International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 22s, 2025
https://theaspd.com/index.php

Cricket Meal In The Diet Of *Penaeus vannamei Postlarvae* In Raceways

Fernando Isea-León[1]*, Galo Cedeño-Zambrano[2], Jean Carlos Pérez Parra[3], Lelly Useche Castro[4], Juan José Bernal-Zambrano[1], Rodolfo Patricio Panta-Vélez[1], Marjorie Armenia Idrovo-Vishuete[1], Juan Carlos Vélez-Chica[1]

[1*]*Technical University of Manabí (UTM), Department of Aquaculture, Fisheries and Renewable Natural Resources, Faculty of Aquaculture and Marine Sciences (FACM), Bahía de Caráquez, Ecuador.*
[2] *Technical University of Manabí (UTM), Department of Aquaculture, Fisheries and Renewable Natural Resources, Faculty of Aquaculture and Marine Sciences (FACM), Aquaculture Degree, Bahía de Caráquez, Ecuador.*
[3]*Technical University of Manabí, Department of Chemistry, Faculty of Basic Sciences. Portoviejo, Ecuador.*
[4]*Technical University of Manabí, Department of Mathematics and Statistics, Faculty of Basic Sciences. Portoviejo, Ecuador.*

Email and ORCID
[1]*Fernando Isea-León https://orcid.org/0000-0002-3766-5108*
[1]*Galo Cedeño-Zambrano*
[2]*Jean Carlos Pérez Parra https://orcid.org/0000-0002-7971-1782*
[3]*Lelly Useche Castro https://orcid.org/0000-0002-4294-9009*
[1]*Juan José Bernal-Zambrano https://orcid.org/0000-0002-6371-2676*
[1]Rodolfo Patricio Panta Vélez https://orcid.org/0000-0003-2969-0765
[1]*Marjorie Armenia Idrovo Vishuete https://orcid.org/0009-0007-4305-1384*
[1]*Juan Carlos Vélez-Chica https://orcid.org/0000-0002-6660-6940*

Corresponding Author: *Fernando Isea-León*
**Email: fernando.isea@utm.edu.ec*

SUMMARY

Objective. *To evaluate the effect of cricket meal on the growth and survival of Penaeus vannamei shrimp postlarvae in raceways.*

Materials and methods. *For the present study, Acheta domesticus cricket meal (CM) was used at different replacement percentages (0, 20, 40, and 60%) of fish meal (FM). Experiments were carried out with a population of 60,000 postlarvae (PL), at the PL-16 stage, with an average weight of 0.007 g ± 0.001 g, which were distributed in three tanks per treatment. Postlarvae were stocked at a density of 10 PL/L of water. The raceway cultivation experiment lasted 21 days. Growth was monitored weekly by recording the weight of a sample of the population. The experimental feed was set at 50% protein, with a feeding rate of 12% of the biomass.*

Results. *The average final weight of postlarvae from the 100% FM, 20, 40, and 60% CM treatments was 0.023±0.002 g; 0.018±0.003 g; 0.020±0.004 g, and 0.024±0.006 g, respectively, with significant differences (p<0.05) in favor of T4 (60% CM and 40% FM). Survival did not show significant differences between treatments, remaining at 90%.*

Conclusions. *Cricket flour demonstrated efficiency due to the weight gain and survival of shrimp postlarvae at the raceway stage.*

Keywords: *Shrimp, raceway, diets, insect meal, survival.*

INTRODUCTION

Aquaculture activity in Ecuador is mainly concentrated on the cultivation of white shrimp (*Penaeus vannamei*) and secondly tilapia (*Oreochromis mossambicus, Oreochromis niloticus, Oreochromis sp.*), exports of this product represent an increase in foreign currency income not related to oil with a production of 1069 tons, generating approximately 7289 million dollars (Central Bank of Ecuador, 2023).

The use of raceway pre-rearing systems has become a widely adopted practice in shrimp aquaculture in South America due to the multiple benefits it offers for improving production performance. This strategy allows shrimp to complete their metamorphosis under controlled conditions, facilitating better adaptation to grow-out ponds, significantly increasing survival, and strengthening their resistance to common diseases such as white spot disease (WSSV), EMS, and vibriosis. Furthermore, managing parameters such as temperature, maintained above 32°C, limits the development of pathogens (Ching, 2014).

From a technical perspective, raceways offer an effective tool for adjusting culture planning, as they allow for accurate estimation of stocked biomass, facilitating the transfer of juveniles with a high probability of survival, both in intensive and semi-intensive systems (Vanoni, 2014; Arias, 2010). Postlarvae reared in these systems reach an average weight of 0.10 g (10 PL/g), and thanks to the compensatory growth effect, they can weigh between 3.0 and 5.0 g just one month after stocking in ponds (Ching, 2014). Furthermore, stocking densities in raceways range from 20 to 40 PL/L, with satisfactory production results; Saldarriaga (1995) indicates that this range allows obtaining individuals with final weights of up to 1.0 g. An example of its effectiveness is reported by Pardo (2012), who observed that, with a density of 30 PL/L in cement raceways with 70 m^3 of water and a 20% replacement, average weights of 30.0 and 35.0 mg were achieved in 12 days, with survival rates of 90.0% and 87.7%, respectively, demonstrating its technical and sanitary viability.

Shrimp is established as an important consumer product; however, it requires comprehensive management and controls at every stage of farming; that is, during planting, growth, development, and harvesting. Despite this, Ecuador ranks second in the world as a shrimp producer and exporter (Caicedo, 2018).

In aquaculture, Fish Meal (FM) is considered the optimal reference raw material to meet the nutritional requirements of all farmed organisms. However, its use is limited due to the overexploitation of marine resources. Therefore, it is important to investigate alternative raw materials with significant potential. Therefore, Insect Meal (IM) could meet the protein requirements of farmed feeds (Carvajal, 2022).

The IM has recently emerged as an economical, cost-effective, and nutritionally viable option for replacing FM. These meals are made from arthropods (insects and crustaceans) that are commonly found in fish's natural diet. The protein content of these meals ranges from 60 to 70%, depending on the species and life cycle stage of the insect. They are characterized by a good balance of essential amino acids, minerals, and vitamins, giving them a nutritional profile similar to FM. Furthermore, they have a high energy, fat, and fiber content, making them a potential alternative for feeding aquatic organisms (Xiaoming et al., 2010).

