Characterization of zooplankton consumed by *Piaractus orinoquensis* larvae, in a system with biofloc technology at different carbon/nitrogen ratios

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Abstract. Research on Venezuelan pacu (*Piaractus orinoquensis*) has been mainly aimed at understanding its biology, anatomy, health, eating habits and nutritional requirements in adults. However, there are few studies that document feeding habits in early stages, such as larval stages, the zooplankton consumed or their food preferences under captive conditions. Therefore, the objective of this study was to characterize the zooplankton consumed by white *P. orinoquensis* larvae, in a system with biofloc technology, at three different carbon/nitrogen (C:N) ratios. For this purpose, three Australian tanks with a volume of 7000 L each were used, with biofloc at 10:1, 15:1 and 20:1 C:N ratios. A total of 1260 *P. orinoquensis* larvae with 90 hours post hatching were distributed in 9 circular plastic containers of 8.6 L (140 larvae container^{-1}), made with windows at the base and covered with 650 µm meshes. During a period of 12 days, a daily collection of 30 *P. orinoquensis* larvae per treatment was carried out for subsequent analysis of stomach contents. A longitudinal ANOVA was carried out to analyze the differences in length of the larvae by treatment. In addition, the stomach content was quantified to establish the importance of each prey in the composition of the diet, estimating the relative importance index. The microorganisms observed in the stomach contents of the larvae in the different treatments were represented in 14 species, which are grouped into 10 families and 9 genera. When evaluating the performance of *P. orinoquensis* in each C:N ratio, the treatment that showed the best growth rate was the C:N ratio of 15:1, reaching an average of 15 mm standard length. This study demonstrates that the biofloc technology system is highly effective for the larviculture of *P. orinoquensis*. It was found that a 15:1 C:N ratio optimizes both water quality and the availability of live food, promoting improved larval growth. This effect is associated with a dietary shift toward the cladoceran *Macrothrix* aff. *triserialis*, a prey item with higher nutritional value.
Key Words: cachama larvae, planktonic communities, growth, stomach contents, C:N ratio, BFT.

Introduction. The Venezuelan pacu (*Piaractus orinoquensis*) is a neotropical Serrasalmidae that is distributed in the Orinoco basins. It is considered a species with productive and commercial potential in extensive, semi-intensive and intensive fish farming in warm continental waters of tropical America (Mesa & Botero 2007). It is native to South American countries such as Colombia, Venezuela, Brazil, and has been introduced in Asian, African and North American countries (Mendoza et al 2013). It is a species resistant to captive management, has high docility and rusticity, is resistant to diseases and easily adapts to unfavorable limnological conditions for non-prolonged periods (Mesa & Botero 2007). The commercial importance of white *P. orinoquensis* lies in the quality and flavor of its meat, market acceptance, omnivorous habits and rapid adaptation to various diets, which favors feed conversion rates (Mendoza et al 2013).

Biofloc is a conglomerate of microorganisms, microalgae, protozoans, detritus and organic matter, established in containers. Biofloc technology (BFT) is attractive to aquaculturists, since it consists of taking advantage of food waste, organic matter and toxic inorganic compounds, through microorganisms present in aquatic environments, giving dominance conditions to chemo/photoautotrophic and heterotrophic bacterial communities, thus substantially solving the problems of nutrient saturation through recycling (Avnimelech 2015). Ekasari & Maryam (2012) maintain that the application of BFT has been the subject of attention for fish farming by promoting high production, improving water quality and fish survival, as well as reducing the requirement for external feeding. since it provides a large amount of live food, all of this simultaneously in the same unit.

