

## EFFECT OF SHRIMP HEAD MEAL INCLUSION LEVEL IN *Litopenaeus schmitti* JUVENILES DIET.

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### ABSTRACT

This study determined the effect of different shrimp head meal (SHM) levels (0, 5, 15, 25 and 30%) in practical diets for Caribbean white shrimp juveniles *Litopenaeus schmitti* (0.29 ± 0.0025 g). A totally randomized experimental design was carried out under laboratory conditions during 54 days. There were no significant differences ( $p > 0.05$ ) in survival of shrimps in all treatments evaluated. This result indicated that SHM included at 5, 15 and 25% in diet promoted growth. The relation of SHM inclusion level in diet with final weight (FW), food conversion rate (FCR) and protein efficiency ratio (PER) were described by the following quadratic equation:  $FW = 0.8023 + 0.0604 S - 0.0018 S^2$ ,  $R^2 = 0.81$ ;  $FCR = 8.0019 - 0.6081 S + 0.0164 S^2$ ,  $R^2 = 0.82$  and  $PER = 0.3695 + 0.0677 S - 0.0018 S^2$ ,  $R^2 = 0.93$ , respectively; which suggested that optimum SHM inclusion level in practical diets was 17%. Chemical score showed that the first and second limiting amino acid were arginine and histidine in all experimental diets.

Key words: shrimp head meal; diets; juveniles; shrimp culture; *Litopenaeus schmitti*.

### RESUMEN

Se evaluó el efecto de diferentes niveles de inclusión (0, 5, 15, 25 y 30 %) de harina de cabeza de camarón (HCC) en dietas prácticas para juveniles de camarón blanco del Caribe *Litopenaeus schmitti* (0.29 ± 0.0025 g). Se desarrolló un diseño experimental completamente aleatorizado en condiciones de laboratorio durante 54 días. No se encontraron diferencias significativas ( $p > 0.05$ ) en supervivencia entre los tratamientos evaluados. Los resultados indicaron que la inclusión de 5, 15 y 25 % de HCC en el alimento promovió el crecimiento. La relación del nivel de inclusión de HCC en la dieta con el peso final (PF), el factor de conversión del alimento (FCA) y la tasa de eficiencia proteica (TEP) fueron descritas por las siguientes ecuaciones cuadráticas:  $PF = 0.8023 + 0.0604 S - 0.0018 S^2$ ,  $R^2 = 0.81$ ;  $FCA = 8.0019 - 0.6081 S + 0.0164 S^2$ ,  $R^2 = 0.82$  y  $TEP = 0.3695 + 0.0677 S - 0.0018 S^2$ ,  $R^2 = 0.93$ , respectivamente, lo que sugiere un nivel de inclusión óptimo de 17 %. El cómputo químico mostró que el primer y segundo aminoácido limitante fueron la arginina y la histidina en todas las dietas experimentales.

Palabras clave: harina de cabeza de camarón; dietas; juveniles; cultivo de camarón; *Litopenaeus schmitti*.

Formulated feed plays an important role as the source of nutrients, and protein is recognized as one of the most principal dietary component (Goytortúa-Bores *et al.*, in press). Levels of protein in commercial shrimp feed vary between 30 and 50%, and most feeds contain some fish meal protein (Martinez-Cordoba *et al.*, 2003). Several previous studies have evaluated various alternative protein sources (Galindo, 2000; Davis and Arnold, 2000; Olvera-Novoa and Olivera-Castillo, 2000; Cruz-Suarez *et al.*, 2004; Yu, 2004; Villarreal *et al.*, 2004; Villarreal *et al.*, 2006).

Shrimp head meal is commonly used in feed for shrimp culture, it is an excellent source of mineral, chitin, cholesterol, phospholipids and the fatty acids, 20:5 $\omega$ 3 and 22:6 $\omega$ 3. Shrimp meal also serves as an attractant with high concentration of glycine betaine (Hertrampf and Farooq, 2001) and

its use is usually limited by fiber content (Akiyama *et al.*, 1991). Ideally, alternative ingredients should have satisfactory nutritional quality for the cultivated species, and be economically practical (D'Abramo and Lovell, 1991). Shrimp head meal has been used as protein source in other penaeid shrimp species foods (Lim and Dominy, 1992; Gallardo *et al.*, 2002; Villarreal *et al.*, 2004; Molina-Poveda and Morales, 2004; Pedroza-Islas *et al.*, 2004; Jaime-Ceballos *et al.*, 2004) but only few authors have evaluated its effects (Fenucci *et al.*, 1982; Chen *et al.*, 1985; Cruz-Suárez *et al.*, 1993).

There are not previous studies on the use of HSM in diets for the Caribbean white shrimp *L. schmitti*.