Van Huis (2012) points out that certain insect species that are cultivated and that meet the established protein conditions for feeding aquatic organisms include: housefly (*Musca domestica*), black soldier fly (*Hermetia illucens*); beetles - mealworm (*Tenebrio molitor*), the lesser mealworm (*Alphitobius diaperinus*); and crickets - house cricket (*Acheta domesticus*), where the commercial, scientific and economic interest in complementing fishmeal as a protein source has led to the analysis and research of various applications of different meals of animal origin, as is the case of cricket meal.

Under this same analysis, cricket meal is another type of IM with aquaculture potential due to the quality of its protein, for this purpose, it has been able to replace fish meal in fish diets, however, it is important to continue studying this nutritional dynamic (Valenzuela et al., 2012).

IM presents an efficient feed conversion and lipid composition (between 29% and 31% of HUFA) and is also characterized by having a good source of vitamins considering the flour formulation (Thomas & Walker., 2014). The use of insects, such as *Acheta domesticus*, in animal feed represents a substantial strategy based on the principles of sustainable aquaculture, contributing to the reduction of overexploitation of bioaquatic resources (Fraijo-Valenzuela et al., 2024). Crickets have the advantage of being low in fat compared to other insects, this aspect facilitates the elaboration of flours, since it is not necessary to extract the fat before formulation, as is the case with other insects. They have high reproduction rates and a relatively short biological cycle. Despite this, there is a lot of uncertainty surrounding the business, due to the lack of regulations that govern the consumption of insects and their derived products (Portillo et al., 2017).

The objective of this research was to evaluate the partial and total replacement of fish meal with cricket meals in the diet of shrimp postlarvae to see if it would strengthen the growth of the organisms for subsequent cultivation.

MATERIALS AND METHODS

Study area

This research was carried out in the Aquatic Organisms Pre-breeding Laboratory (Room A), located in the facilities of the Aquaculture program, Faculty of Aquaculture and Marine Sciences, Technical University of Manabí (UTM), Sucre extension.

Obtaining raw materials

Acheta domesticus L. meal was obtained from the commercial company "Crick" (CM) located in the city of Quito, Ecuador. Fish meal (FM), Yellow Corn Meal (YCM), and Rice Bran Meal (RBM) were obtained from commercial establishments in the city of Bahía de Caráquez. All samples, of selected animal and plant origin, underwent physicochemical analyses in triplicate (% moisture, % ash, % crude protein, % crude fat, and % non-nitrogenous extracts (NNE) by difference).

Physicochemical analysis

Proximate analysis (humidity, ash, fat and protein) of each raw material (CM, FM, YCM, RBM) was carried out in triplicate, in order to know its nutritional value through the methods of humidity (Gravimetric), ash (Gravimetric), lipids/fats by solvent extraction (Soxhlet), protein by digestion, distillation and titration (Kjeldahl) (Association of Official Analytical Collaboration [AOAC], (2016). Proximate analysis consisted of the separation of each chemical compound that makes up the sample after being subjected to a series of methodological processes, with which it is intended to know the proportions of each component from the fragmentation of water and organic matter (Caravaca et al., 2003).

Table 2 details the physicochemical composition (g/100 g) of the raw materials used in the preparation of diets. Where the FM presented a moisture content of 9.52% and protein of 53.96%, in accordance with the level required by the Ecuadorian National Institute for Standardization (INEN 472 1988-04). However, its ash content did not meet the requirements, having a value (21.17%) higher than the maximum allowed by 10%. In the case of fat, it presented a value of 3.38% lower than the required level (6% minimum).

Table 2. Average and standard deviation of the physicochemical analysis of the raw materials FM (Fish Meal), CM (Cricket Meal), RB (Rice Bran), YCM (Yellow Corn Meal).

Parameter (%)	FM	CM	RB	YCM
MD	90.48 ± 0.055	96.51 ± 0.100	90.37 ± 0.137	88.59 ± 0.063
Humidity	9.52 ± 0.055	3.44 ± 0.067	9.63 ± 0.137	11.44 ± 0.059
Protein	53.96 ± 0.248	51.35 ± 0.676	11.98 ± 0.266	6.52 ± 0.212
Fat	3.38 ± 0.400	26.84 ± 0.218	6.85 ± 0.919	1.12 ± 0.117
Ash	21.17 ± 0.039	3.13 ± 0.028	6.65 ± 0.002	0.44 ± 0.035
ENN	11.75 ± 1.151	20.11 ± 8.784	63.02 ± 3.223	80.35 ± 0.446

MD= Dry matter; ENN = Non-nitrogenous extracts.

Feed formulation

Once the proximate analysis of the raw materials was carried out, the required proportions of raw materials for the preparation of food were obtained, taking into account the specifications of the percentage of protein required (50% PC) for the shrimp from pl 16 selected (postlarvae), and the replacement percentages set as treatments: T_1 = 0% CM + 100% FM; T_2 = 20% CM + 80% FM; T_3 = 40% CM + 60% FM; T_4 = 60% CM + 40% FM (Table 3).

Food processing

Once the balanced proportion of the ingredients was achieved, the experimental foods were prepared. Weighing the dry flours: FM, CM, YCM, RBM, mineral mix, vitamin mix and the carboxymethylcellulose binder (CMC), these were placed in the mixing container of the DIMETAL brand bakery kneading equipment to homogenize them, they were mixed for 10 minutes, then the fish oil and water were added until obtaining a homogeneous and manageable mixture; to then pass it to the JR brand meat grinder, in order to obtain by pressing cylindrical strips (similar to noodles) of 3 mm in diameter, and these were subsequently distributed in aluminum trays covered with waxed paper for drying at 55 ºC for 24 h. Once the balanced were dried, they were packaged, labeled and stored at 4 ºC until their experimental use.

Balanced foods

Table 3 shows the physicochemical composition (g/100 g) of the balanced feeds, where the experimental feeds had isoprotein levels close to 50% according to their previous formulation, complying with the physicochemical composition established in the INEN Standard for feeds in the postlarvae stage of Shrimp 1767 (1990-07).

Table 3. Percentage proportion of ingredients for the preparation of experimental balanced foods obtained by Linear Programming.