One of the major problems in the production of juvenile freshwater fish is larviculture, this phase being the main bottleneck of aquaculture production systems, where the highest mortality rates are reported, mainly attributed to factors such as: inadequate environmental conditions, low knowledge of their habitat and feeding habits in natural systems (Atencio-García & Zaniboni-Filho 2006). Therefore, it is very important during larval culture to guarantee high quality living organisms that serve as a food source that sustain the growth and success of this phase, which turns out to be of vital importance when these are species with indirect development in early stages (Atencio-García et al 2003; Lim et al 2003). The supply of these organisms offers advantages mainly due to the nutritional value, which is based on the content of amino acids and essential fatty acids, among other elements that favor the growth and survival of the larvae (Atencio-García 2001). Recent studies demonstrate that cultivating *P. orinoquensis* larvae in BFT systems is a viable approach. Manipulating the carbon-to-nitrogen ratio (C:N) of the system has been identified as a critical factor for optimizing larval performance. Specifically, a C:N ratio of 15:1 has proven to be the most effective, resulting in higher survival and final weight compared to ratios of 10:1 and 20:1 (Collazos-Lasso et al 2021). It has been documented that in these systems, the zooplankton community is dominated by rotifers and protists, and their abundance can be influenced by the carbon source used (Collazos-Lasso et al 2022).

Despite the clear correlation between biofloc quality and larval performance, there is still a lack of information on the direct and explicit characterization of the zooplankton actually consumed by *P. orinoquensis* larvae in BFT systems. The objective of this research was to characterize the zooplankton consumed by *P. orinoquensis* larvae, in a system with BFT, at three different carbon/nitrogen (C:N) ratios.

Material and Method

Description of the study sites. This study was carried out from March to May 2019 in the bioassay unit with biofloc technology, located at the Aquaculture Institute of the University of the Llanos, Villavicencio - Colombia.

Experimental conditions. Three Australian tanks were used, with an approximate volume of 7 m^3 of biofloc water. To guarantee the concentration of oxygen and movement of the water, a 1.75 HP blower was used and microperforated hoses as a diffuser. The biofloc of each tank was previously stabilized at three different carbon/nitrogen (C:N) ratios for each treatment (10:1, 15:1 and 20:1), taking into account the approaches of Avnimelech (1999) and De Schryver et al (2008), as well as the methodology previously implemented by Collazos-Lasso et al (2022) for biofloc system stabilization. For this study, a total of 1260 *P. orinoquensis* larvae of 90 HPE obtained through induced reproduction were used. The larvae were previously acclimated with biofloc water for 6 hours. Subsequently, they were stocked in 9 circular plastic containers with a volume of 8.6 L (140 larvae $container^{-1}$), made with meshes of 650 μm tissue opening (SEFAR ®), accompanied by a hose ring at the top to allow buoyancy in the water. Three containers were placed in each of the Australian tanks with their respective treatments. In order to guarantee balanced conditions between the replicas and the outside, *P. orinoquensis* larvae were also cultured in the tanks at a density of 30 larvae L^{-1}.

Larval sample collection. During a period of 12 days, a daily random collection of 30 *P. orinoquensis* larvae per treatment was carried out. The collected biological material was placed in tricaine methanesulfonate (MS-222); after losing horizontal swimming it was fixed with 4% buffered formalin in 1.5 mL Eppendorf tubes. For the evaluation of larval performance, for each treatment and sampling day, growth measurements (standard length) were obtained, which were acquired from the original images transformed from a TPS file, obtained with the tpsUtil program version 1.74 Rohlf-2019a, to locate the measurement points on the side profile of the body. By means of a ventral dissection and with the help of 1 mL insulin syringes and a stereoscope, samples of stomach contents were obtained. Subsequently, a setup was made for microscopic observation (Nikon model C-D55115) and identification of the food consumed by the larvae. For the taxonomic classification of the observed groups of zooplankton in the stomach contents of *P. orinoquensis* larvae, the lowest possible taxonomic level was carried out.

***Water quality monitoring**.* During the process, the water quality was monitored in the three tanks. Temperature, pH, and dissolved oxygen (DO) parameters were measured twice daily with the HANNA HI98194 multiparameter. Values of nitrite (NO_2^-), nitrate (NO_3^-), total ammonia nitrogen (TAN) and total alkalinity were weekly registered using the YSI 9500 photometer (Collazos-Lasso et al 2022).

