in 1-h periods increased progressively with time of seawater exposure (Fig. 1; $P<0.05$). In the first hour of water immersion, WA*i* reached 60.8%. Although WA*i* occurred continuously over the 8-h immersion period, no statistical differences were observed ($P>0.05$). Feed lost a significant and progressive amount of dry matter (DM) with time of water exposure (Fig. 2; $P<0.05$). The first hour of water immersion showed the lowest percentage of dry matter leaching (DM*i*; 4.65 ± 0.34%).

Leaching of crude protein (CP) and lipid in the feed exhibited a reducing trend with time of water immersion (Fig. 1), although without consistency. Hourly losses ranged from 0.54% to 6.91% (minimum and maximum) for CP and from 0.11% to 5.95% for lipid. A major loss of CP level was observed between the 2nd and 3rd hour of water exposure. Maximum lipid leaching loss was detected between the 4th and 5th hour. After 8 h of water immersion, CP and lipid dropped from 39.58% to 34.07% and from 9.25% to 7.88%, respectively. ANOVA revealed no statistical differences in the leaching of CP and lipid over the 8-h immersion period ($P>0.05$).

3.3. Shrimp grow-out patterns

L. vannamei grew continuously over the study period (Table 1). Shrimp body weight gains during grow-out in pond enclosures showed statistically significant differences between feeding frequencies ($P<0.05$). In general, shrimp submitted to a five-daily-ration regime grew less when compared to other treatments ($P<0.05$). On the other hand, shrimp fed three and four times daily tended to exhibit a

Table 1
Weekly grow-out patterns of *L. vannamei* reared under five diurnal feeding frequencies in 50-m^2 open-bottom enclosures

Day	Feeding frequency (number of daily rations)					
	2	3	4	5	6	*P*
7	4.0 ± 1.22^{a}	4.5 ± 1.17^{b}	$4.4\pm1.34^{a,b}$	4.0 ± 1.18^{a}	$4.2\pm1.35^{a,b}$	0.008
14	$4.0\pm1.23^{a,b}$	4.2 ± 1.39^{a}	$3.9\pm1.22^{a,b}$	3.6 ± 1.22^{b}	$3.8\pm1.21^{a,b}$	0.005
21	4.7 ± 1.18^{a}	5.1 ± 1.14^{b}	$4.8\pm1.08^{a,b}$	4.3 ± 1.11^{a}	$4.8\pm1.17^{a,b}$	<0.001
28	5.5 ± 1.09^{a}	6.2 ± 1.01^{b}	5.5 ± 1.14^{a}	4.7 ± 1.14	5.5 ± 1.18^{a}	<0.001
35	6.1 ± 1.16^{a}	7.2 ± 1.38^{b}	$6.7\pm1.30^{b,c}$	5.6 ± 1.19	$6.5\pm1.24^{a,c}$	<0.001
42	$6.7\pm1.46^{a,b}$	7.8 ± 1.40	$7.1\pm1.31^{a,c}$	6.2 ± 1.36^{b}	$6.9\pm1.17^{a,c}$	<0.001
49	$7.4\pm1.38^{a,c}$	8.2 ± 1.43^{b}	$7.8\pm1.27^{a,b}$	7.0 ± 1.16^{c}	$7.3\pm1.23^{a,c}$	<0.001
56	$7.9\pm1.41^{a,d}$	8.9 ± 1.71^{b}	$8.7\pm1.38^{b,c}$	7.6 ± 1.32^{d}	$8.2\pm1.34^{a,c}$	<0.001
63	8.8 ± 1.41^{a}	$9.4\pm1.63^{a,b}$	$9.5\pm1.77^{b,c}$	8.1 ± 1.45	$9.0\pm1.47^{a,c}$	<0.001
70	$9.6\pm1.67^{a,d}$	$10.3\pm1.89^{b,c}$	$9.9\pm1.76^{a,b}$	9.0 ± 1.60^{d}	$9.7\pm1.63^{a,c}$	<0.001
77	$9.8\pm1.92^{a,c}$	10.7 ± 1.81^{b}	$10.2\pm1.78^{a,b}$	9.4 ± 1.67^{c}	$10.1\pm1.71^{a,b,c}$	<0.001
84	$9.9\pm1.81^{a,c}$	10.9 ± 1.90^{b}	$10.6\pm2.02^{a,b}$	$9.7\pm1.75^{c,d}$	$10.5\pm1.88^{a,b,c}$	<0.001
CV	18.9%	17.4%	19.1%	18.0%	18.0%	–

