

Feeding *Colossoma macropomum* with black soldier fly (*Hermetia illucens*) larvae in floating cages in the Peruvian Amazon

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ADDITIONAL KEYWORDS

Balanced meal.
Gamitana.
Floating cage.
Black soldier fly.
Termites.

SUMMARY

This study was carried out at the “Centro de Investigaciones Fernando Alcántara Bocanegra” (CIFAB) of the “Instituto de Investigaciones de la Amazonía Peruana” (IIAP) to determine the variation in the growth of *Colossoma macropomum* “gamitana” fed with larvae of *Hermetia illucens* black soldier fly (BSFL), termites and conventional balanced feed. A total of 180 C. macropomum of 3-4 cm initial size and weighing 1.5 to 2 g were used. Sixty fish per treatment were used, distributed in 9 floating cages, 20 fish in each cage. The floating cages were installed inside a fish pond from IIAP. Treatments (T) consisted of T1: fish fed with BSFL, T2: fish fed with termites, and T3: fish fed with balanced feed. BSF larvae were obtained using orange waste for their production. Termites were collected from natural environments and balanced feed was purchased from a trading company in Iquitos, Peru. The results of the study showed that fish fed with balanced feed gained more size and weight than fish fed with BSFL and termites; however, fish fed with BSFL showed adequate and better zootechnical indices than fish fed with termites, with small differences between the values reported for fish fed with balanced feed. It is concluded that fish fed with BSFL show adequate growth and weight gain, with better zootechnical indices values than fish fed with termites.

Alimentación de *Colossoma macropomum* con larvas de *Hermetia illucens* en jaulas flotantes en la Amazonía del Perú

RESUMEN

Este estudio se realizó en el «Centro de Investigaciones Fernando Alcántara Bocanegra» (CIFAB) del «Instituto de Investigaciones de la Amazonía Peruana» (IIAP) para determinar la variación en el crecimiento de *Colossoma macropomum* «gamitana» alimentada con larvas de *Hermetia illucens* “mosca soldado negra” (MSN), termitas y alimento balanceado convencional. Se utilizó un total de 180 C. macropomum de 3-4 cm de tamaño inicial y de 1,5 a 2 g de peso. Se utilizaron 60 peces por tratamiento, distribuidos en 9 jaulas flotantes, 20 peces en cada jaula. Las jaulas flotantes se instalaron dentro de un estanque de peces del IIAP. Los tratamientos (T) consistieron en T1: peces alimentados con BSFL, T2: peces alimentados con termitas, y T3: peces alimentados con pienso equilibrado. Las larvas de MSN se obtuvieron utilizando residuos de naranja para su producción. Las termitas se recolectaron de ambientes naturales y el alimento balanceado se adquirió en una empresa comercial de Iquitos, Perú. Los resultados del estudio mostraron que los peces alimentados con alimento balanceado ganaron más talla y peso que los peces alimentados con larvas de MSN y termitas; sin embargo, los peces alimentados con larvas mostraron índices zootécnicos adecuados y mejores que los peces alimentados con termitas, con pequeñas diferencias entre los valores reportados para los peces alimentados con alimento balanceado. Se concluye que los peces alimentados con larvas de MSN muestran un crecimiento y ganancia de peso adecuados, con mejores valores de índices zootécnicos que los peces alimentados con termitas.

PALABRAS CLAVES

Alimento balanceado.
Gamitana.
Jaulas flotantes.
Mosca soldado negra.
Termitas.

INFORMACIÓN

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INTRODUCTION

Currently, Amazonian fish farming focuses on the breeding of native species such as *Colossoma macropomum*, *Piaractus brachipomus*, *Brycon amazonicus*, and *Prochilodus nigricans*, species whose captive culture technologies are known and put into practice in the Peruvian Amazon. Recorded production of these species varies between 695 and 705 tonnes in Loreto-Peru, destined for local consumption (Campos-Baca, 2015).

One of the species with the greatest technological advances in Loreto is *Colossoma macropomum*, popularly known in Peru as 'gamitana', considered to be the largest characid in the Amazon. Studies of the diet of individuals in the juvenile stage show their preference for the consumption of zooplankton, fruits, and seeds (Campos-Baca, 2015). This fish is farmed in different ways, using different environments and various farming technologies. Its culture in the Peruvian Amazon is mainly small-scale and, despite being the species with the most technological advances, many aspects still need to be improved to ameliorate production processes.