This study was conducted to determine the optimum inclusion level of shrimp head meal

(SHM) in feed formulations for juvenile white shrimp *L. schmitti* under laboratory conditions.

## MATERIAL AND METHODS

### Ingredients and experimental diets

Shrimp head meal was prepared at the Centro de Investigaciones Pesqueras (CIP) facilities at Ciudad de La Habana, Cuba. It was prepared from heads on fresh commercially culture *L. schmitti*. The ingredients were boiled, oven-dried in a forced-air at 50°C for 12 h, ground in a hammer mill, and stored in plastic bags under refrigeration until used.

Five experimental diets were formulated containing 0, 5, 15, 25 and 30% SHM (Table 1). Control diet contained fish meal, soybean meal and torula yeast as main protein sources.

Before preparing the experimental diets, all ingredients were ground in a hammer mill and passed through a 350 µm mesh sieve. The dry ingredients of each diet were mixed thoroughly in a food mixer before an oil mixture (shark liver and sunflower oils) was added. After the oil was dispersed, water was added (approximately 50% of the total “as is” ingredient weight) and finally mixed. The resulting mixture was pelleted using a meat grinder and a 2 mm die. The pellets were dried in a forced-air oven at 50°C for 12 h. Diets were analyzed in triplicate using AOAC (1995) procedures for crude protein (N x 6.25), ether extract and crude fiber. The gross energy values of diets were calculated from Cuzon and Guillaume (1997), with 21.3 kJ g<sup>-1</sup> for protein, 17.6 kJ g<sup>-1</sup> for carbohydrate and 39.1 kJ g<sup>-1</sup> for lipid.

Chemical score was also determined according to García (1993), where amino acid composition of *L. schmitti* juveniles served as reference (Gallardo *et al.*, 1989) and amino acid composition of protein sources was taken from Díaz-Guzmán (1996).

### Feeding trial

A feeding trial was conducted during 54 days in the Nutrition Laboratory at CALISUR Commercial Hatchery (Manzanillo, Granma province, Cuba). Juveniles of *L. schmitti* were obtained from the commercial nursery (CALISUR Farm, Rio Cauto, Granma province, Cuba). The trial was performed in 25 plastic containers (0.65 x 0.40 x 0.265 m) containing 30 l filtered seawater (0.5 µm) and UV-sterilized to reduce bacterial contamination.

Constant aeration was provided via air stones using a 5 HP turbo blower. To maintain the water quality and eliminate faecal residues or food remains, a 30% water exchange was done daily. A photoperiod of 12:12 h light: dark cycle was used throughout the experiment. Temperature, salinity and dissolved oxygen were monitored daily before water exchange (27.5 ± 0.22°C; 36 ± 0.57 ppt; 5.3 ± 0.13 mg l<sup>-1</sup> respectively), whereas pH and ammonium concentration were determined once in week (8.1 ± 0.08 and 0.19 ± 0.03 mg l<sup>-1</sup> respectively).

Shrimp specimens were individually weighed to nearest 0.01 g using a digital balance. Ten shrimp juveniles with an average initial weight of 0.29 ± 0.0025 g (mean ± standard deviation) were placed into each tank (stocking density related to bottom surface area: 40 shrimp m<sup>-2</sup>).

Dietary treatments were randomly assigned to the tank and the shrimps were fed at 10% of the biomass, distributed manually twice a day (50% at 09:00 hours and 50% at 16:00 hours). Rations were adjusted daily, after noting the presence or absence of residual feed.

At the conclusion of the day trial, final weight (FW), growth rate (GR), survival (S), feed offered, feed conversion ratio (FCR) and protein efficiency ratio (PER) were determined for each replicate of each treatment as follows: GR (%) = [(final mean weight - initial mean weight) / initial mean weight] x 100; S (%) = (final number of shrimp / initial number of shrimp) x 100; FCR = feed offered / [(final biomass - initial biomass) + ½ (initial average weight + final average weight) (number of death organisms)]; PER = [(final biomass - initial biomass) + ½ (initial average weight + final average weight) (number of death organisms)] / total protein offered.