Ingredients (g/100 g)	T_1	T_2	T_3	T_4
Commercial Fish Meal	83	64	44	38
Cricket meal (*Acheta domesticu*)	0	20	40	55
Yellow corn flour	7	7	5	1
Rice bran flour	1	3	5	2
Fish oil	4	1	1	1
Vitamin premix	1	1	1	1
Mineral pre-mix	1	1	1	1
Carboxymethylcellulose	3	3	3	1
Total	100	100	100	100
Composition (g/100g)				
Dry Matter	97.39 ± 0.182	97.12 ± 0.188	96.38 ± 0.173	97.87 ± 0.071
Humidity	2.54 ± 0.182	2.78 ± 0.088	3.71 ± 0.106	2.13 ± 0.071
Protein	54.35 ± 0.325	53.59 ± 0.110	54.00 ± 0.502	54.22 ± 0.580
Fat	10.37 ± 0.136	12.44 ± 0.270	14.07 ± 0.028	16.94 ± 0.001
Ash	22.92 ± 0.056	19.69 ± 0.071	14.60 ± 0.131	13.03 ± 0.025
Non-Nitrogenated Extracts	9.83 ± 0.860	11.50 ± 1.492	13.62 ± 0.187	13.64 ± 0.3669

Transportation and acclimatization of shrimp postlarvae

A total of 60,000 shrimp postlarvae were obtained from a commercial laboratory located in the province of Manabí, Sucre canton, Leónidas Plaza parish. 5,000 shrimp postlarvae were transported in 15-liter bags to the Aquatic Organisms Pre-rearing Laboratory (Room A) of the Aquaculture program. The postlarvae were then acclimatized 3 days prior to the test and fed a commercial balanced feed containing 50% protein.

The organisms were placed in a 1000-liter circular fiberglass tank with a continuous aeration supply and daily measurement of water quality parameters: temperature (°C), salinity (‰), pH, and dissolved oxygen (mg/L), adjusted to the shrimp's acclimatization needs (20 ‰, 7.5 ± 0.6 pH, 4.8 ± 0.2 mg/L DO, and 28°C) according to Chávez et al. (2003). Siphoning and a 50% water exchange were performed daily. The organisms were acclimatized for a period of 3 days prior to the bioassay.

Experimental design and treatments

A control was designed with three treatments and three replicates respectively: T_1 (control feed with 100% fish meal), T_2 (20% Cricket Meal (CM) and 80% fish meal), T_3 (40% cricket meal and 60% fish meal), T_4 (60% cricket meal and 40% fish meal), which were randomly distributed in the experimental tanks with 5000 organisms (table 1).

Table 1. Experimental design of the feeding bioassay of *Penaeus vannamei* shrimp postlarvae in a raceway with *Acheta domesticus* cricket flour.

Treatment	**Organism/tank number**	**Replicas**	**Total number of organisms**

T_1	5000	3	15000
T_2	5000	3	15000
T_3	5000	3	15000
T_4	5000	3	15000
Total	20000	12	60000

T_1 (control feed with 100% fish meal), T_2 (20% cricket meal and 80% fish meal, T_3 (40% cricket meal and 60% fish meal), T_4 (60% cricket meal and 40% fish meal).

Bioassay

The experimental area consisted of 12 circular experimental units (tanks) with a capacity of 1,000 liters (1.25 m diameter x 0.70 m height), supplied with an operational volume of 500 liters of water. Each tank was stocked at a stocking density of 10 PL/L, resulting in an average population of 5,000 postlarvae. Three replicates were used for each treatment, and the bioassay lasted 21 days.

Feeding of shrimp postlarvae

Shrimp postlarvae were fed different experimental diets (T_1 = 0% CM + 100% FM; T_2 = 20% CM + 80% FM; T_3 = 40% CM + 60% FM; T_4 = 60% CM + 40% FM). The daily ration was supplied at 12% of the biomass present in each tank, determined for each of them at the beginning of the experiment and in each weekly biometric sampling. The daily ration was supplied three times a day (08:00 with 30%, 12:00 with 30% and 16:00 with 40%). The amount was modified according to feed consumption and biometries performed. For this purpose, the Daily Equation was used:

- **Daily Ration (DR)**

$$\boldsymbol{DR} = (AWE\ x\ \#T\ org)\ x\ \%B$$

Where:
AWE= average weight of each organism in grams.
#T org= total number of organisms.
%B= percentage of biomass.

Growth parameters

At the beginning and end of the experimental phase, postlarvae weight (g) was determined gravimetrically using a 0.001-g digital scale. Nutritional response indicators were calculated based on the equations detailed below:

- **Weight gain (WG)**

$$\boldsymbol{WG} = FAW\ (g) - AIW\ (g)$$

Where:
FAW: Final average weight.
AIW: Average initial weight.

- **Feed Conversion Rate (FC)**

$$\mathbf{FC} = \frac{\mathrm{C(g)}}{\mathrm{GW(g)}}$$

Where:
C: Feed consumption (g)
GW: Weight gain (g)

- **Feed efficiency (FE)**

$$\boldsymbol{FE} = \frac{GW(g)}{\mathrm{IF\ (g)}} * 100$$

Where:
GW: Weight gain (g)
IF: Food ingested (g)

- **Survival percentage (S)**

Shrimp survival was checked in each tank. The presence of dead organisms was verified daily. The survival rate was then determined using the following equation:

$$S(\%) = \frac{N° \, final \; shrimp}{N° starter \; shrimp} * 100$$

Protein analysis of postlarvae meat

To determine the percentage of protein in the meat of shrimp fed with CM-based diets, a sample of organisms of approximately 5 g/tank/treatment was taken, which was analyzed in triplicate and carried out in the Laboratory of the Faculty of Zootechnical Sciences, Chone extension (FSZ-LAB), of the Technical University of Manabí.

Water quality parameters

Daily monitoring of the physical and chemical parameters of the water in the experimental tanks used for growing postlarvae of the shrimp *P. vannamei was recorded* using a multiparameter (AZ8403). A refractometer (ATC) was used to measure temperature (°C), dissolved oxygen (mg/L), salinity (‰), and pH with a pH meter (Isolab). A weekly monitoring of TAN (mg/L) was carried out using an ammonium test kit, and the Blue Aqua application was used to determine the toxicity of ammonia in the water, entering the pH, temperature, and TAN/sample/treatment values.