Each value represents the mean body weight (g) ± standard deviation of 120 animals sampled from three enclosures. Lines with common letters denote non-significant differences between treatments at the $\alpha=0.05$ level by Scheffé's multiple range. Coefficient of variation (CV) refers to the mean body weight and standard deviation of shrimp at harvest. ANOVA results are presented in the last right-hand column.

Table 2
Grow-out performance of *L. vannamei* fed 2, 3, 4, 5 and 6 times/day over 84 days of rearing

Feeding frequency	Shrimp survival (%)	Shrimp yield (kg/m^2)	Shrimp growth (g/week)	Shrimp biomass (kg)	FCR
2	67.3	0.47	0.82^{a,b}	14.04	2.65
3	53.5	0.41	0.91^{b}	11.08	3.25
4	58.5	0.44	0.88^{a,b}	12.44	2.88
5	85.0	0.58	0.81^{a}	19.72	1.98
6	56.0	0.41	0.87^{a,b}	11.20	3.49
SE	4.5	0.03	0.01	1.45	0.44
P	0.108	0.320	0.013	0.320	0.480

Data expressed as the mean ± standard error (SE). Each mean value was obtained from three open-bottom enclosures. Columns with common letters denote non-significant differences between treatments at the $\alpha=0.05$ level by Scheffé's multiple range. ANOVA results are presented in the last line.

higher body weight than other remainder treatments ($P<0.05$). The Coefficient of variation (CV) of final body weight at shrimp harvest did not vary substantially between treatments.

Shrimp fed five times/day showed improved grow-out performance indices when compared to other treatments, except weekly growth (Table 2). However, ANOVA indicated no significant differences for shrimp survival, yield, biomass gained and FCR between feeding regimes (Table 2; $P>0.05$). Shrimp weekly growth differed statistically between the five times/day and three times/day feeding regime ($P<0.05$), although similar to the others.

4. Discussion

In the present study, progressive losses in crude protein (CP), lipid and dry matter (DM) were observed when period of water immersion was increased. In the first hour of water exposure, DM losses of 4.65 ± 0.34% were similar to those detected by Cruz-Suárez et al. (2002). The authors evaluating the digestibility of nine Mexican commercial shrimp feeds reported an average DM leaching level of 3.8% (minimum of 1.8% and maximum of 6.3%) after 1 h of water immersion in a salinity of 34 to 35 ppt. The authors suggested that DM losses of 5% are considered normal in commercial shrimp feeds. In the present study, starting in the second hour of water immersion, losses of DM exceeded 6% reaching a peak at 8 h (10.20 ± 0.48%). However, this level of DM leaching was still inferior to the one registered by Smith et al. (2002). The authors reported losses of 12% after 4 h of water immersion.

Although in the present study, feed CP and lipid losses reached, respectively, 12.63% and 14.00%, after 8 h of water immersion, analyses revealed no statistical differences over the observation period. Even at the 8-h immersion period, feed still retained sufficient CP and lipid levels (34.58% and 7.89%, respectively) to meet the nutritional requirements of *L. vannamei* (Pedrazolli et al., 1998). These observations agree with Smith et al. (2002) when studying the effect of feeding frequency on *P. monodon* growth. In their work, the authors suggested that losses of 15% in feed CP after 4 h of water immersion were not critical to shrimp growth or were in sufficient amounts to meet the species requirements. It is probable that this factor could have biased or reduced the effect of feeding frequency on *L. vannamei* growth under the present study. The effects of feeding frequency may become more evident when shrimp are fed with lower CP feeds or with feeds more prone to rapid nutritional and physical leaching losses. This may be particularly more apparent under more intensive conditions, without the presence of natural food.