### Statistical analysis

Normality and variance homogeneity of data were evaluated using the Kolmogorov-Smirnov and Bartlett's tests. The dependence of FW, FCR and PER on the percent of inclusion level of SHM was determined using a quadratic equation (Shearer, 2000):

$$Y = a_0 + a_1S + a_2S^2$$

where Y represents FW (or FCR or PER), a<sub>0</sub>, a<sub>1</sub>, a<sub>2</sub>, are regression coefficients and S is the inclusion level of SHM. The inclusion level yielding the

Table 1. Ingredient composition (g 100 g diet<sup>-1</sup>) and proximate analysis (g 100 g dry wt<sup>-1</sup>) of practical diets containing increasing levels of SHM

	Diets				
	SHM-0	SHM-5	SHM-15	SHM-25	SHM-30
Fish meal <sup>a</sup>	29	24	20	15	10
Soybean meal <sup>b</sup>	25	33	27	22	22
Wheat meal <sup>c</sup>	28	20	20	20	20
Torula yeast <sup>d</sup>	5	5	5	5	5
Shark liver oil <sup>e</sup>	1	1	1	1	1
Sunflower oil <sup>f</sup>	1	1	1	1	1
Vitamin and mineral premix <sup>g</sup>	2	2	2	2	2
CaCO <sub>3</sub> <sup>h</sup>	3	3	3	3	3
PO <sub>4</sub> (CO <sub>3</sub> ) <sub>2</sub> <sup>i</sup>	2	2	2	2	2
Binder <sup>j</sup>	2	2	2	2	2
Zeolite <sup>k</sup>	2	2	2	2	2
Vitamin C	0.25	0.25	0.25	0.25	0.25
SHM <sup>l</sup>	0	5	15	25	30
Proximate analysis <sup>m</sup>					
Crude protein (N x 6.25)	34.71	36.41	36.38	36.16	35.41
Ether extract	5.80	6.23	6.70	7.42	7.31
Crude fiber	2.57	3.32	3.19	3.37	3.59
Gross energy (kJ g <sup>-1</sup> )	15.2	15.2	15.2	15.3	15.3

<sup>a</sup> Anchoveta fish meal (*Engraulis* sp.) CORPESCA S.A. Chile

<sup>b</sup> Soybean meal (Molinera de Santiago de Cuba, Cuba)

<sup>c</sup> Wheat meal (Rice Co., USA)

<sup>d</sup> Torula yeast (ICIDCA, MINAZ, Cuba)

<sup>e</sup> Shark liver oil (Tburonera de Cojimar, Cuba)

<sup>f</sup> Sunflower oil (Empresa de Aceites y Grasas, Ciudad Habana, Cuba)

<sup>g</sup> Vitamin and mineral premix (Formula of the Union of Companies feeds MINAGRI, Cuba, for commercial feeds for shrimp culture. One metric ton of premix. Retinol 12.500. UI; Thiamine 10.000 mg; Riboflavin 20.000, mg; Pyridoxine 10.000 mg; Cianocobalamin 40,0 mg; Ascorbic acid 500.000 mg; Cholecalciferol 0,5 2.400.000 UI; DL- $\alpha$ -tocopherol 100.000; Menadione 4.000 mg; Pantothenic acid 40.000 mg; Choline chloride 1.600. mg; Folic acid 2.000 mg; Nicotinic acid , 140.000 mg; Biotin 1.000 mg; Inositol 300.000 mg; Paraminobenzoic acid 35.000 mg; Cobalt 200 mg; Copper 2.000 mg; Iron 20.000 mg; Iodine 1.500 mg; Manganese 40.000 mg; Zinc 20.000 mg; Selenium 100,0 mg)

<sup>h</sup>CaCO<sub>3</sub> (Cargill, USA)

<sup>i</sup>PO<sub>4</sub>(CO<sub>3</sub>)<sub>2</sub> (Cargill, USA)

<sup>j</sup>Carboxymethylcellulose sodium

<sup>k</sup>Zeolite (Yacimiento Tasajeras, Villa Clara, Cuba)

<sup>l</sup>Prepared in laboratory

<sup>m</sup>Values are means of three determinations

optimum values of FW, FCR or PER ( $Y_m$ ) was calculated from the previous equations as:

$$Y_m = - a_1(2a_2)^{-1}$$

This model quadratic model fits dose-response relations on the basis of mathematical and/or biological principles (Gurure *et al.*, 1995).

ANOVA and Tukey's HSD test were used to test for possible significant differences on FW, GR and S. In order to determine the possible effect of population density within experimental units on growth parameters, linear regression analysis were conducted to define the possible relationship. Significance level was set at  $p = 0.05$  for all cases.

Procedures available in STATISTICA 6.0 were used to conduct analyses. GR and S datas were transformed to arc sine values prior to statistical analysis.