Statistical analysis

The zootechnical parameter data were stored and processed in Excel spreadsheets (version 2019) and Jamovi (version 1.6.23) as a tool for analysis of variance (ANOVA). Results are presented as mean ± standard deviation. All data were compared using the modified Shapiro-Wilk normality test and the Levene test for homogeneity of variance. Descriptive statistics were used to analyze the results for water quality parameters.

RESULTS

The Final Average Weight (FAW), Feed Efficiency (FE) and survival values presented adequate data for the management of the culture, as well as the variable Feed Conversion (FC), the analysis of variance did not detect significant differences ($p>0.05$) between treatments (Table 4), indicating that the treatments with cricket flour showed the same response with respect to the control (fish meal).

The values of the final total weight of the postlarvae of *Penaeus vannamei shrimp fed with Acheta domesticus* cricket flour are shown in table 4 and figure 1. In the case of the final total weight (g) the analysis of variance detected significant differences in treatment T_2 ($p<0.05$), which presented the lowest final weight value (0.018 g) unlike treatments T_1, T_3 and T_4 which did not present significance (Figure 1).

Table 4. Average and standard deviation of the zootechnical parameters (g) ($\bar{X}$±SD) of the postlarvae of the shrimp *Penaeus vannamei* in the evaluated treatments. tw (Total weight), FMW (Final average weight), FC (Feed conversion), FE (Feed efficiency), S (Survival).

Parameters	T_1	T_2	T_3	T_4	P-value
Days of cultivation	21	21	21	21	-
Initial pt (g)	0.007±0.001	0.007±0.001	0.007±0.001	0.007±0.001	0.977
Final pt (g)	0.023a±0.002	0.018b±0.003	0.020ab±0.004	0.024ab±0.006	0.005
WG (g)	0.016±0.002	0.012±0.001	0.016±0.001	0.017±0.006	0.307
FC (g)	1.19±0.100	1.52±0.210	1.54±0.380	1.26±0.260	0.273
FE	88.37±5.207	71.43±5,051	75.81±2.382	70.75±0.001	0.224
S (%)	86.95±8.641	88.20±6.392	85.71±8.697	91.73±8.443	0.973

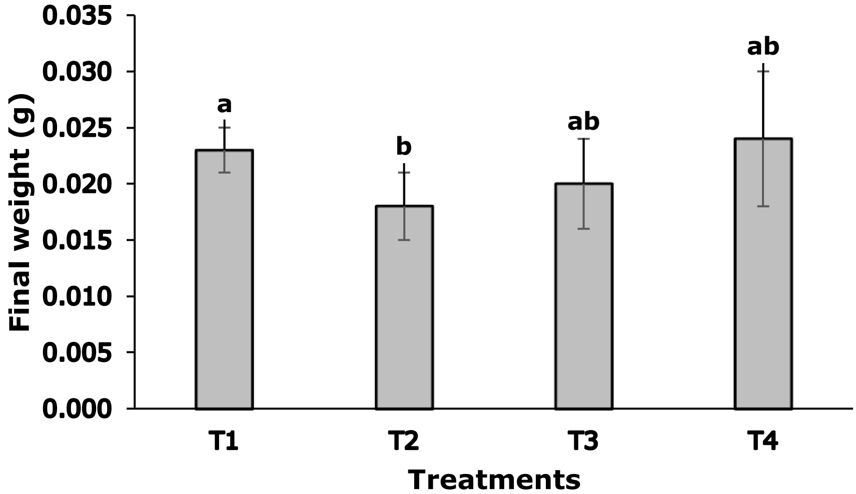

Figure 1. Final weight of *Penaeus vannamei* shrimp postlarvae in the different treatments. T_1 (100% fish meal FM), T_2 (20% CM and 80% FM cricket meal), T_3 (40% CM and 60% FM) and T_4 (60% CM and 40% FM).

Protein determination

The protein percentage analyses of the meat of the postlarvae fed with the different treatments are shown in Figure 2, which indicate that as the percentage of cricket flour in the feed increased, the protein level in the shrimp muscle increased.

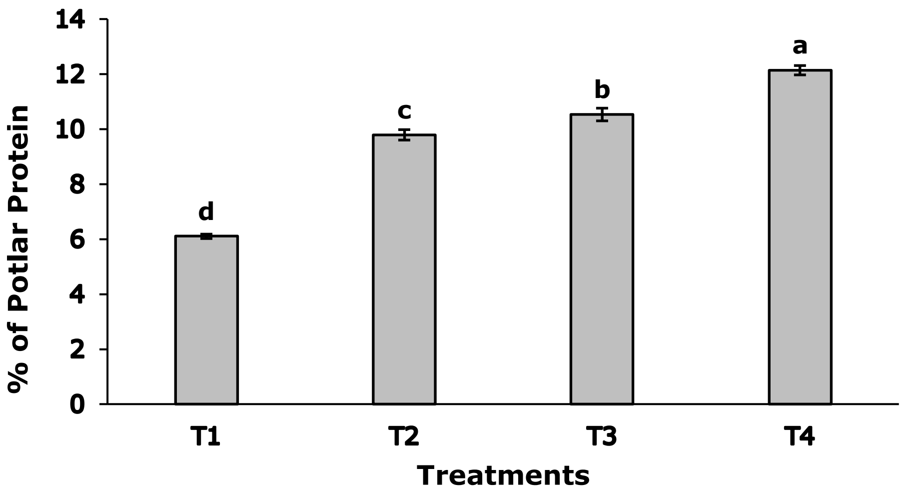

Figure 2. Mean and standard deviation of protein percentage of meat of postlarvae fed with experimental diets T_1 (100% fish meal FM), T_2 (20% cricket meal CM and 80% FM), T_3 (40% CM and 60% FM) and T_4 (60% CM and 40% FM).

Water quality

The values of the physicochemical parameters of the water, in the different treatments during the culture of the shrimp postlarvae, are presented in Table 5, where the pH showed ranges between 7.66 and 7.68. For its part, the temperature presented values between 26.99 and 27.24 °C and with respect to dissolved oxygen in this experiment, values of 5.06 and 5.38 mg/L were obtained. Finally, the salinity presented a single value of 30 ‰, which is located in the necessary range.

Table 5. Physicochemical parameters of the culture water for *Penaeus vannamei postlarvae* in the evaluated treatments; temperature (°C), salinity (‰), dissolved oxygen (mg/L), and pH. Average ± SD.