One of the problems that Amazonian fish farmers express is related to fish feed, reflected in the high costs of production or acquisition of feed, generating high expenses for fish farmers, making it impossible for them to grow (Campos-Baca, 2015). The main input used for the production of balanced feed is fishmeal, a product of marine origin that has a high value for low-income producers; additionally, aquaculture centers are far from the city, making it difficult to acquire (Garzón and Gutiérrez-Espinosa, 2019).

Experiences from foreign countries in incorporating local inputs for fish feed production have been

successful, using, for example, fruits, vegetables, and insects (Avendaño et al. 2020). Rural fish farmers in the Peruvian Amazon, mostly indigenous, spend their daily efforts on activities such as subsistence farming, fishing, hunting, and fruit gathering. Daily, they generate organic waste such as banana and other vegetable peels, shells, seeds, and other waste from wild fruits, which are discarded in the forest itself or thrown into rivers (García-Dávila, 2018).

Among the insects used globally as animal protein, *Hermetia illucens*, popularly known as the 'black soldier fly', degrades organic matter and has a short production cycle, making its larvae very good candidates for intensive and controlled production for use as animal protein (Figueredo and Albarracín, 2021).

Given the importance of sustainable alternatives in the feeding of Amazonian fish, this study evaluated the growth and weight gain of *Colossoma macropomum* fry fed with *H. illucens* 'black soldier fly' larvae and termites, compared to traditional commercial feed.

MATERIAL AND METHODS

The study was conducted at the Centro de Investigación Fernando Alcántara Bocanegra - CIFAB, of the Instituto de Investigaciones de la Amazonía Peruana - IIAP in San Juan Bautista, Loreto-Peru (03° 48', 48.9" S, 73° 19', 2" W). One hundred eighty (180) *C. macropomum* was used with 3.5 ± 0.5 cm standard length and 2.5 ± 0.5 g weight. Nine 1 m³ floating cages made of polyethylene bags and plastic tubes were used. The distance between the top of each cage and the water surface was 20 cm. The cages were placed inside a fish pond at CIFAB-IIAP in a row (Fig. 1A).



Figure 1. A. Experimental units used in feeding *Colossoma macropomum* with three types of feed. B. Modules of production of BSF larvae (Unidades experimentales utilizadas para alimentar a *Colossoma macropomum* con tres tipos de pienso. B. Módulos de producción de larvas de BSF).

Three treatments (T) were used: T1 = fish fed with black soldier fly larvae (BSF); T2 = fish fed with termites and, T3 = fish fed with balanced feed. Each treatment consisted of three replicates, making a total number of 20 fish per replicate and 60 per treatment. The duration of the experiment was 60 days.

BSF larvae were produced in the production modules of CIFAB-IIAP (Fig. 1B), following the protocol established by Morey et al. (2023). The life cycle of BSF lasted 29 days, being noticed the eggs five days after

copula between male and female specimens, the larvae phase lasted 15 days, pre-pupa 7 days and the pupa another 7 days before finally given way to adults that copulated to repeat the life cycle (Fig. 2). Termites were acquired from collections made in forested areas of CIFAB-IIAP. The commercial feed used presented 32% of crude protein, which was purchased from external suppliers. According to the information on the feed label, the feed was made with the following ingredients: fish meal, soybean cake, rice powder, vitamins and minerals, and essential amino acids.