## RESULTS

Final weight of white shrimps fed diets SHM-5, SHM-15 and SHM-25 were significantly higher ( $p < 0.05$ ) compared to that of shrimp fed diets SHM-0 and SHM-30 (Table 2). Juvenile shrimps fed diet SHM-0 showed the poorest FW and GR. Survival did not differ significantly ( $p > 0.05$ ) among treatments and it was in the range of 75 – 92.5%. Differences in growth were attributed to diets rather than the population density since final

Table 2. Response of *L. schmitti* juveniles after 54 days of feeding on experimental diets containing increasing levels of shrimp head meal (mean  $\pm$  standard deviation, n = 5)

Diet	Final weight (g)	Survival (%)	Growth rate (%)
SHM-0	0.73 $\pm$ 0.098 <sup>c</sup>	75.0 $\pm$ 10.0 <sup>a</sup>	151.7 $\pm$ 10.896 <sup>c</sup>
SHM-5	1.195 $\pm$ 0.017 <sup>a</sup>	80.0 $\pm$ 11.5 <sup>a</sup>	312.07 $\pm$ 5.976 <sup>a</sup>
SHM-15	1.20 $\pm$ 0.137 <sup>a</sup>	87.5 $\pm$ 12.6 <sup>a</sup>	313.79 $\pm$ 47.362 <sup>a</sup>
SHM-25	1.198 $\pm$ 0.095 <sup>a</sup>	85.0 $\pm$ 12.9 <sup>a</sup>	312.9 $\pm$ 32.881 <sup>a</sup>
SHM-30	0.958 $\pm$ 0.093 <sup>b</sup>	92.5 $\pm$ 9.57 <sup>a</sup>	230.17 $\pm$ 32.147 <sup>b</sup>

Values within the same column with different superscripts are significantly different (p<0.05).

growth was not found to depend significantly on the percentage of survival ( $r = 0.39$ ,  $p > 0.05$ ).

Regression analysis showed that there was a significant relationship between FW and SHM inclusion level (Fig. 1a), described by the quadratic equation:

$$FW = 0.8023 + 0.0604 S - 0.0018 S^2$$

From this equation, the inclusion level yielding maximum final weight of juveniles was:

$$Y_m = 16.77$$

For FCR values a significant response to SHM inclusion level in diet was described by the equation (Fig. 1b):

$$FCR = 8.0019 - 0.6081 S + 0.0164 S^2$$

The percent SHM inclusion level yielding lower FCR was:

$$Y_m = 18.54$$

Polynomial regression analysis between PER and SHM inclusion level in diet (Figure 1c) indicated a PER peak at the inclusion level of 18.81 (PER =  $0.3695 + 0.0677 S - 0.0018 S^2$ ).

The chemical score (Fig. 2) showed that the first and second limiting amino acids were arginine and histidine all experimental diets.

## DISCUSSION

Protein levels of experimental diets (average  $35.67 \pm 0.76$ ) used in this study were close to the range considered optimal for *L. schmitti* (Galindo, 2000).

The results indicate that using SHM for juvenile *L. schmitti* promotes growth. Growth of juveniles can

be significantly improved by SHM inclusion at 5, 15 and 25%. Other authors have found that SHM has also been beneficial in diet for other penaeid species (Cruz-Suárez *et al.*, 1993; Cuzon *et al.*, 1994; Goytortúa, 2007).

Fitting a quadratic model showed that the maximum FW response would occur at inclusion level of 17% and better FCR and PER at inclusion level of 19%.

Similar results obtained with growth parameters were observed for FCR. The efficiency in FCR was sensitive to the inclusion of SHM. Differences in FCR values may derive from improved protein quality content in diets with SHM, or from higher consumption levels of these diets. Further studies that take into account uneaten feed must be conducted to determine effective consumption, and to elucidate the role of these factors in feed efficiency.

PER was also improved by the inclusion of SHM in the diets, possibly as an effect of increased palatability and protein digestibility. A high palatability minimizes the time the feed remains uneaten, and thereby minimizes nutrient losses through leaching (Tacon *et al.*, 2000).

Mazid *et al.* (1997) reported that protein quality also affects PER values. In the present study, dietary protein content was similar among diets, but different PER values suggested differences in dietary protein quality. Nevertheless, PER results must be interpreted carefully because this parameter assumes that all protein is used for growth (Tacon, 1989). The high PER in shrimp fed SHM-15 diet suggests a better utilization of dietary protein.

High chitin levels in shrimp meals are not well digested (Meyers *et al.*, 1973). Galindo (2000) assessed different protein sources in *L. schmitti* diets at 30% inclusion level. Relative growth and

PER were lower in shrimp fed with diet containing SHM, it may derive from chitin content as in our results and the low *in vitro* digestibility shown by this protein source (Akiyama *et al.*, 1989; Galindo, 2000).