Treatments	pH	Temperature (°C)	OD (mg/L)	Salinity (‰)
T_1	7.68 ± 0.025	27.08 ± 0.281	5.08 ± 0.083	30 ± 0.001
T_2	7.66 ± 0.019	27.24 ± 0.264	5.38 ± 0.334	30 ± 0.001
T_3	7.66 ± 0.026	27.13 ± 0.271	5.09 ± 0.086	30 ± 0.001
T_4	7.68 ± 0.028	26.99 ± 0.299	5.06 ± 0.088	30 ± 0.001

The ammonia concentration values for the *Penaeus vannamei postlarvae culture* are presented in Figure 3, showing values below 0.1 mg/L in all treatments. Under this same analysis, no toxicity problems were observed in the different treatments because the temperature and pH parameters were maintained within their optimal range during culture, in addition to the practice of siphoning 10% of the water volume each day and subsequently replenishing each tank with the extracted water.

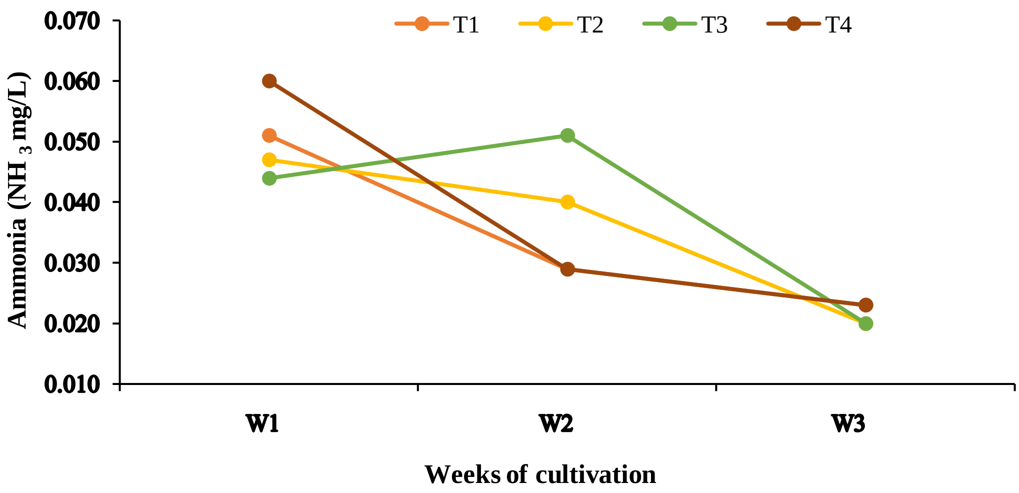

Figure 3. Ammonia concentration in the water of the *Penaeus vannamei postlarvae culture* in the different treatments T_1 (100% fish meal FM), T_2 (20% cricket meal CM and 80% FM), T_3 (40% CM and 60% FM) and T_4 (60% CM and 40% FM).

DISCUSSION

The CM presented a moisture content of 3.44%, 26.84% fat and 3.13% ash with average values that differ from those reported by Ayala & Elias (2019), who obtained 4.85%, 29.78% and 2.83%, respectively, indicating that both raw materials have lower humidity favoring their conservation. Regarding the protein content (51.35%) and fat (26.84%), it was relatively lower than that reported by Taufek et al. (2013) who found a higher crude protein content (57%) and lower lipid content (25%). However, it falls within the range reported by Zielińska & Pankiewicz, (2023) and Kowalski et al., (2022), who report that cricket flour not only maintains a high protein content, ranging between 49.89% and 62.51%, but is also rich in essential minerals such as iron, zinc and magnesium, which are often deficient in many diets.

In turn, CM protein contains varieties of essential amino acids, such as methionine, lysine, histidine, valine, and leucine, which are important for formulating and processing feeds (Phesatcha et al., 2022). For their part, Fraijo-Valenzuela et al., (2024) mention that CM contains a protein profile comparable to that of fishmeal, with essential amino acids beneficial for shrimp growth. For its part, the amino acid profile is superior to that of many conventional protein sources, except for histidine and cysteine, making it a valuable source of nutrients in diets (Murugu et al., 2020). However, Kowalski et al., (2022) report that this flour has high nutritional levels in feeds, where values ranging from 40% to 70% have been reported with only 10% inclusion of cricket flour.

The YCM and RBM presented physicochemical composition values that comply with the requirements of INEN 1690 (1989-02) and INEN 2051 (1995-09) standards, respectively.

The replacement of cricket meal (CM) in shrimp postlarvae diets yielded favorable results in terms of growth and survival, with no significant differences among treatments. This indicates that CM has a comparable nutritional potential to fishmeal, allowing substitution levels of up to 60% according to the findings of this study, which represents a highly satisfactory outcome. These results contrast with those reported by Lee et al. (2017), who evaluated the inclusion of domestic cricket meal (*Acheta domesticus*, CMD) in red tilapia (*Oreochromis* sp.) diets and observed significant differences in growth and survival, with the diet containing 60% CMD and 40% rice bran producing the best performance. Such interspecific variability highlights the importance of considering the physiological and metabolic differences of each cultured species when assessing alternative ingredients. In this regard, the present study provides robust evidence supporting the feasibility of CM utilization in white shrimp (*Penaeus vannamei*), reinforcing its potential as a sustainable protein source and a strategic option to reduce fishmeal dependency in modern aquaculture.

In *P. vannamei*, insect meals often maintain performance at moderate substitution levels, but responses are ingredient- and processing-specific; for example, defatted black soldier fly meals have supported high replacement rates in grow-out under some formulations, underscoring that matrix effects (lipid fraction, chitin, amino acid balance) and techno-functional traits modulate outcomes (Chang et al., 2025; Lin et al., 2023). Digestibility studies in *P. vannamei* demonstrate that apparent digestibility coefficients differ among insect taxa—including crickets—highlighting the need to quantify CM's bioavailability (protein and indispensable amino acids) and to correct for chitin-associated nitrogen when computing dietary protein equivalence (Shin et al., 2021). Beyond growth, emerging syntheses indicate insect meals can influence mucosal immunity, gut integrity, and product quality, suggesting that immune and histomorphometric endpoints should accompany performance metrics in future CM trials (Islam et al., 2024; Serra et al., 2024). Recent cricket-focused reviews further support CM's nutritional potential while emphasizing gaps on optimal inclusion levels, processing (defatting/hydrolysis), and species-specific palatability—factors that likely explain interspecific contrasts with finfish reports (Fraijo-Valenzuela et al., 2024). Collectively, while our nursery-phase data are encouraging, definitive adoption will require longer grow-out evaluations integrating nutrient digestibility, cost–benefit analysis, and health/quality readouts under industry-relevant systems.