On the other hand, according to Velasco et al. (1999), multiple feedings were not necessary in a static system stocked with *L. vannamei*, even when lower CP feeds were used. The authors fed *L. vannamei* stocked at 150 and 15 shrimp/m^2 with a 19% CP diet in zero-water exchange tanks. Under such conditions, multiple feedings did not benefit shrimp growth performance. In a similar rearing system, Buford et al. (2004) worked with *L. vannamei* under 120 shrimp/m^2. The authors found that natural food derived from flocculated material contributed 18% to 29% of daily nitrogen retention of the shrimp with 1 to 9 g body weight.

The results of the present study indicated that long feed water exposure periods generate significant losses in DM. Although leaching of CP and lipid in the feed were not statistically significant over the study period, under commercial culture conditions prolonged water exposure should be avoided as it can represent economical losses. It can be estimated that for every 1 Mt of 35%-CP feed delivered in diurnal intervals of 8 h, feed losses can account for

102 kg of DM and 44 kg of CP. However, when delivered in 2-h intervals, losses are reduced by 39% (62 kg) for DM and 59% (18 kg) for CP.

In the present study, shrimp weight gains were not directly influenced by feeding frequency. Also, no consistent growth pattern could be detected in relation to feeding treatments over the rearing period. The lowest weight gain observed for shrimp fed 5 times/day was probably the result of a higher final shrimp biomass.

Marques (1997) working with juveniles of *Farfantepenaeus paulensis* in 1.85-m^3 floating cages reported no differences on shrimp growth when feeding frequency was increased from 2 to 4 times/day. Conversely, Robertson et al. (1993) found a positive influence of feeding frequency on shrimp growth when working with *L. vannamei* stocked at 40 shrimp/m^2 in 1-m^2 open-bottom enclosures. The authors concluded that shrimp fed 4 times/day attained faster growth than when fed once and twice per day. Similar results were reported by Jaime et al. (1996) when working with *Litopenaeus schmitti* at 4 shrimp/m^2 in 500-m^2 ponds.

In the present study, a higher diurnal feeding frequency showed no apparent correlation with better growth indices of *L. vannamei*. This was contrary to the hypothesis that shorter diurnal feeding intervals in the multiple feeding frequency regimes would favor better shrimp grow-out performance. Also, delivering feed rations more often did not result in more uniform shrimp body weights within harvested animals of each treatment.

In the present study, opposed to commercial practices, feed remains collected from feeding trays were not used as a parameter to adjust meals. When feeding exclusively in feeding trays, the possibility of tailoring feed rations to individualized feeding sites is regarded as a major advantage over other traditional feed delivery methods (Jory et al., 2001; Nunes and Suresh, 2001). Frequent adjustments in feed meals may lead to a reduction in feed wastes and improvement in FCR. Smith et al. (2002), working with *P. monodon*, adopted daily adjustments in feed rations based on the amount of feed remains collected from the previous day. Similarly, such practice does not reflect those adopted commercially in Brazil, where rations are adjusted at each feed delivery time based on visual assessments of feed remains.

The present work has shown that when feed rations are only adjusted weekly using as the sole criteria estimated shrimp biomass, delivering feed more than twice per day is not advantageous in the grow-out of *L. vannamei*. However, when feeding exclusively in feeding trays or when using feeds with low physical and nutritional quality under intensive conditions, multiple daily feedings should still be considered as a strategy to reduce FCR and control feed costs in shrimp farms.

Acknowledgments

This study was funded by the Associação Brasileira dos Criadores de Camarão (ABCC). The authors thank CEAQUA farm (Ceará Aquacultura Ltda.) for allowing access to grow-out facilities, Agribrands Purina do Brasil Ltda. for supplying shrimp feed and Plastsan Plásticos do Nordeste Ltda. for donating feeding trays. The first author was supported by a scholarship under Fundação Cearense de Apoio ao Desenvolvimento Científico e Tecnológico (FUNCAP).

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