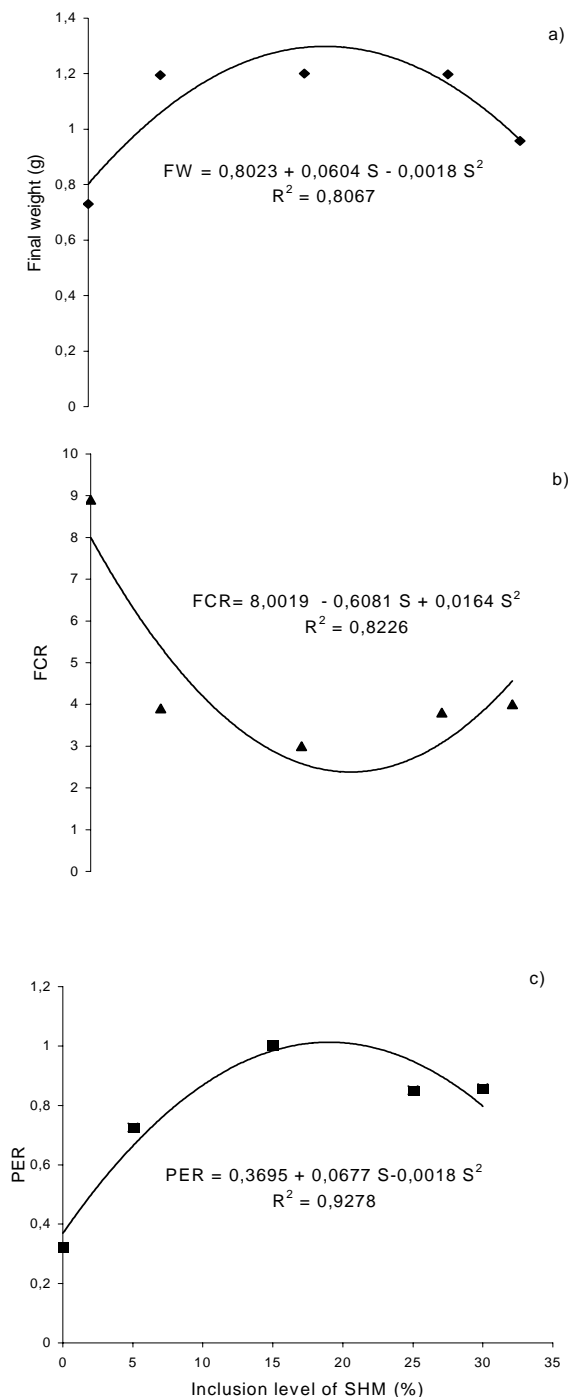


Fig. 1 Nutritional response of *Litopenaeus schmitti* juveniles to SHM inclusion level in diet a) final weight (FW) b) food conversion ratio (FCR) c) protein efficiency ratio (PER)

Crustacean meals are known to improve the palatability of diets for shrimps. Fox *et al.* (1994) observed that the inclusion of SHM in diets for juvenile *Penaeus monodon* significantly improved palatability, when compared to a diet based on fish meal.

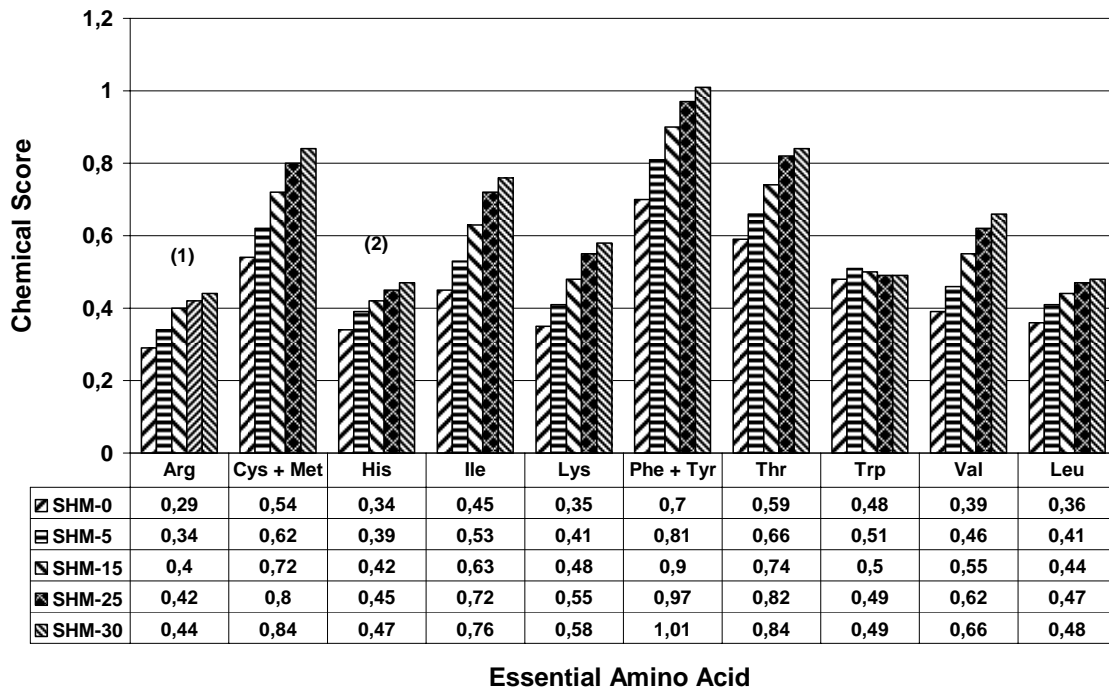
Like other crustacean meals, SHM contains nitrogenous compounds such as amino acids, peptides, and nucleotides that have been identified as feeding stimulants for several species (Cruz-Suárez *et al.*, 1993; Harpaz, 1997; Lee and Meyers, 1997; Smith *et al.*, 2005).

