Aquaculture Research

Aquaculture Research, 2012, **43**, 430–437 doi: 10.1111/j.1365-2109.2011.02846.x

Spirulina meal has acted as a strong feeding attractant for *Litopenaeus vannamei* at a very low dietary inclusion level

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Abstract

The present work aimed at studying the growth performance and feeding preference of *Litopenaeus vannamei* juveniles fed on diets supplemented or not with Spirulina meal. *Litopenaeus vannamei* juveniles (3.89 ± 0.25 g) were stocked for 72 days in 28 round 500-L tanks at 44 shrimp/tank (77 juveniles/m^2). The diets were supplemented with 0.5% of a commercial feed attractant (C25 and C50) or with Spirulina meal (S25 and S50). In C25/S25 and C50/S50 there were reductions of 25% and 50% in fishmeal inclusion level respectively. In a further study, two feeding trays with different diets were allowed to shrimp at the same moment and they were located in opposite walls of the tank. The feed remains in each feeding tray were collected and weighted to calculate the dry feed remains. The weekly growth rate of shrimp fed on S25 (0.89 ± 0.03 g) was not significantly different from those fed on C25 (0.89 ± 0.01 g). The attractiveness experiment showed that S25 was preferred significantly more by shrimp than C25. In conclusion, Spirulina meal added at 0.5% in a complete diet for *L. vannamei* juveniles, with 14% of Peruvian fishmeal, has proved itself as a nutritionally efficient feeding attractant.

Keywords: aquaculture, shrimp, aqua feed, feed additive, algae meal

Introduction

The artificial diets for crustaceans must be chemically attractant to elicit its fast finding and intake by the animal. The addition of small quantities of stimulating compounds can improve feed intake and, as a consequence, boost the animal's growth, survival and feed efficiency (Carr 1988). Previous studies with penaeid shrimp have demonstrated that shrimp meal, krill meal (Smith, Tabrett, Barclay & Irvin 2005); fish soluble protein and bivalve mollusk biomass supplemented with synthetic amino acids (Nunes, Sá, Andriola-Neto & Lemos 2006) show high attractiveness for these animals. Therefore, the best attractiveness results for marine shrimps were obtained only with products of animal and marine origin. Nevertheless, promising results have indicated that Spirulina, *Spirulina platensis*, a filamentous cyanobacteria, has high attractiveness for *Litopenaeus schimitti* (Jaime-Ceballos, Villarreal, Garcia, Pérez-Jar & Alfonso 2005; Jaime-Ceballos, Cerecedo, Villarreal, Lopéz & Perez-Jar 2007).

Spirulina is one of the cyanobacterium more frequently found in tropical and salty waters with alkaline pH. Its growth rate in culture is higher than those observed for any other vegetal species and it is comparable to yeasts and bacteria (Richmond 1988). Spirulina's life cycle allows that its biomass doubles each 3–5 days. This could represent a productivity of up to 25 ton $ha^{-1} yr^{-1}$ or 15 ton protein $ha^{-1} yr^{-1}$ (Göhl 1991). Currently, 22 companies around the world produce Spirulina's biomass which is intended mainly to supply natural product shops or drugstores. In these places, the dry Spirulina biomass, frequently in capsules, is sold as a feed supplement to improve human health. Moreover, the use of Spirulina meal in animal nutrition industry is increasing nowadays (Morais, Radmann, Andrade, Teixeira, Brusch & Costa 2009).

In spite of its superior nutritional quality, no study was carried out until now about the use of Spirulina meal as an attractant in complete diets for *Litopenaeus vannamei* juveniles, the chief species of marine shrimp commercially cultured in the Western. The present work aimed at study the growth performance and feeding preference of *L. vannamei* juveniles reared in controlled lab conditions and fed with different diets supplemented or not with 0.5% of Spirulina meal as an feeding attractant.