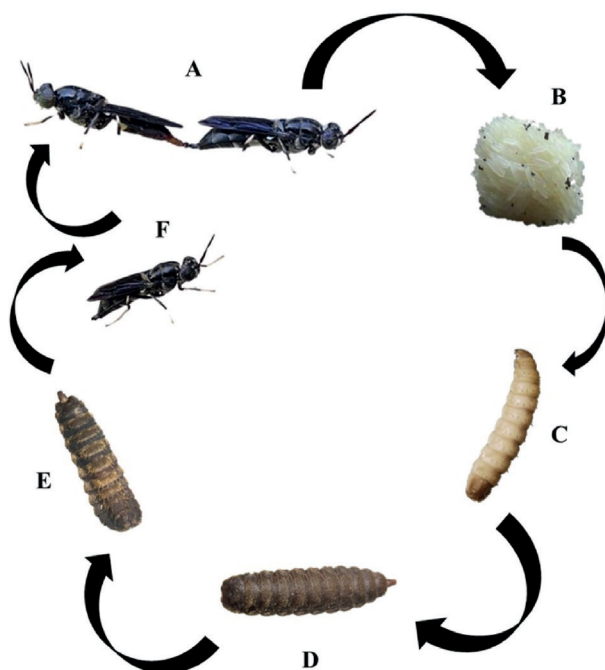


Figure 2. The life cycle of Black soldier fly *Hermetia illucens*. A. Male and female copulate. B. Female deposit their eggs into the organic matter. C. Larvae hatch and feed on the organic matter for approximately 15 days. D. Larvae develop into pre-pupae. E. Larvae develop into pupae. F. Pupae develop into adult specimens (El ciclo de vida de la mosca soldado negra *Hermetia illucens*. A. El macho y la hembra copulan. B. La hembra deposita sus huevos en la materia orgánica. C. Las larvas eclosionan y se alimentan de la materia orgánica durante aproximadamente 15 días. D. Las larvas se convierten en prepupas. E. Las larvas se convierten en pupas. F. Las pupas se convierten en especímenes adultos).

To determine the amount of feed supplied, the biomass of each experimental unit was previously calculated by carrying out an initial sampling of the size and weight of the fish. The feeding frequency was 02 times a day (7:30 a.m. and 5:30 p.m.). The evaluations of growth and weight gain were carried out every 15 days, with sampling in which biometric data such as standard length and weight were taken (Fig. 3A, 3B). After sampling, fish were returned to their respective experimental units. After 60 days of experimentation, the final data were taken in a last sampling where the final values of growth and weight gain were recorded. Subsequently, the data obtained were analyzed, cal-

culating the zootechnical indices described by Castell and Tiews (1980):

(a) - Average initial weight of fish - AIW (g)

$AIW = [\text{total weight of sample (kg)} \times \text{number of fishes in sample}] \times 1000$

(b) Final average fish weight FAF (g)

$FAF \text{ is equal to } [\text{total weight of the sample (kg)} \times \text{number of fishes in the sample}] \times 1000$

(c) Average weight gain (g) - AWG

$AWG = \text{average final weight} - \text{average initial weight}$

d) Daily growth in weight - DGW (DGW)

DGW = Weight gain/time in days

(e) Initial Biomass - iBIO (kg)

iBIO = Average initial weight (g) x Number of seeded fishes

(f) Final Biomass - fBIO (kg)

fBIO = Average final weight x Number of harvested fishes

(g) Biomass gain - BG (kg)

BG = Final biomass - Initial biomass.

(h) AFCR (Apparent feed conversion ratio)

AFCR = Amount of feed consumed / Biomass gained

i) Survival rate

S% = [N° of fish present at the end of the experiment / N° of initial fish] x 100. Water quality values were recorded daily, and temperature, oxygen, conductivity, and pH were measured using a Hanna HI 9146 multi-parameter instrument (Fig. 3C).



Figure 3. A, B. Biometric sampling taken every fortnight. C. Recording of physical and chemical water parameters (Muestreo biométrico quincenal. C. Registro de parámetros físicos y químicos del agua).

The data were stored in Microsoft Excel spreadsheets. An Analysis of Variance test (ANOVA) was performed to determine significant differences between treatments using the statistical program BioEstat 5.0 for Windows.

Concerning permits to work with biological samples, the IIAP has the respective permits for collection, handling, and experimentation with fish through the documents: Directorial Resolution (R.D) N°

217-2016-GRL-DIREPRO and PTH-068-16-PEC-SA-NIPES.

RESULTS

The highest growth (cm) and weight gain (g) were reported in fish fed with balanced feed (T3), followed by fish fed with T1 (BSF) larvae and finally fish fed with termites (T2) (Fig. 4).