This response is possibly the result of a slightly higher content of some basic essential amino acids, as reported in Ezquerro *et al.* (1997). An indication of the biological value of the dietary protein is the lysine and arginine dietary relationship. Hence, in SHM-15 diet the lysine: arginine ratio is closer to those recommended for shrimp by Akiyama *et al.* (1992). It is probably that this improvement in amino acid profile due to the incorporation of SHM to the diets could be the cause of the growth enhancement of the organisms observed in the present experiment.

Williams *et al.* (2005) demonstrated that SHM contained a growth factor; nevertheless research is necessary to determine specific roles that SHM may play in improving the quality of diets for the shrimp species. Our results indicated that SHM can be included between 5–25% in diets for *L. schmitti*. However, an optimum of 17% is suggested.

## REFERENCES

- Akiyama, D.M., S.R. Coelho, A.L. Lawrence and E.H. Robinson (1989): Apparent digestibility of feedstuffs by the marine shrimp *Penaeus vannamei* (Boone). *Nippon Suisan Gakk.* 55(1), 91-98.
- Akiyama, D.M., W.G. Dominy and A.L. Lawrence (1991): Penaeid shrimp nutrition for the commercial feed industry: revised. In: (D.M. Akiyama and R.K.H. Tan, eds.), *Proceedings of the Aquaculture Feed Processing and Nutrition Workshop*. Thailand Indonesia, September 19-25. American Soybean Association, Singapore, pp 80-98.
- Akiyama, D.M., W.G. Dominy and A.L. Lawrence (1992): Penaeid shrimp nutrition. In: *Marine Shrimp Culture: Principles and Practices* (A.W. Fast, and J. Lester, eds.), Elsevier Science Publishers B.V. Amsterdam, pp: 535-567.



**Essential Amino Acid**

Fig. 2 Chemical score of the experimental diets in relation to amino acid composition of *L. schmitti* ([1]: first limiting amino acid, [2]: second limiting amino acid).

AOAC (1995): *Official Methods of Analysis of the Association of Official Analytical Chemist*, Vol. I, 16th ed. Washington, D. C., USA. 1234 pp.

Chen, H.Y., Z.P. Zein-Eldin and D.V. Aldrich (1985): Combined effects of shrimp size and dietary protein source on the growth of *Penaeus setiferus* and *Penaeus vannamei*. *J. World Maricult. Soc.* 16: 288-296.

Cruz-Suárez, L.E., M. Nieto-López, D. Ricque-Marie, C. Guajardo-Barbosa y U. Scholz (2004): Uso de harinas de subproductos avícolas en alimentos para *L. vannamei*. In: *Avances en Nutrición Acuícola VII. Memorias del VII Simposium Internacional de Nutrición Acuícola* (L.E. Cruz-Suárez, D. Ricque-Marie, M.G. Nieto-López, D.

Cruz-Suárez, L.E., D. Ricque-Marie, J.A. Martínez-Vega and P. Wesche-Ebeling (1993): Evaluation of two shrimp by-product meals as protein sources in diets for *Penaeus vannamei*. *Aquaculture* 115: 53-62.

Cuzon, G. and J. Guillaume (1997): Energy and Protein. Energy Ratio. In:(L.R. D’Abramo, D.E Conklin and D.M. Akiyama, eds), *Crustacean*

*Nutrition* Vol 6. World Aquaculture Society, Louisiana, US. pp: 51-70.

Cuzon, G., J. Guillaume and C. Cahu (1994): Composition, preparation and utilization of feeds for Crustacea. *Aquaculture* 124: 253-267.

D’Abramo, L.R. and R.T. Lovell (1991): Aquaculture research needs for the year 2000: fish and crustacean nutrition. *World Aquacult.* 22: 57-62.