***Statistical analysis**.* To analyze the differences between the water quality conditions of each of the treatments, the Infostat-2020 program was used, through the Tukey test, taking into account a significance level of 5% ($p \leq 0.05$), using different letters to indicate statistically significant differences. The data obtained from the observations recorded for the study of the stomach contents of *P. orinoquensis* larvae were organized in Microsoft Excel ®. From this information, a longitudinal or repeated measures ANOVA was carried out to analyze the differences in length of the *P. orinoquensis* larvae according to the carbon-nitrogen ratio in the biofloc. This analysis was carried out in the R-statix library of the statistical package R-studio. Stomach contents were quantified using two methods expressed as proportions: frequency of occurrence (FA) and numerical frequency (FN). To determine the importance of each prey type in the diet composition, the relative importance index (RII) was estimated. This index is expressed as a percentage (0–100%), where values from 0 to 9.9% indicate trophic groups of low relative importance, values between 10 and 40% correspond to trophic groups of secondary relative importance, and values between 40 and 100% represent trophic groups of high relative importance (Zúniga et al 2014).

Results and Discussion

***Physical and chemical parameters of water**.* In this study, temperature, dissolved oxygen saturation and pH levels were within the comfort range for the species and the BFT system. Additionally, they were statistically similar across the different C:N ratio treatments, as shown in Table 1.

Table 1

Water quality parameters during larviculture of *Piaractus orinoquensis* in a biofloc system at three C:N ratios 12 days for 12 days

Parameters	*Treatments (C:N)*		
	10:1	*15:1*	*20:1*
Temperature (°C)	27.1 ± 0.4^a	27.3 ± 0.4^a	27.3 ± 0.4^a
DO (mg L^{-1})	7.2 ± 0.3^a	7.1 ± 0.2^a	7.1 ± 0.2^a
OS (%)	95.97 ± 3.1^b	95.01 ± 2.1^{ab}	93.08 ± 2.4^a
pH	7.64-8.11	7.84-8.32	8.04-8.49
TA (mg L^{-1} $CaCO_3$)	87.9 ± 9.2^a	104.8 ± 21.6^b	133.3 ± 9.1^b
TAN	0.26 ± 0.21^a	0.45 ± 0.1^b	0.7 ± 0.1^c
NO_2^- (mg L^{-1})	0.09 ± 0.0^a	0.35 ± 0.1^b	0.4 ± 0.2^b
NO_3^- (mg L^{-1})	245.6 ± 141.9^a	226.0 ± 151.5^a	226.8 ± 138^a

Data are presented as the mean ± standard deviation. Different letters in the same row indicate statistical differences ($p \leq 0.05$). DO-dissolved oxygen, OS-oxygen saturation, TA-total alkalinity, TAN-total ammoniacal nitrogen.

The TAN values presented significant differences among all treatments; NO_2^- levels showed differences between 10:1 treatment with respect to the other treatments; finally, NO_3^- did not present differences among the treatments, as can be seen in Figure 3, which shows the behavior of the biofloc nitrification processes for the three treatments at different C:N ratios in the 12 days of sampling.

In general, the water quality parameters (Table 1) were in similar ranges to those reported for fish farming with biofloc technology in terms of temperature, oxygen saturation, pH and total alkalinity (Emerenciano et al 2017). Regarding to TAN, the different treatments resulted in values similar to those reported by Collazos-Lasso et al (2021) in *P. orinoquensis* larviculture. The concentrations of the different forms of nitrogen (NO_2^- and NO_3^-) in the three experimental treatments were lower than the levels proposed for fish culture in biofloc by Emerenciano et al (2017). The measurement of the physicochemical parameters of water quality in any aquaculture culture system is necessary to guarantee the generation of different types of microorganisms. Furthermore, in fish cultures with biofloc it is vital to maintain the parameters within the comfort ranges of each species (Collazos-Lasso & Arias-Castellanos 2015).