Materials and methods

Shrimp and culture system

Twelve-day-old postlarvae of *L. vannamei* were obtained from a commercial shrimp larviculture and transported by road to the Laboratory of Nutrition of Aquatic Organisms (CEAC, Labomar/UFC, Eusébio, Ceará, Brazil). There, the postlarvae were stocked in the hatchery sector of the laboratory in four 3000-L tanks. The postlarvae were reared for 45 days in the hatchery tanks when an individual body weight greater than 1.5 g was reached. After two additional weeks in 1000-L outdoor tanks, the juveniles (3.89 ± 0.25 g) were stocked in the experimental system comprised by 28 round polyethylene 500-L tanks at 44 shrimp/tank or 77 juveniles m^{-2}.

The culture system was formed by six cells of tanks each one with five inter-connected recirculation tanks. In each tank cell, water was pumped at night and passed through a 45-kg sand filter to remove particulate matter. The tanks were supplied with constant aeration provided by one 2.5-hp air blower. The salty water used to fill in the tanks was pumped directly from a nearby estuary (Pacoti River, 03°50′01.55″S and 38°25′22.74″W) and stored in two 20 000-L water reservoirs. Before the use, the water was disinfected with sodium hypochlorite for 1 week and strongly aerated afterwards to eliminate the residual chlorine. After the 1-week acclimation period, when the animals fed on a complete commercial diet (Camaronina 35HP, Evialis do Brasil Nutrição Animal, São Lourenço da Mata, PE, Brazil), shrimp were fed on with the experimental diets for 72 days.

Diets and experimental design

Seven isonitrogenous and isoenergetic diets were formulated and made in the laboratory. There were three control diets (STD, N25 and N50) and four experimental diets (C25, S25, C50 and S50). Since previous works made in our laboratory have demonstrated that no significant differences exist between the tank cells, an entirely randomized design was adopted with three controls and four treatments, each one with four replicates.

STD was the positive control of the study in which regular levels of fishmeal and soybean meal were included in the diet. Besides, STD was supplemented with a reliable and efficient feed attractant for shrimp diets at 0.5%. This is a commercial product that contains a complex of amino acids (alanine, valine, glycine, proline, serine, histidine, glutamic acid, tyrosine and betaine) with enzymatically digested bivalve mollusk. In the negative-control diets (N25 and N50), there was a reduction of 25% and 50% in the STD's fishmeal inclusion level respectively. In both diets, no feed attractant was added. The experimental diets C25, S25, C50 and S50 were supplemented with 0.5% of the commercial feed attractant (C25 and C50) or with 0.5% of Spirulina meal (S25 and S50). In C25 and S25, there was a reduction of 25% in the STD's fishmeal inclusion level. In C50 and S25, the STD's fishmeal inclusion level was reduced by 50% (Table 1).

All diets were made in laboratory as follows: firstly, the soybean meal and broken rice were finely ground to attain a particle size lower than 300 μm. Fishmeal and poultry by-product meal were sieved at 600 μm to eliminate coarse particles. Finely ground wheat flour was obtained in the local market; secondly, the ingredients were blended in a industrial baker-type mixer for 15 min, when small quantities of warm water were added; thirdly, the dough was steam cooked for 30 min in a perforated pan and passed through a 1.5-hp meat-grinder equipped with a 2 mm die; fourthly, the strands produced were put in a recirculation oven at 60 °C overnight; lastly, the dry strands were cut with a food multiprocessor, the pellets put in labeled plastic bags and stored at − 18 °C until the use.

Feeding, water quality husbandry and growth performance variables

Shrimp were fed twice a day at 07:30 and 15:30 hours The diets were given to shrimp in small feeding trays with 150 mm diameter and 30 mm edge. There was just one feeding tray per tank. Shrimp had 24-h access to the diet in two allowance periods: 8 h (from

Table 1 Ingredient and nutritional composition of the control and experimental diets (ingredient and nutritional values expressed on an as fed and dry matter basis, respectively, g 100 g^{-1})