Davis, D.A. and C.R. Arnold (2000): Replacement of fish meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. *Aquaculture* 185: 291-298.

Díaz-Guzmán, J.R. (1996): Principales ingredientes a utilizar en dietas para acuicultura. In: *Fundamentos de nutrición en acuicultura* (M. del P. Soler Jaramillo, H. Rodríguez Gómez, and P. Victoria Daza, eds.) INPA, Republica de Colombia, pp:179-236.

Ezquerria, J.M., F.L. García-Carreño, R. Civera and N.F. Haard (1997): pH-stat method to predict protein digestibility in white shrimp (*Penaeus vannamei*). *Aquaculture* 157: 249-260.

- Fenucci, J.L., A. Casal de Fenucci, A.L. Lawrence and C.P. Zein-Eldin (1982): The assimilation of protein and carbohydrate from prepared diets by the shrimp *Penaeus stylirostris*. *J. World Maricult. Soc.* 13: 134-145.
- Fox, C.J., P. Blow, J.H. Brown and I. Watson (1994): The effect of various processing methods on the physical and biochemical properties of shrimp head meals and their utilization by juvenile *Penaeus monodon* Fab. *Aquaculture* 122: 209-226.
- Galindo, J. (2000): Evaluación de niveles y fuentes de proteína en la dieta de juveniles de camarón blanco *Litopenaeus schmitti* (Burkenroad, 1939) (Crustacea, Decapoda, Penaeidae). *Wiñay Yachhay* 4: 17-47.
- Gallardo, N., R. González, O. Carrillo, O. Valdés and A. Forrellat (1989): Una aproximación a los requerimientos de aminoácidos esenciales de *Penaeus schmitti*. *Rev. Invest. Mar.* 10, 259-267.
- Gallardo, P.P., R. Pedroza-Islas, T. García-Galano, C. Pascual, C. Rosas, A. Sánchez and G. Gaxiola (2002): Replacement of live food with microbound diet in feeding *Litopenaeus setiferus* (Burkenroad) larvae. *Aquacult. Res.* 33, 681-691.
- García, T. (1993): Nutrición. In: (E. Alfonso, L. Ramos, E. Díaz, T. García and C. Rosas, eds.). *Manual del II Curso Internacional de Producción de Postlarvas de Camarones Peneidos del Atlántico de América*. Centro de Investigaciones Marinas, Universidad de La Habana, Cuba, pp. 97-115.
- Goytortúa, E. (2007): Harina de camarón. En: (T. García, H. Villarreal and J.L. Fenucci, eds). *Manual de ingredientes proteicos y aditivos empleados en la formulación de alimentos balanceados para camarones peneidos*. FUDEM, ISBN: 978-987-1371-02-0. pp. 56-65.
- Goytortúa-Bores, E., R. Civera-Cerecedo, S. Rocha-Mesa and A.Green-Yee (in press): Partial replacement of red crab (*Pleuroncodes planipes*) meal for fish meal in practical diets for the white shrimp *Litopenaeus vannamei*. Effects on growth and *in vivo* digestibility. *Aquaculture*.
- Gurure, R.M., R.D. Moccia and J.L. Atkinson (1995): Optimal protein requirements of young Arctic charr (*Sarvelinus alpinus*) fed practical diets. *Aquacult. Nutr.* 1: 227-234.
- Harpaz, S. (1997): Enhancement of growth in juvenile freshwater prawns *Macrobrachium rosenbergii*, through the use of chemo attractant. *Aquaculture* 156: 221-227.
- Hertrampf, J.W. and A. Farooq, (2001): Judging the attractability of aquafeeds, *International AQUAFEED* 4: 34-36.
- Jaime-Ceballos, B., H. Villarreal-Colmenares, T. García-Galano, R. Civera-Cerecedo and G. Gaxiola-Cortes (2004): Empleo del polvo de *Spirulina platensis* en la alimentación de zoeas y mysis de *Litopenaeus schmitti* (Pérez-Farfante y Kensley, 1997). In: *Avances en Nutrición Acuicola VIII Memorias del IV Simposium Internacional de Nutrición Acuicola* (L.E. Cruz-Suárez, D. Ricque-Marie, M.G. Nieto-López, D. Villarreal, U. Schols and M. González, eds.), Hermosillo, Sonora., México, pp: 617-635.
- Lee, P.G. and S. Meyers (1997): Chemoattraction and feeding stimulation. In: *Crustacean Nutrition* (L.R. D'Abramo, L.R. Conklin and D.M. Akiyama, eds.), World Aquaculture Society, Louisiana, US, vol. 6, pp: 292-352.
- Lim, C. and W. Dominy (1992): Substitution of full-fat soybeans for commercial soybean meal in diets for shrimp, *Penaeus vannamei*. *J. Appl. Aquacult.* 1(3), 35-45.
- Martinez-Cordoba, L.R., A. Campaña-Torres and Porchas-Cornejo (2003): Dietary protein level and natural food management in the culture of blue (*Litopenaeus stylirostris*) and white shrimp (*Litopenaeus vannamei*) in microcosms. *Aquacult. Nutr.* 9: 155-160.
- Mazid, M.A., M. Zaher, N.N. Begum, M.Z. Ali and F. Nahar (1997): Formulation of cost-effective feeds from locally available ingredients for carp polyculture system for increased production. *Aquaculture* 151: 71-78.
- Meyers, P., J. Samuel, E. Rutledge and S., Nonu (1973): Variability in proximate analysis of different processed shrimp meals. *Feedstuffs* 44, 34 pp.
- Molina-Poveda, C. and M.E. Morales (2004): Use of mixture of barley-based fermented grains and wheat gluten as an alternative protein source in practical diets for *Litopenaeus vannamei* (Boone). *Aquacult. Res.* 35, 1158-1165.