The study's results showed that the 10:1 C:N ratio treatment had the lowest concentration of total ammoniacal nitrogen (TAN), followed by the 15:1 and 20:1 treatments. This finding appears to be counterintuitive when considering the primary mechanism of BFT, where higher C:N ratios are expected to promote greater heterotrophic assimilation and thus TAN levels (Wang et al 2015; Saha et al 2022). A study on tilapia, for instance, found that a 20:1 C:N ratio provided the best water quality in terms of nitrogen control (Dauda et al 2018). However, a closer look at the data and the underlying biological processes reveals a crucial distinction in how these systems operate.

The efficient nitrogen removal observed at the 10:1 C:N ratio suggests that the primary mechanism at play may not be heterotrophic assimilation but rather autotrophic nitrification. Autotrophic nitrifying bacteria, such as Nitrosomonas and Nitrobacter, are chemosynthetic organisms that thrive in lower C:N conditions, deriving their energy from the oxidation of inorganic compounds like ammonia and nitrite. The process of nitrification is known to consume alkalinity (Ebeling et al 2006). In support of this, the study's water quality data (Table 1) shows that the total alkalinity concentration was statistically lower in the 10:1 C:N treatment compared to the others. This correlation provides a strong indication that the 10:1 system operates more as a mixed heterotrophic-autotrophic environment, with a higher rate of nitrification, which explains the efficient nitrogen removal without the need for a high C:N ratio. While this system effectively manages nitrogen, its ultimate impact on larval growth is not as significant as the live food component of the 15:1 system.

Characterization of the zooplankton present in the stomach contents of P. orinoquensis larvae. Based on the review of the stomach contents of *P. orinoquensis* larvae grown in biofloc at 3 different C:N ratios, 14 species were recorded, belonging to 10 families and 9 genera (Table 2). In this study, the main microorganisms observed in the stomach contents of *P. orinoquensis* larvae in the different treatments were protozoa, cladocerans and rotifers, represented in 14 species, which are grouped into 10 families and 9 genera. These results are related to what was found by Prieto-Guevara & Atencio-García (2008) and Prieto et al (2006) for larvae of the genus *Piaractus* with exogenous feeding in the natural environment, where the diet is mainly based on the consumption of rotifers, protozoa and crustaceans. In traditional culture media evaluated by Zaniboni (1992) in stomach contents of *Colosoma macropomum* larvae, where the cladocerans were preyed upon by the larvae, under different culture densities. In works such as Sandoval et al (2020) in culture of *P. orinoquensis* juveniles in TBF, the most representative groups of microorganisms in this study were ciliates, rhizopods, rotifers and chlorophytes; suggesting that TBF systems are an optimal culture medium for these organisms, in addition to being an important source of enrichment for floc aggregates, since they have a higher protein-energy ratio and are capable of synthesizing polyunsaturated fatty acids of long chain when feeding on bacteria (Sandoval et al 2020).

Table 2

Taxonomic record, frequency of appearance, numerical frequency and relative importance index