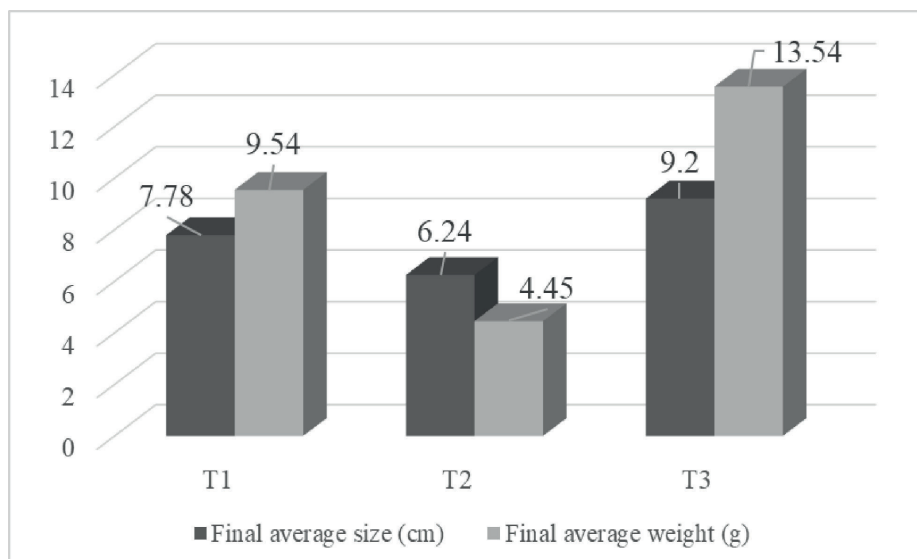


Figure 4. Values of Final average size (cm) and Final average weight (g) of *Colossoma macropomum* feed with three types of feed. T1 = BSF larvae, T2 = termites and T3 = balanced feed (Valores de tamaño promedio final (cm) y peso promedio final (g) de *Colossoma macropomum* con tres tipos de alimento: T1 = larvas de BSF, T2 = termitas y T3 = alimento balanceado).

There were significant differences ($p < 0.0001$) between all treatments. The values of the other zootechnical indices evaluated showed the same trend, with the

highest values for fish from T3, followed by T2, and finally fish from T1 (Table 1).

Table 1. Values of the zootechnical indices calculated on *Colossoma macropomum* feeding using three types of feed: Black soldier fly larvae – BSF (T1); termites- Te (T2) and balanced food – BF (T3) (Valores de los índices zootécnicos calculados sobre la alimentación de *Colossoma macropomum* utilizando tres tipos de alimento: larvas de mosca soldado negra – BSF (T1); termitas- Te (T2) y alimento balanceado – BF (T3)).

Zootechnical indices	Tratamientos			p value
	T1 = BSF	T2 = Te	T3 = BF	
Initial growth (cm)	4.35 ± 0.56 ^a	4.63 ± 0.73 ^a	4.74 ± 0.60 ^a	> 0.05
Final growth (cm)	7.78 ± 1.48 ^a	6.24 ± 0.94 ^b	9.20 ± 0.92 ^c	< 0.0001
Initial weight (g)	1.29 ± 0.57 ^a	1.68 ± 0.94 ^a	1.78 ± 0.90 ^a	> 0.05
Final weight (g)	9.54 ± 5.34 ^a	4.45 ± 2.18 ^b	13.54 ± 4.13 ^c	< 0.0001
Growth gain (cm)	3.61 ± 0.74 ^a	1.65 ± 0.50 ^b	4.46 ± 0.08 ^c	< 0.0001
Weight gain (g)	8.87 ± 2.64 ^a	2.75 ± 0.54 ^b	11.76 ± 0.26 ^c	< 0.0001
Daily weight gain (g)	0.15 ± 0.04 ^a	0.05 ± 0.01 ^b	0.20 ± 0.01 ^c	< 0.05
Initial Biomass (Kg)	0.02 ± 0.01 ^a	0.03 ± 0.01 ^a	0.04 ± 0.01 ^a	> 0.05
Final Biomass (Kg)	0.12 ± 0.01 ^a	0.05 ± 0.02 ^b	0.27 ± 0.01 ^c	< 0.05
Biomass gain (Kg)	0.10 ± 0.02 ^a	0.02 ± 0.01 ^b	0.24 ± 0.01 ^c	< 0.05
Consumed feed (Kg)	0.15 ± 0.01 ^a	0.12 ± 0.04 ^a	0.37 ± 0.03 ^b	< 0.05
Apparent feed conversion ratio	1.52 ± 0.20 ^a	6.00 ± 1.51 ^b	1.58 ± 0.08 ^a	< 0.05
Survival rate	95% ^a	60% ^b	95% ^a	< 0.05

Regarding the physical and chemical parameters of the water, during the whole experiment average values were recorded for treatment 1: Temperature 29.06 ± 0.69 OC; dissolved oxygen 6.41 ± 0.53 mg/L; conductivity of 67.82 ± 2.89 μ S/cm and 6.77 ± 0.31 UI of pH. For treatment 2: Temperature 29.15 ± 0.82 OC; dissolved oxygen 6.30 ± 0.60 mg/L; conductivity of 69.10 ± 2.99 μ S/cm and 6.88 ± 0.40 IU of pH. For treatment 3: Temperature 29.20 ± 0.70 OC; dissolved oxygen 6.5 ± 0.55 mg/L; conductivity of 68.9 ± 2.91 μ S/cm and 6.85 ± 0.35 IU of pH.