- Olvera-Novoa, M.A. y L. Olivera-Castillo (2000): Potencialidad del uso de las leguminosas como fuente proteica en alimentos para peces. In: (R. Civera-Cerecedo, C.J. Pérez-Estrada, D. Ricque-Marie and L.E. Cruz-Suárez, eds.), *Avances en Nutrición Acuícola IV Memorias del IV Simposium Internacional de Nutrición Acuícola*. Noviembre 15-18, 1998. La Paz, B.C.S., México. pp 327-348.
- Pedroza-Islas, R., P. Gallardo, E.J. Vernon-Carter, T. García-Galano, C. Rosas, C. Pascual y G. Gaxiola (2004): Growth, survival, quality and digestive enzyme activities on larval shrimp feed microencapsulated, mixed and live diets. *Aquacult. Nutr.* 19: 167-173.
- Shearer, K. (2000): Experimental design, statistical analysis and modeling of dietary nutrient requirement studies for fish: a critical review. *Aquacult. Nutr.* 6: 91-102.
- Smith, D.M., S.J. Tabrett, M.C. Barclay, and S.J. Irvin, S.J. (2005): The efficacy of ingredients included in shrimp feeds to stimulate intake. *Aquacult. Nutr.* 11: 263-272.
- Tacon, A.G.J. (1989): *Nutrición y alimentación de peces y camarones cultivados. Manual de Capacitación*. Proyecto Aquila II. Documento de Campo No. 4, GCP/RLA/102/ITA. Programa Cooperativo Gubernamental FAO-Italia, 572 pp.
- Tacon, A.G.J., W.G. Dominy and G.D. Pruder (2000): Tendencias y retos globales de los alimentos para el camarón. In: *Avances en Nutrición Acuícola IV. Memorias del IV Simposium Internacional de Nutrición Acuícola* (R. Civera-Cerecedo, C.J. Pérez-Estrada, D. Ricque-Marie y L.E. Cruz-Suárez, eds.), 1998, La Paz, B.C.S., México, 27 pp.
- Villarreal, H., R. Civera-Cerecedo and A. Hernández-Llamas (2006): Effect of partial and total replacement of fish, shrimp head, and soybean meals with red crab meal *Pleuroncodes planipes* (Stimpson) on growth of white shrimp *Litopenaeus vannamei* (Boone). *Aquacult. Res.* 37: 293-298.
- Villarreal, H., A. Hernández-Llamas, M.C. Rivera, A. Millan and S. Rocha (2004): Effect of substitution of shrimp meal, fish meal and soy meal with red crab *Pleuroncodes planipes* (Stimpson) meal in pelleted diets for postlarvae and juvenile *Farfantepenaeus californiensis* (Holmes). *Aquacult. Res.* 35: 178-183.
- Williams, K.C., D.M. Smith, M.C. Barclay, S.J. Tabrett and G. Riding (2005): Evidence of a growth factor in some crustacean-based feed ingredients in dietas for the giant tiger shrimp *Penaeus monodon*. *Aquaculture* 250: 377-390.
- Yu, Y. (2004): Replacement of fish meal with poultry by-product meal and meta and bone meal in shrimp, tilapia and trout diets. In: *Avances en Nutrición Acuícola VII. Memorias del VII Simposium Internacional de Nutrición Acuícola* (L.E. Cruz-Suárez, D. Ricque-Marie, M.G. Nieto-López, D. Villarreal, U. Scholz and M. González, eds.), Noviembre 16-19, 2004. Hermosillo, Sonora, México, 183-2001.

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