Taxonomy			*Treatments (C:N)*								
			10:1			*15:1*			*20:1*		
Family	*Genera*	*Species*	*FA*	*N*	*RII%*	*FA*	*N*	*RII%*	*FA*	*N*	*RII%*
Macrothricidae	*Macrothrix*	*Macrothrix* aff. *triserialis*	6.4	0.9	0.3	44.1	91.9	96.4	14.0	11.8	8.4
Daphniidae	*Daphnia*	*Daphnia* sp.	3.7	0.0	0.0	24.5	5.4	3.2	0.4	0.2	0.0
Canthocamptidae	*Elaphoidella*	*Elaphoidella* sp.	0.0	0.0	0.0	0.4	0.0	0.0	1.4	0.5	0.0
Lecanidae	*Lecane*	*Lecane* aff. *obtusa*	19.5	32.2	35.2	2.6	0.2	0.0	25.2	34.5	44.4
		Lecane aff. *bulla*	21.8	29.1	35.4	2.2	0.2	0.0	21.8	29.0	32.2
		Lecane aff. *lunaris*	13.7	10.3	7.9	1.2	0.1	0.0	16.0	14.2	11.5
Lepadellidae	*Lepadella*	*Lepadella* sp.	12.6	14.9	10.5	0.9	0.1	0.0	5.0	2.7	0.7
Epiphanidae	*Epiphanes*	*Epiphanes* sp.	3.3	2.1	0.4	0.3	0.0	0.0	1.1	0.4	0.0
Arcellidae	*Arcella*	*Arcella* sp.	1.0	0.4	0.0	2.2	0.2	0.0	0.1	0.1	0.0
Centropyxidae	*Centropyxis*	*Centropyxis* aff. *constricta*	0.1	0.0	0.0	7.6	0.6	0.1	0.1	0.1	0.0
		Centropyxis aff. *aculeata*	0.4	0.1	0.0	11.5	1.1	0.3	0.3	0.1	0.0
Euglyphidae	*Euglypha*	*Euglypha* aff. *tuberculata*	2.2	1.2	0.1	1.3	0.2	0.0	1.0	0.6	0.0
Lynceidae		*Lynceidae* morphotype 1.	11.2	6.9	4.3	1.1	0.1	0.0	10.5	4.8	2.6
		Lynceidae morphotype 2.	50.0	2.1	6.0	0.1	0.0	0.0	3.0	1.1	0.2

According to the results of the relative importance index for the 10:1 treatment, the species *Lecane* aff. *obtusa* (IIR 35.15%), *Lecane* aff. *bulla* (IIR35.35%) and *Epiphanes* sp. (IIR 10.47%) were those of greatest nutritional importance (secondary), the rest of the items represent trophic groups of relatively low importance (<IIR 7.87%). For the 15:1 treatment, *Macrothrix* aff. *triserialis* (IIR 96.39%) was the food item of greatest importance for consumption, the rest of the items represented trophic groups of lesser importance (<IIR 3.15%). For the 20:1 treatment*,* *Lecane* aff. *obtusa* (IIR 44.35%) represented the most important food item in the diet, followed by *Lecane* aff. *bulla* (IIR 32.21%) and *Epiphanes* sp. (IIR 11.54%) as the items of secondary nutritional importance, for the rest of the items they represented trophic groups of relatively low importance (<IIR 8.39%).

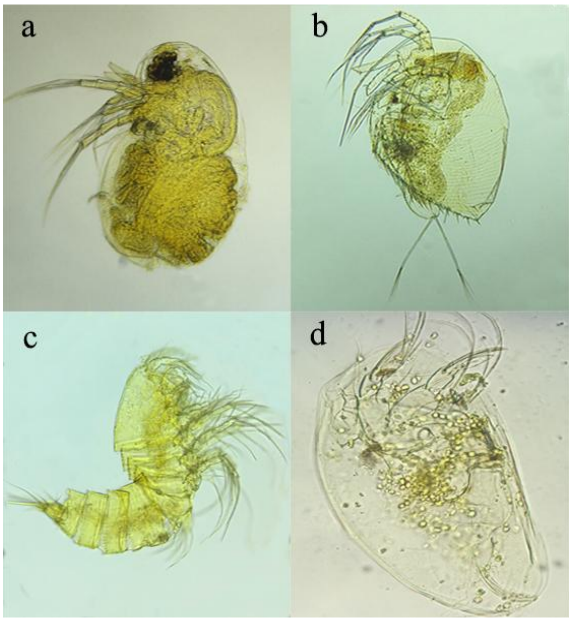

Figure 1. (a) *Daphnia* sp., (b) *Macrothrix triserialis*, (c) *Elaphoidella* sp., (d) Lynceidae.