Ingredient	Diet STD	N25	N50	C25	S25	C50	S50
Wheat flour	13.26	17.45	15.22	17.65	17.41	15.22	15.17
Soybean meal 46	25.00	27.47	35.44	27.86	27.08	35.44	35.02
Peruvian fish meal 69	18.50	13.87	9.24	13.87	13.87	9.24	9.24
Broken rice	15.27	10.00	10.00	10.00	10.00	10.00	10.00
Poultry by-product meal 61	8.00	10.00	10.00	10.00	10.00	10.00	10.00
Spirulina meal*	0.00	0.00	0.00	0.00	0.50	0.00	0.50
Commercial attractant†	0.50	0.00	0.00	0.50	0.00	0.50	0.00
Fish oil	4.18	4.14	4.41	4.18	4.15	4.41	4.41
Corn gluten meal 62	4.00	4.91	3.00	3.78	4.84	3.00	3.00
Soybean lecithin	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Cholesterol	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Common salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral-vitamin C premix‡	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Binder§	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Di-calcium phosphate	2.71	3.01	3.55	3.01	3.00	3.55	3.54
Bentonite	4.43	5.00	4.99	5.00	5.00	4.49	4.97
Nutritional composition							
Crude protein (CP)¶	36.56	36.34	35.34	35.86	36.13	36.10	35.93
Ether extract¶	9.80	9.87	9.56	9.56	9.57	9.66	9.89
Acid-detergent fiber¶	3.90	4.43	4.51	3.57	3.49	3.85	3.91
Ash¶	14.08	14.57	14.64	14.34	14.27	14.11	14.47
Nitrogen-free extract‖	36.66	34.79	35.95	36.67	36.54	36.28	35.80
Calcium**	2.17	2.13	2.07	2.13	2.13	2.07	2.07
Available phosphorus**	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Lysine**	2.05	1.99	1.99	1.98	1.98	1.99	1.99
Methionine**	0.76	0.72	0.66	0.71	0.73	0.66	0.66
Gross energy (kJ g^{-1})¶	17.43	17.25	17.97	18.04	18.05	17.86	17.80
Digestible energy (DE, kJ g^{-1})††	15.91	15.92	15.93	15.92	15.91	15.93	15.93
DE:CP ratio (kJ g^{-1})	43.5	43.8	45.1	44.4	44.0	44.1	44.3

*Organic Spirulina powder.

†Complex of amino acids (alanine, valine, glycine, proline, serine, histidine, glutamic acid, tyrosine and betaine) with enzymatically digested bivalve mollusk.

‡Guaranteed levels per kg of product: vitamin A 1 250 000 UI, vitamin D_3 350 000 UI, vitamin E 25 000 UI, vitamin K_3 500 mg, vitamin B_1 5000 mg, vitamin B_2 4000 mg, vitamin B_6 5000 mg, vitamin B_{12} 10 mg, nicotinic acid 15 000 mg, pantotenic acid 10 000 mg, biotin 150 mg, folic acid 1.25 mg, vitamin C 25 000 mg, coline 50 000 mg, inositol 30 000 mg, iron 2000 mg, copper 3500 mg, chelated copper 1500 mg, zinc 10 500 mg, chelated zinc 4500 mg, manganese 4000 mg, selenium 15 mg, chelated selenium 15 mg, iodine 150 mg, cromium 80 mg and filling (Rovimix Camarões Intensivo, DSM Nutritional Products, São Paulo, Brazil).

§Pegabind® (Bentoli Agrinutrition, FL, EUA).

¶Nutritional composition determined by standard methods (AOAC 2000).

‖Nitrogen-free extract calculated by difference (dry matter − crude protein − ether extract − ash − fiber).

**Nutritional composition calculated according to Rostagno (2000).

††Digestible energy for wheat flour, soybean meal, Peruvian fish meal and poultry by-product meal was calculated according to Siccardi III, Lawrence, Gatlin III, Castille and Fox (2006); digestible energy for broken rice was calculated using the following coefficients: 16.74 kJ g^{-1} for crude protein, 12.55 kJ g^{-1} for nitrogen-free extract and 33.47 kJ g^{-1} for ether extract (Hertrampf & Piedad-Pascual 2000); energy from fish oil was considered 100% digestible.

07:30 to 15:30 hours) and 16 h (from 15:30 to 07:30 hours). At the end of each period, the feeding trays were collected and the feed remains weighted in a precision scale. The amount of diet allowed to each tank was calculated according to the feeding rates presented by Nunes and Parsons (2000), which aim to feed the animals up to near the satiety. The amount of diet to each tank was adjusted every 3 weeks after shrimp weightings. Before that, an additional amount of diet was allowed weekly to each tank based on an estimated weight gain of 0.6 g shrimp^{-1} wk^{-1}.