Similarly, Tilami et al., (2020) evaluated the effect of feeding rainbow trout a commercial diet and its partial and total replacement with two species of live insects, *A. domesticus* and the mealworm (*Zophobas morio*). Where five treatments were evaluated: 1) control (commercial feed); 2) 25% replacement of the Gross Energy (GE) of the commercial feed with the equivalent in live adults of *A. domesticus* ; 3) 25% replacement of the GE by live adults of the mealworm *Z. morio* ; 4) 25% replacement of the GE by a mixture of both insects (12.5% each) and 5) a group fed only with insects (50% of GE of each). No significant differences in growth or survival were observed between treatments.

One advantage of using cricket meal is that its digestibility is comparable to that of common plant-based foods, ranging from 80% to 88%, although slightly lower than animal proteins (Murugu et al., 2020). However, other studies show that cricket meal has a protein digestibility of approximately 67.4%, making it a viable alternative for shrimp diets (Toribio et al., 2024).

Likewise, it is important to consider that this meal also contains beneficial fatty acids, such as oleic, palmitic, and linoleic acids, which contribute to its overall nutritional value (Kowalski et al., 2022). All of this makes this raw material a viable alternative for formulating feeds for post-larvae shrimp.

In other studies, carried out by Magalhaes et al., (2017), they indicated that better fish growth was obtained when they were fed with the inclusion of the black soldier fly *Hermetia illucens* in their diets, similar to that observed in other freshwater and marine fish species, it is partly attributed to the fact that the essential amino acid profile of this meal is similar to FM, and therefore covers the requirements of fish, including marine carnivores. The results of this research show that a percentage of FM substitution by *Hermetia illucens* in diets for *Totoaba macdonaldi* up to 50% does not produce adverse effects on growth. These positive results serve as a basis to recommend studies with higher levels of FM substitution by *Hermetia illucens*.

Regarding the optimal protein requirement for *P. vannamei*, it is between 20 to 45 % depending on the shrimp size, water conditions and dietary characteristics such as protein quality, energy content and palatability (Yun et al., 2016). These results differ from those reported by Panini et al., (2017) who found that the protein content

of shrimp muscle is not significantly influenced when fishmeal is replaced by the mealworm *Tenebrio molitor* (IM), while the lipid content did increase linearly with reduced levels of fishmeal replaced by mealworm.
Under this scenario, it is important to highlight that the use of cricket meal in shrimp feed is a promising alternative considering the protein source, this attributes to the fact that it can improve growth and sustainability in aquaculture. Research indicates that black cricket meal can replace up to 50% of fishmeal in diets for juvenile whiteleg shrimp (*Litopenaeus vannamei*), allowing efficient results in weight gain, survival rates, and feed conversion ratios (Peh, et al., 2021). Similarly, Fraijo-Valenzuela et al., (2024) state that cricket meal stands out for its high protein content and digestibility, making it a viable substitute for traditional fishmeal, however, it is important to consider production costs.
With respect to the results of the physicochemical parameters of the water, the water temperature (26.99 and 27.24 ° C) are located in the ranges reported by Ponce et al., (1997) who indicated that shrimp species grow better at temperatures of 25 to 32 ° C, while Clifford (1994) states that the optimal temperature range for this species is 20 to 30 ° C. The values obtained for dissolved oxygen (5.06 and 5.38 mg / L) are located in the necessary ranges reported by Clifford (1994) who considers that the optimal interval of dissolved oxygen for shrimp farming is between 6 and 10 mg / L. The salinity presented a single value of 30‰, which is located in the necessary range reported by Senasica (2003) who refers that the optimal levels of Salinity are 20 to 35 ‰.
The concentration of ammonia in the culture was below 0.1 mg/L in all treatments, these values indicate that there was good management of water quality, as confirmed by Hirono (1983), who indicates that the optimal value of ammonia for shrimp culture should be less than 0.1 mg/L. However, Lee and Wickings (1992) suggested optimal levels of 0.09 to 0.11 mg/L. The pH and temperature values remained constant throughout the experiment. According to Frías Espericueta and Páez Osuna (2001), ammonia presents toxicity, which increases significantly under high pH and temperature conditions in the water.
Although the present findings provide promising evidence regarding the potential of cricket meal as a partial substitute for fishmeal in shrimp diets, several limitations must be acknowledged. The bioassay was restricted to a 21-day period, which, although adequate for the nursery phase, may not fully capture the long-term impacts on growth performance, feed efficiency, and survival during the grow-out stage. Similar studies with alternative protein sources have demonstrated that short-term benefits are not always sustained under commercial grow-out conditions, highlighting the need for extended trials. Moreover, the absence of an economic assessment limits the ability to evaluate the large-scale feasibility and cost-effectiveness of cricket meal, an aspect that has been emphasized as decisive in previous investigations addressing alternative feed ingredients. Future research should therefore prioritize longer experimental periods and incorporate detailed cost–benefit analyses to strengthen the applicability of the results to intensive farming systems. Additionally, the optimization of inclusion levels, palatability, and nutrient digestibility, together with evaluations of intestinal health, immune response, and product quality, will be crucial to establish the robustness of cricket meal as a sustainable ingredient within aquaculture nutrition.

CONCLUSIONS

Cricket meals, due to its high protein content, represent a functional ingredient in shrimp diet formulations, supporting both growth and survival. In particular, treatments T3 (40% CM and 60% FM) and T4 (60% CM and 40% FM) achieved final weights comparable to the control group T1 (100% FM), highlighting their potential as sustainable alternatives for the partial replacement of fishmeal. The gradual substitution of fishmeal with cricket meal also enhanced the protein fraction of shrimp muscle, thereby improving the nutritional quality of the final product. Throughout the trial, the physicochemical parameters of the culture water for *Penaeus vannamei* postlarvae remained within the optimal ranges established for the species, ensuring favorable environmental conditions for the development of the organisms across all treatments evaluated. Together, these results validate the use of cricket flour as a strategic and sustainable ingredient to reduce dependence on fishmeal in shrimp aquaculture.