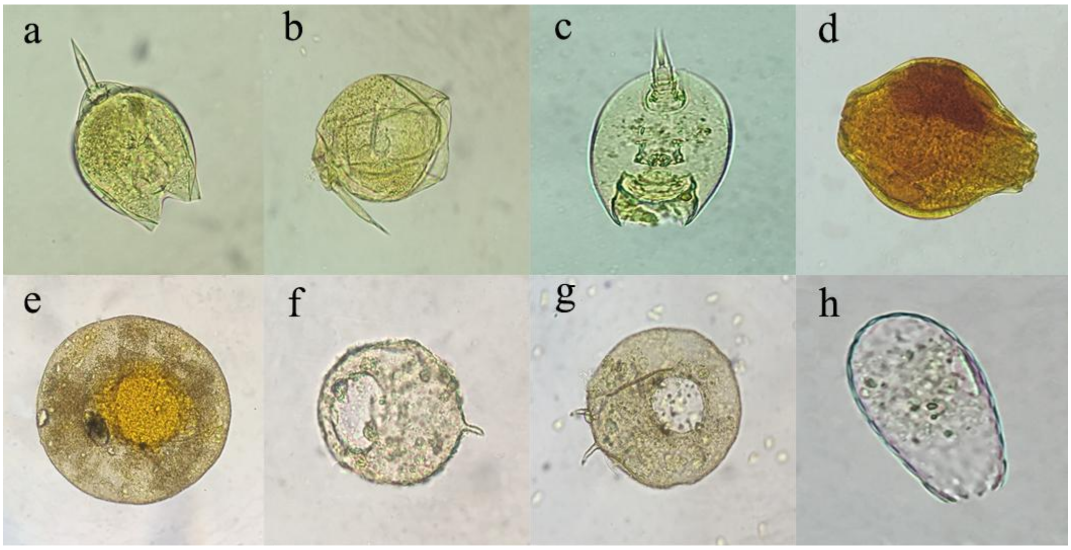

Figure 2. (a) *Lecane bulla*, (b) *Lecane lunaris*, (c) *Lepadella* sp., (d) *Epiphanes* sp., (e) *Arcella* sp., (f) *Centropyxis constricta*, (g) *Centropyxis aculeata,* (h) *Euglypha tuberculata*.

Regarding rotifers, 3 genera *Lecane*, *Elaphoidella* and *Lepadella* were observed, where *Lecane* represented the most important trophic group in treatments 1 and 3 with an IIR of approximately 35%. Of the zooplankton group, rotifers are the best reported initial food, because they do not jump and are easy prey (David et al 2011). Loureiro et al (2012) indicate that rotifers are frequently associated with biofloc. This is because rotifers can fragment the flocs and consume the attached bacteria, and the mucilage produced by their excretions also helps the formation of new flocs (Monroy et al 2013).