Daily at 09:00 hours, water temperature, pH and salinity of all tanks were recorded using portable equipments. At each partial weighting, 20% of shrimp population were collected and weighted individually. All shrimp were weighted in the final biometry. The following growth performance variables and indices were observed in each tank replicate: final weight, weight gain, survival, feed conversion rate and protein efficiency rate (weight gain/protein consumed).

Attractiveness experiment

After the growth performance study, a brand new work was carried out with the remaining shrimp to better evaluate the Spirulina meal as a feeding attractant for *L. vannamei*. In a preliminary phase, 20 subadults shrimp (12.0 ± 0.65 g) per tank were stocked in the same units used in the first experiment. Shrimp were fed with the commercial diet (Camaronina 35HP, Evialis do Brasil Nutrição Animal) that was allowed to the animals in two equal feeding trays per tank. The same amount of commercial diet was provided to each tray. The preliminary phase aimed to validate the experimental system to perform studies on attractiveness. The experimental diets would be confronted two-by-two in a further phase only if no significant differences existed between the two feeding trays in terms of shrimp feed intake in each of the 24 tanks.

The total amount of diet in each feeding tray was calculated according to the shrimp biomass and the feeding rates obtained from Nunes and Parsons (2000). Feed was allowed in excess, twice the recommended amount in order to guarantee that feed remains would be found in the trays. The two feeding trays were allowed to shrimp at the same moment, and they were located in opposite sides of the tank. Furthermore, the feeding trays were withdrawn simultaneously. The following day, the feeding trays had their positions inverted to avoid the formation of undesirable habits. There was just one meal per day. The feeding trays were allowed to shrimp at 07:30 hours and collected at 15:30 hours. The feed remains in each feeding tray were collected and weighted to calculate the dry feed remains. The validation phase lasted 1 week and seven observations were made in each tank.

The following phase of the attractiveness study used the same design and management reported in the previous phase. Six selected comparisons were made between the experimental diets. The diets under comparison in the attractiveness study's second phase were the followings: C25 vs. S25; C50 vs. S50; STD vs. S25; STD vs. S50; N25 vs. S25 and N50 vs. S50.

Statistical analyses

The results of growth performance and attractiveness were analysed through the one-way ANOVA for completely randomized experiments using the statistical package SPSS, version 7.5.1 (Chicago, IL, USA). When significant differences were detected between the means, they were compared two-by-two with Tukey's test. The significant level of 5% was adopted in all statistical tests employed.

Results and discussion

The differences between the tanks in regards to water salinity, pH and temperature were not significant ($P > 0.05$). The tanks' water salinity ranged between 26 and 33 ppt, averaging 29.4 ± 1.81 ppt ($n = 1530$); pH between 7.0 and 8.4 (7.4 ± 0.36; $n = 1530$); and temperature between 25.7 and 29.5 °C (28.2 ± 0.48 °C; $n = 1530$). These values are inside the proper ranges for the culture of *L. vannamei* juveniles.

The final body weight, weight gain and survival of shrimp fed on C25 were not significantly different from those observed for N25 and STD respectively. On the other hand, the final body weight and weight gain of shrimp fed on N25 was significantly lower than that for STD ($P < 0.05$). Likewise, FCR and PER for shrimp fed on C25 were not significantly different from those seen for N25 and STD respectively. The final body weight, weight gain and survival of shrimp fed on S25 were not significantly different from those observed for N25 and STD. Similarly, FCR and PER for shrimp fed on S25 were not significantly different from those seen for N25 and STD (Table 2).

Shrimp fed on diet with 50% less fishmeal and supplemented with the commercial attractant (C50) exhibited a weight gain significantly greater than that observed for N50. Besides, the FCR of shrimp fed on C50 was significantly better than reported for N50. No significant differences were detected between C50 and STD for any of the growth performance variables surveyed. Shrimp fed on N50 presented also a final weight, weight gain and FCR significantly poorer than those seen for STD (Table 2).