Conflict of interest

The authors state that there are no conflicts of interest in the research.

Acknowledgments
This study was carried out within the framework of the Interinstitutional Collaboration Project No. PYTCOLAB3637-2024-FACM0004, entitled "Valorization of alternative protein sources of animal and plant origin in the nutrition of aquatic organisms", funded and implemented by Technical University of Manabí, Ecuador.

REFERENCES

1. AOAC. (2016). Official Methods of Analysis Association of Official Analytical Chemists. AOAC Official Method 938.08 Ash of Seafood. Washington, D.C. http://files.foodmate.com/2013/files_2921.html
2. Arias, S. (2010). Experiences with raceway management in marine shrimp farming in Ecuador. Nicovita Bulletin, pp. 1-6.
3. Ayala S. and Elias L. (2019). Development of an export plan for *Acheta domesticus* (domestic cricket) flour to the Spanish market. [Bachelor's thesis, University of Guayaquil]. http://repositorio.ug.edu.ec/handle/redug/41391
4. Caicedo, N. (2018). Supply and demand analysis of shrimp in the province of El Oro and Ecuador over the last eight years. [Thesis]. http://repositorio.utmachala.edu.ec/bitstream/48000/12221/1/DE00006_EXAMENCOMPLEXIVO.pdf
5. Caravaca, F., Castel, M., Guzmán, J., Delgado, M., Mena, Y., María Alcalde, P.G. (2003). Basis of animal production. University of Seville. https://editorial.us.es/es/detalle-libro/291061/bases-de-la-produccion-animal
6. Carvajal, K. (2022). Effect of replacing fishmeal with insect meal (*Hermetia illucens* and *Acheta domesticus*) on digestibility, enzyme activity, and acid profile. [Master's thesis]. https://cicese.repositorioinstitucional.mx/jspui/bitstream/1007/3670/1/tesis_Karen%20Elyne%20Carvajal%20Soriano_03%20feb%202022.pdf
7. Central Bank of Ecuador (2023). Shrimp and tilapia statistics. Aquaculture Journal. 82p. https://www.cna-ecuador.com/revista-acuacultura/
8. Chávez, M., & Higuera, I. (2003). Manual of good practices in shrimp aquaculture production for food safety. [Online monograph]. www.anfacal.org/media/Biblioteca_Digital/Acuicultura/JM-Manual-Camaron.pdf.
9. Chang, T., Lin, H., Han, F., Xu, C., & Li, E. (2024). Impact of defatted black soldier fly (*Hermetia illucens*) larvae meal on health, muscle texture, and intestinal microbiota in Pacific white shrimp (*Penaeus vannamei*). Aquaculture, 596, 741755. https://doi.org/10.1016/j.aquaculture.2024.741755
10. Ching, C. (2014). Raceway and/or nursery management in marine shrimp farming. Nicovita-VITAPRO. Tumbes, Peru.
11. Clifford, C.H. (1994). Shrimp pond management (A case study on shrimp pond management) pp. 1-39. In Zendejas-Hernández. J. (Ed) Proceedings of the International Seminar on Shrimp Farming in Mexico. Ralson purina International. Sinaloa, Mexico.
12. Ecuadorian National Institute for Standardization INEN 1690. (1989). Zootechnical feeds. Rice by-products. Quito, Ecuador https://ia802909.us.archive.org/19/items/ec.nte.1690.1989/ec.nte.1690.1989.pdf
13. Ecuadorian National Institute for Standardization INEN 1767. (1990). Compound zootechnical feeds for shrimp. Requirements. Quito, Ecuador. https://docplayer.es/96788927-Alimentos-zootecnicos-compuestos-para-camarones-requisitos-1-objeto.html
14. Ecuadorian National Institute for Standardization INEN 2051. (1995) (Spanish): Grains and cereals. Ground corn, semolina, flour, grits. Quito, Ecuador https://ia601900.us.archive.org/8/items/ec.nte.2051.1995/ec.nte.2051.1995.pdf
15. Ecuadorian National Institute for Standardization INEN 472. (1988). Fishmeal requirements for animal consumption. Quito, Ecuador. https://es.scribd.com/doc/293181623/Nte-Inen-472-Consumo-Animal-Requisitos
16. Fraijo-Valenzuela, A., Arias-Moscoso, J.L., García-Pérez, O.D., Rodríguez-Anaya, L.Z., & González-Galavíz, J.R. (2024). The biotechnological potential of crickets as a sustainable protein source for fishmeal replacement in aquafeed. Biotech, 13(4), 51. https://doi.org/10.3390/biotech13040051