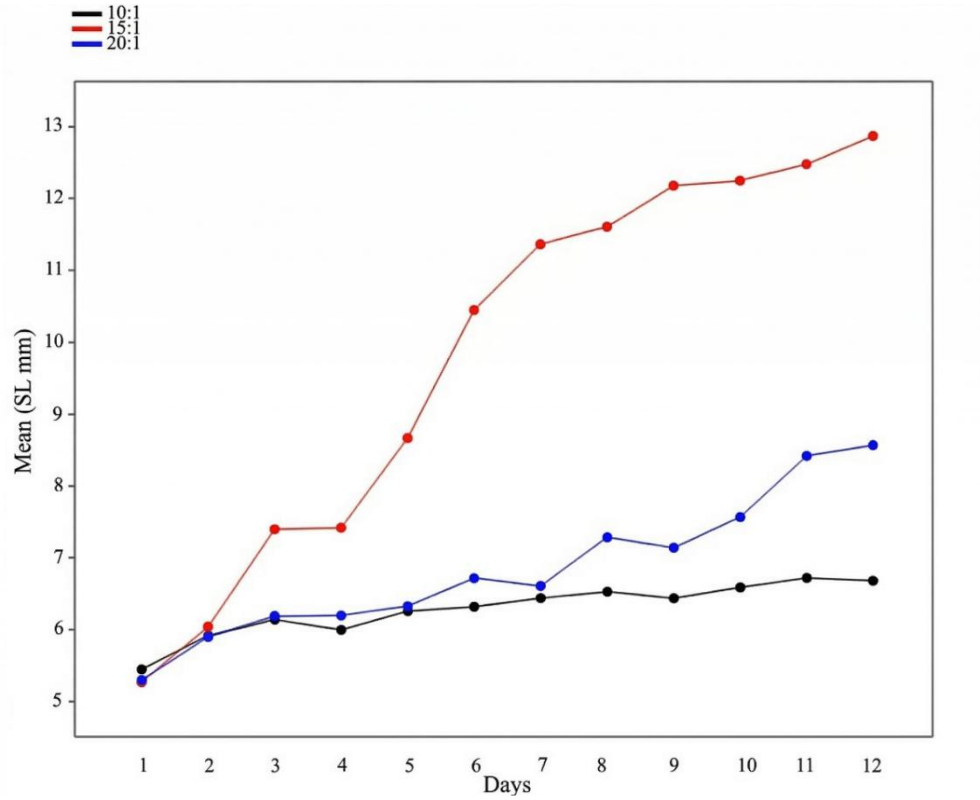

Figure 3. Longitudinal or repeated measures ANOVA, differences in the length of *Piaractus orinoquensis* larvae according to the carbon-nitrogen ratio in the biofloc, (10:1) (15:1) (20:1).

The IIR allows quantifying the importance of a certain trophic group within the diet of a species (Zúñiga et al 2014). According to the stomach content analysis, at the 15:1 C:N ratio, *Macrothrix* aff. *triserialis* proliferated and accounted for almost all consumed biomass (IIR 96.39%), whereas at the lower (10:1) and higher (20:1) ratios rotifers (*Lecane* aff. *obtusa* and *Lecane* aff. *bulla*) comprised a greater fraction of the diet. This leads us to assume that the *Macrothrix* genus provides an important crude protein, which favors the growth of the larvae (Ueno-Fukura et al 2020). This pattern underscores how C:N manipulation shifts community structure: higher carbon encourages heterotrophs and floc formation, favoring certain microfauna. David et al (2011) stated that zooplankton as a live food has comparative advantages to formulated artificial rations or diets, thanks to its movement and colorful coloring, which increases the capture instinct of the larvae, in addition to being small organisms, with a soft texture, easy digestion and high nutritional value (crude protein 52-64%, lipids 5-26%, minerals 6-8%, carbohydrates 10-30% and gross energy 4800-5445 kcal kg^{-1} dry matter). The protein content of fish can be affected by various factors, such as the management of the system, feeding, existing microbial community, C:N ratio, external source of organic carbon, among others (De Schryver et al 2008).

The most significant finding of this study is the superior growth performance of *P. orinoquensis* larvae at a 15:1 C:N ratio, reaching an average of 15 mm in standard length (SL) after 12 days. This result corroborates previous research conducted by Collazos-Lasso et al (2021) on the same species, whose reported similar lengths (13.7±1.4 mm) under comparable conditions. The success of the 15:1 ratio is consistent with findings for other aquaculture species, where intermediate C:N ratios have been linked to improved growth and survival. For instance, studies on juvenile *Cyprinus carpio* (Wang et al 2015), *Clarias* *gariepinus* (Dauda et al 2018), *Oreochromis niloticus* (Mirzakhani et al 2019), and *Heteropneustes fossilis* (Saha et al 2022) demonstrated significantly better growth performance at 15:1 and 20:1 C:N ratios compared to control groups. These studies collectively suggest that BFT systems, by providing a protein-rich microbial biomass, can enhance feed efficiency and the overall health and immunity of the cultured organism.