Although insignificant differences were seen for weight gain or survival, shrimp fed on S50 exhibited a significantly better FCR than for N50. On the other

Table 2 Final weight, weight gain, survival, feed conversion rate (FCR), protein efficiency rate (PER) and feed intake of the Pacific white shrimp *Litopenaeus vannamei* (3.89 ± 0.08 g) reared under controlled conditions for 70 days and fed on isonitrogenous (35.3–36.5% CP) and isolipidic (9.5–9.5%) diets with reduced levels of fishmeal and supplemented with different attractants (mean ± SD; $n = 4$)

Diet	Attractant	Fishmeal reduction	Final weight (g)	Weight gain (g wk^{-1})	Survival (%)	FCR*	PER†	Total feed intake‡ (g tank^{-1})
N25	None	25%	12.25 ± 0.45 b§	0.82 ± 0.06 b	93.8 ± 1.14 ab	2.83 ± 0.16 a	1.09 ± 0.06 ab	925.5 ± 14.7
N50		50%	12.29 ± 0.32 b	0.83 ± 0.02 b	89.8 ± 2.27 ab	3.07 ± 0.21 b	1.01 ± 0.07 b	947.8 ± 10.8
C25	Commercial¶	25%	12.83 ± 0.27 ab	0.89 ± 0.01 ab	95.5 ± 4.15 a	2.50 ± 0.10 a	1.23 ± 0.05 a	911.3 ± 29.8
C50		50%	13.05 ± 0.54 ab	0.92 ± 0.06 ab	87.5 ± 7.07 b	2.75 ± 0.28 a	1.13 ± 0.10 ab	911.75 ± 29.4
S25	*Spirulina* meal ‖	25%	12.80 ± 0.46 ab	0.89 ± 0.03 ab	94.9 ± 2.86 ab	2.55 ± 0.08 a	1.21 ± 0.04 a	928.1 ± 14.0
S50		50%	12.30 ± 0.50 b	0.85 ± 0.06 b	90.9 ± 4.15 ab	2.83 ± 0.19 a	1.09 ± 0.08 ab	917.5 ± 22.3
STD**	Commercial	0%	13.22 ± 0.90 a	0.95 ± 0.08 a	89.0 ± 0.0 ab	2.61 ± 0.29 a	1.10 ± 0.11 ab	902.6 ± 14.1
	ANOVA *P*		0.007	<0.001	0.037	0.008	0.006	0.101††

*FCR (Feed conversion ratio) = feed allowance/shrimp weight gain.
†PER (Protein efficiency ratio) = shrimp weight gain/protein consumed.
‡Total feed intake = total feed allowance – [(feed remains/feed's water absorption coefficient) × feed's leaching coefficient].
§Means with distinct letters in a same column are significantly different between themselves by the Tukey's test ($P < 0.05$).
¶Complex of amino acids (alanine, valine, glycine, proline, serine, histidine, glutamic acid, tyrosine and betaine) with enzymatically digested bivalve mollusk).
‖Organic Spirulina powder.
**Standard fishmeal based diet for *Litopenaeus vannamei* juveniles (lab made; 36.5% crude protein and 9.8% lipids; 0.5% of commercial attractant).
††Not significant ($P > 0.05$).

hand, shrimp fed on S50 gained significantly less body weight than those fed on STD (Table 2). Besides, no considerable differences were detected between S50 and C50 for any growth performance indices studied.

The attractiveness experiment showed that S25 was preferred significantly more by shrimp than C25. Besides, the difference of dry diet's remains between S25 and STD was not significant ($P > 0.05$). On the other hand, no significant difference was seen for the dry diet's remains between N25 and S25, although the latter diet produced considerably less remains than the former (Fig. 1). In the comparisons between the diets with high reduction of fishmeal inclusion level (50% less), no significant differences were observed between C50 and S50. In contrast, the dry diet's remains of S50 were significantly greater than those reported for STD. Besides, shrimp preferred significantly more S50 than N50 (Fig. 1).