DISCUSSION

In the present study, the highest values of weight and length gain were reported for fish fed with balanced feed, however, the values between fish fed with BFS larvae and balanced feed did not have such a marked difference; unlike fish fed with termites, whose values were much lower than those of the other treatments. Similar results were reported in a study on juvenile *C. macropomum* using whole black soldier fly larvae (treatment 1), balanced feed (treatment 2), and a mixture of balanced feed + whole black soldier fly larvae (treatment 3). The results showed that fish fed balanced feed + black soldier fly had similar growth and weight gain values to fish fed only balanced feed. However, lower growth values were recorded for fish fed only with black soldier fly larvae, although the difference in values was only 80g in 120 days of experimentation (Ordoñez et al., 2022).

In the present investigation, fish fed with T3 (balanced feed) grow and gain weight faster than fish fed with BFS larvae (T1) and termites (T2), however, the values of the zootechnical indices between fish fed with T3 and T1 are not so different compared to fish fed with T2. Similar results were reported in Bahia, Brazil where they used BFS larvae for feeding *C. macropomum*, registering higher values in zootechnical indices for fish fed with balanced feed, however, fish fed with BFS larvae presented similar zootechnical indices to Almeida (2019).

In addition, the high protein content, digestibility, and amino acid profiles of BFS larvae have been targeted as an input in fish diets. This meal has successfully replaced other conventional sources of protein in fish diets in different parts of the world: channel catfish (*Ictalurus punctatus*) (Zhang et al., 2014a,b), blue tilapia (*Oreochromis aureus*) (Bondari and Sheppard, 1987), Nile tilapia (*Oreochromis niloticus*) (Muin et al., 2017), sabaki tilapia (*Oreochromis spilurus*) (Furrer, 2011), rainbow trout (*Oncorhynchus mykiss*) (Sealey et al., 2011), Atlantic salmon (*Salmo salar*) (Lock et al., 2015), turbot (*Psetta maxima*) (Kroeckel et al., 2012), yellow catfish (*Tachysurus fulvidraco*) (Zhang et al., 2014a) and African catfish (*Clarius gariepinus*) (Idowu and Afolayan, 2013).

The results of the present research present the use of BFS larvae as a nutritionally adequate food for the growth of *C. macropomum*. Arana et al. (2023), mention that larvae and larval meals of black soldier fly larvae in the Peruvian Amazon are a good source of protein, minerals, essential amino acids, and unsaturated fatty acids with high nutritional value. These authors report

that BFS larvae fed with orange bagasse have a high protein content between 40-44 %BP, lipids 27-31%, high potassium and calcium content, as well as iron and manganese content. Taking into consideration that the commercial balanced feed used in the Peruvian Amazon to feed *C. macropomum* in its initial stages has a protein value of between 32-38%, having a natural and low-cost feed, with similar or better nutritional profiles, represents a promising alternative for the sustainable development of Amazonian fish farming.

This indicates that it is viable to feed *C. macropomum* with BFS larvae due to the good results in growth and weight gain presented in this study. In addition, it is a cheaper alternative than balanced feed and that, in turn, it fits within circular economy technologies, being a production alternative for low-income rural fish farmers who could use their organic waste generated daily as a substrate for the production of BFS larvae and consequent use in the feeding of farmed fish.

In the recording of the values that measure water quality, values considered normal and adequate for the rearing of Amazonian fish were recorded, which means that the use of the three types of food used in the feeding of the fish does not negatively influence the physical and chemical parameters of the water. Similar results in the values of physical and chemical parameters of water were reported in the work carried out by Almeida (2019; Ordoñez et al. (2022).

CONCLUSIONS

This study showed the use of BFS larvae of *H. illucens* as part of fish feed represents a feasible approach that can contribute to the development of fish farming, and consequently to the sustainable development of fish farming in the Peruvian Amazon.

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