17. Frías-Espericueta, M.G., and F. Páez-Osuna. (2001). Toxicity of nitrogen compounds in shrimp. National Autonomous University of Mexico. https://www.researchgate.net/publication/250309870_Toxicidad_de_los_compuestos_del_nitrogeno_en_camarones.
18. Hirono, Y. (1983). Preliminary Report on Shrimp Culture Activities in Ecuador. Journal of the world Mariculture Society, 14, 451-457. https://doi.org/10.1111/j.1749-7345.1983.tb00097.x
19. Islam, S. M., Siddik, M. A., Sørensen, M., Brinchmann, M. F., Thompson, K. D., Francis, D. S., & Vatsos, I. N. (2024). Insect meal in aquafeeds: A sustainable path to enhanced mucosal immunity in fish. Fish & Shellfish Immunology, 150, 109625. https://doi.org/10.1016/j.fsi.2024.109625
20. Kowalski, S., Mikulec, A., Mickowska, B., Skotnicka, M., & Mazurek, A. (2022). Supplementation of wheat bread with various edible insect flours. Influence of chemical composition on nutritional and technological aspects. 159, 113220. https://doi.org/10.1016/j.lwt.2022.113220
21. Lee, DOC, & Wickins, J.F. (1992). Crustacean farming: ranching and culture. Blackwell Scientific Publications.
22. Lee, SW, Tey, HC, Wendy, W., Wan Zahari, M. (2017). The effect of house cricket (*Acheta domesticus*) on the growth performance of red hybrid tilapia (*Oreochromis* sp.). International Journal of Aquatic Sciences, 8(2), 78-82.
23. Lin, H., Liang, X., Han, F., Luo, X., & Li, E. (2023). Growth, Biochemical Characteristics, Flesh Quality, and Gut Microbiota of the Pacific White Shrimp (*Penaeus vannamei*) Fed a Defatted Superworm (*Zophobas atratus*) Larvae Meal. Aquaculture Nutrition, 2023, 1-25. https://doi.org/10.1155/2023/8627246
24. Magalhães, R., Sánchez-López, A., Leal, RS, Martínez-Llorens, S., Oliva-Teles, A., & Peres, H. (2017). Black soldier fly (*Hermetia illucens*) pre-pupae meal as a fish meal replacement in diets for European seabass (*Dicentrarchus labrax*). Aquaculture, 476, 79-85. https://doi.org/10.1016/j.aquaculture.2017.04.021
25. Murugu, DK, Onyango, AN, Ndiritu, AK, Osuga, I.M., Xavier, C., Nakimbugwe, D. and Tanga, C. (2021). From farm to table: Crickets as an alternative source of protein, minerals and vitamins. Frontiers in Nutrition, 8, 704002. https://doi.org/10.3389/FNUT.2021.704002
26. National Service of Health, Safety and Agrifood Quality (SENASICA). (2003). In Manual of Good Practices for Shrimp Aquaculture Production for Food Safety. pp. 38
27. Panini, RL, Pinto, SS, Nóbrega, RO, Vieira, FN, Fracalossi, DM, Samuels, RI, & Amboni, RD (2017). Effects of dietary replacement of fishmeal with maggot meal on muscle quality of the farmed shrimp *Litopenaeus vannamei* . Food Research International, 102, 445–450. https://doi.org/10.1016/j.foodres.2017.09.017
28. Pardo, W. (2012). Acclimatization, feeding, growth, and survival of *Litopenaeus vannamei* postlarvae in a cement raceway. (Pre-professional practice report). National University of Tumbes. Tumbes, Peru.
29. Peh KL; Shapawi R.; Lim LS (2021). Black cricket (*Gryllus bimaculatus*) meal as a protein source in the practical diets for juvenile whiteleg shrimp (*Litopenaeus vannamei*). Iranian Journal of Fisheries Sciences. 20(3) 731-740. DOI: 10.22092/ijfs.2021.124045
30. Phesatcha, B., Phesatcha, K., Viennaxay, B., Matra, M., Totakul, P., & Wanapat, M. (2022). Cricket (*Gryllus bimaculatus*) flour as a protein supplement for in vitro fermentation and methane mitigation. *Insects*, 13 (2), 129. https://doi.org/10.3390/insects13020129
31. Ponce-Palafox, J., C.A. Martínez-Palacios, L.G. Ross. (1997). The effects of salinity and temperature on the growth and survival rates of juvenile white shrimp *Penaeus vannamei* Boone 1931. Aquaculture. 157: 107–115
32. Portillo, R., & Edwin, O. (2017). Pilot cost estimate for the production and processing of cricket (*Acheta domesticus*) flour as a source of protein for human diets at the Santa Marta farm, Morazán, El Salvador. [Undergraduate thesis]. https://bdigital.zamorano.edu/server/api/core/bitstreams/d1db6147-d9ca-4b38-b87e-12ba235e8720/content
33. Saldarriaga, D. (1995). Conditioning and management of shrimp ponds. Tumbes, Peru. Department of Aquaculture. Faculty of Fisheries Engineering. National University of Tumbes.
34. Serra, V., Pastorelli, G., Tedesco, D. E. A., Turin, L., & Guerrini, A. (2024). Alternative protein sources in aquafeed: Current scenario and future perspectives. Veterinary And Animal Science, 25, 100381. https://doi.org/10.1016/j.vas.2024.100381

35.Shin, J., & Lee, K. (2021). Digestibility of insect meals for Pacific white shrimp (*Litopenaeus vannamei*) and their performance for growth, feed utilization and immune responses. PLoS ONE, 16(11), e0260305. https://doi.org/10.1371/journal.pone.0260305
36.Taufek, N.M., Razak, S.A., Alias, Z., & Muin, H. (2013). Potential value of black cricket meal as a protein replacement for fishmeal in the nutrition of African catfish (*Clarias gariepinus*) fingerlings. [Thesis]. DOI: 10.22092/ijfs.2021.124045
37.Thomas J. & Walter (2014). Entomology and Nematology. Featured Critters. https://entnemdept.ufl.edu/creatures/misc/crickets/adomest.html
38.Tilami, S.K., Turek, J., Červený, D., Lepič, P., Kozák, P., Burkina, V., & Mráz, J. (2020). Insect meal as a partial replacement of fishmeal in a formulated diet for perch *Perca fluviatilis*. *Turkish Journal of Fisheries and Aquatic Sciences*, 20(12), 867-878. http://doi.org/10.4194/1303-2712-v20_12_03
39.Toribio, E., Correa, M.J., Médici, S., Ferrero, C., & Arp, C.G. (2024). Characterization of cricket flour from *Gryllus assimilis* : an alternative nutrient source for sustainability. *International Journal of Food Science and Technology*, 59(10), 7509–1716. https://doi.org/10.1111/ijfs.17503
40.Valenzuela-Quiñónez, W., Esparza-Leal, H.M., Nava-Pérez, E., & Rodríguez Quiroz, G. (2012). Shrimp culture in low salinity water with worm meal-based feed. *Ra Ximhai*, 8(3), 131-6.
41.Van Huis A. (2012). Potential of insects as food and feed in food security. *Annu Rev Entomol.* 2013;58:563–83. doi: 10.1146/anurev-ento-120811-153704. Epub 2012 Sep 27. PMID: 23020616.
42.Vanoni, F. (2014). Alternatives for early-stage systems in aquaculture 2014. Epicore Bio Networks Inc. Latin America Technical Sales Manager.
43.Xiaoming, C., Ying, F., Hong, Z., & Zhiyong, C. (2010). Review of the nutritive value of edible insects. *Forest insects as food: humans bite back*, 85.
44.Yun, H., Shahkar, E., Katya, K., Jang, I.K., Kim, SK, & Bai, S.C. (2016). Effects of bioflocs on dietary protein requirement in juvenile whiteleg shrimp, *Litopenaeus vannamei*. *Aquaculture research*, 47(10), 3203-3214.
45.Zielińska, E., and Pankiewicz, U. (2023). The potential of using edible insects in the production of protein supplements for athletes. *Foods* , 12. https://doi.org/10.3390/foods12193654