The results obtained in the present work suggest that it is possible to reduce the inclusion level of fishmeal in a complete diet for *L. vannamei* by 25% (from 18.5% to 13.9%) without compromising growth if an effective feeding attractant is supplemented in the diet. Besides, it was also noted that Spirulina meal acted as efficiently as the commercial attractant used in eliciting shrimp's feed response when a moderate fishmeal reduction was carried out. In this case, shrimp chose significantly more the diet supplemented with Spirulina meal than with the commercial feeding attractant. On the other hand, a higher reduction in the dietary level of fishmeal (from 18.5% to 9.2%) would be feasible without growth retardation only if a complex of amino acids with enzymatically digested bivalve mollusk, or a similar product, be supplemented at 0.5% in the diet. To this diet, the supplementation with Spirulina meal would not be capable to sustain shrimp's feed intake and, by consequence, shrimp's weight gain and FCR. These growth performance results were confirmed by the attractiveness experiment carried out in the following phase of the present work.

It is important to note that just 0.5% of Spirulina meal was added in diets S25 and S50 and that much higher levels were used in other works. Olvera-Novoa, Domínguez-Cen, Castillo-Olivera and Martínez-Palacios (1998) conducted a study with *Oreochromis mossambicus* fry to assess the potential of *Spirulina maxima* meal to replace fish meal in diets for that fish species. They included Spirulina meal from 10.5% up to 52.3% in the diets, and concluded that up to 40% of the fish meal protein could be replaced by Spirulina meal. Nandeesha, Gangadhara, Manissery and Venkataraman (2001) included Spirulina powder in balanced diets for two Indian major carps, *Catla catla* and *Labeo rohita*, in levels between 7.4% and 30.9%,

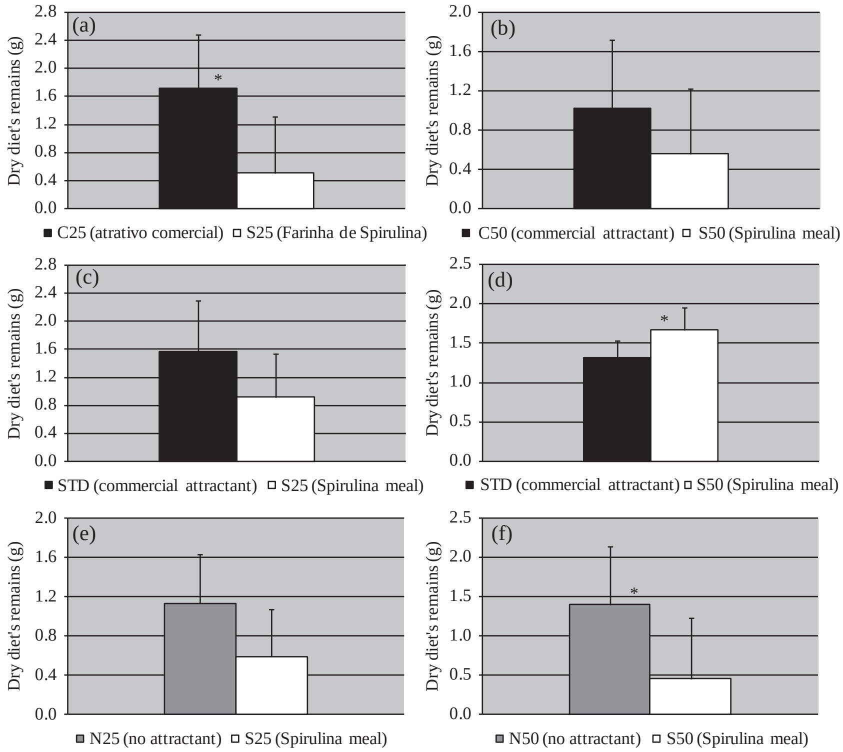

Figure 1 Dry diet's remains in feeding trays after 8 h of feed exposure to *Litopenaeus vannamei* juveniles. Bars in a same graph with an asterisk indicate that the means are significantly different between themselves by the Student's *t*-test ($P < 0.05$). The numbers 25 and 50 after the letters C (commercial attractant; 0.5%) or S (Spirulina meal; 0.5%) stand for the dietary reduction levels of fish meal at 25% and 50% respectively; STD was the standard diet with 18.5 g 100 g^{-1} Peruvian fish meal.

and concluded that Spirulina is capable to replace partially or completely fish meal in complete diets for those species. A similar conclusion was made by Palmegiano, Agradi, Forneris, Gai, Gasco, Rigamonti, Sicuro and Zoccarato (2005) to the Siberian sturgeon, *Acipenser baeri*. These authors included up to 60% of Spirulina meal in the diet. Ju, Forster and Dominy (2009) observed significantly higher growth and survival rates in a *L. vannamei* study to the animals that fed on diets supplemented with 9.0% of dried *Thalassiosira weissflogii* or *Nannochloropsis*. Therefore, it would be possible to achieve even better growth performance's results if higher levels of Spirulina meal had been used in the present work. Notwithstanding this, it was not our purpose to test Spirulina meal as a source of macronutrients, such as amino acids or fatty acids. Our aim was to test Spirulina meal as a feed additive, included at very low dietary levels. This question needs to be highlighted because the price of Spirulina meal is very high, making its use not economically feasible to high dietary inclusion levels.

Jaime-Ceballos *et al.* (2007) in a work with *L. schimitti* concluded that *S. platensis* included at 5% in the diet improved the attractability of the feed. These authors suggested that the Spirulina meal's nucleotides, amino acids and/or pigments were the active compounds responsible for its attractability. Spirulina meal has, approximately, 8.7% of glutamic acid, 6.6% of aspartic acid and 5.0% of leucine, which are its amino acids most found. Among these, glutamic acid, the amino acid highest found in Spirulina, was cited by the classic chapter of Lee and Meyers (1997) as one of the amino acids with proved chemoattraction for penaeid shrimp. Therefore, glutamic acid might be the main active feeding effector of Spirulina meal for *L. vannamei*. That supposition deserves a further investigation.

In the present work, Spirulina meal acted as a feeding attractant in a dietary inclusion level 10 times lower than that used by Jaime-Ceballos *et al.* (2007). In spite of the two studies have employed different shrimp species, the present work's results suggest that Spirulina has the capacity to stimulate the marine shrimp's feed intake in a very low dietary level of inclusion. As a matter of fact, the inclusion level of Spirulina meal was the same used for the commercial attractant (0.5%). Perhaps higher dietary inclusion levels of Spirulina meal could produce positive effects on shrimp's feed intake even for diets with low or very low levels of fishmeal.

At high fish meal replacement levels (i.e., 50%), the commercial feeding attractant used in the present work has revealed itself superior over Spirulina meal to stimulate *L. vannamei*'s feed intake. Nevertheless, it is noteworthy that while the commercial attractant is a proprietary product with a closed formula, possibly containing many different compounds, Spirulina meal is composed by a single raw material with known chemical composition. On the other hand, the current price of Spirulina meal is four times more expensive than the commercial feeding attractant. Hence, it is necessary that new and cheaper industrial manufacturing technologies are deployed to produce Spirulina meal as a cost-effective ingredient for aqua feeds. FAO (2010) reports a significant growth in Spirulina production in recent years, the bulk originating from Asia, from 16.483 MT in 2003 to 68.390 MT in 2008. Owing to its considerable potential for development (Habib, Parvin, Huntington & Hasan 2008), global Spirulina production should continue to increase possibly making it more accessible to aquaculture.

Therefore, although at the present time no economical advantage exists in replacing the commercial attractant by Spirulina meal, it has acted as a strong feeding effector for *L. vannamei* at a very low dietary inclusion level. This should serve as a foundation for further and more refined studies with Spirulina meal in diets for marine shrimp. In conclusion, Spirulina meal added at 0.5% in a complete diet for *L. vannamei* juveniles, with 14% of Peruvian fishmeal, has proved itself as a nutritionally efficient feeding attractant. However, at present time, a broader use of Spirulina meal in grow-out diets for marine shrimp has yet to achieve economical feasibility.

Acknowledgments

The first author (José F. Silva-Neto) would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq for the grant received and to the Departamento de Engenharia de Pesca (CCA, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil) for the opportunity to obtain his MSc degree in Fisheries Engineering.

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