Figure 4. Comparison of standard length by treatment, lateral body profile of *Piaractus orinoquensis* larvae.

The most profound implication of these findings is the observed disconnect between the "best" water quality and the "best" growth performance. The C:N ratio of 10:1 provided the lowest TAN, but the 15:1 ratio yielded superior larval growth. This result demonstrates that for a species like *P. orinoquensis*, success in BFT is not solely a function of managing nitrogenous waste. Instead, it is a complex interaction where the C:N ratio's effect on the live food community within the biofloc is a more critical determinant of larval success than its direct effect on nitrogen removal. The subsequent analysis of stomach contents provides the evidence for this conclusion.

Conclusions. This research successfully demonstrates that BFT is a highly effective system for *P. orinoquensis* larviculture. The findings highlight the critical importance of selecting an optimal C:N ratio not just for water quality management, but for shaping the live food community available to the larvae. The study establishes that the 15:1 C:N ratio provides the ideal conditions, resulting in the best growth performance of the larvae. This success is directly linked to a shift in the larval diet from rotifers to the cladoceran *Macrothrix* aff. *triserialis*, a larger and more nutritionally valuable prey item. The C:N ratio influences the microbial community, which in turn supports a specific, highly nutritious zooplankton community that drives superior larval growth. This finding opens new pathways for research and commercial application, suggesting that BFT should be viewed not only as a water treatment method but as a complete production system that synthesizes live food.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

Atencio G. V., 2001 [Production of fingerlings of native species]. Revista Medicina Veterinaria y Zootecnia Córdoba 6(1):9-14. [in Spanish]
Atencio G. V., Zaniboni-Filho E., Pardo-Carrasco S., Arias-Castellanos A., 2003 [Influence of the first feeding on larviculture and frying of yamú *Brycon siebenthalae* (Characidae)]. Acta Scientiarum Animal Sciences 25(1):61-72. [in Portuguese]

Atencio-García V. J., Zaniboni-Filho E., 2006 [Cannibalism in fish larviculture]. Revista de la Facultad de Medicina Veterinaria y de Zootecnia Córdoba 11(2):9-19. [in Spanish]
Avnimelech Y., 1999 Carbon/nitrogen ratio as a control element in aquaculture systems. Aquaculture 176(3-4):227-235.
Avnimelech Y., 2015 [Biofloc technology: a practical guide book]. 3rd edition. World Aquaculture Society, USA, 258 p.
Collazos-Lasso L., Arias-Castellanos J., 2015 [Fundamentals of biofloc technology (BFT), an alternative for fish farming in Colombia: a review]. Orinoquia 19(1):77-86. [in Spanish]
Collazos-Lasso L., Ueno-Fukura M., Arias-Castellanos A., Arana-Vinatea L., 2021 [Larvae and juveniles performance of *Piaractus orinoquensis* grown at different densities in systems with biofloc technology BFT]. Biotecnología en el Sector Agropecuario y Agroindustrial 19(2):1-13. [in Spanish]
Collazos-Lasso L. F., Ueno-Fukura M., Suárez-Contento L., Aya-Baquero E., 2022 [Establishment of biofloc at three carbon/nitrogen ratios, with the aim of promoting zooplankton production]. Revista de la Facultad de Medicina Veterinaria y de Zootecnia Córdoba 3:281-298. [in Spanish]
Dauda A. B., Romano N., Ebrahimi M., Teh C., Ajadi A., Chong M. C., Karima M., Natrah I., Kamarudin M. S., 2018 Influence of carbon/nitrogen ratios on biofloc production and biochemical composition and subsequent effects on the growth, physiological status and disease resistance of African catfish (*Clarias gariepinus*) cultured in glycerol-based biofloc systems. Aquaculture Research 483:120-130.
David C., Lenis G., Castañeda G., Lopera A., Restrepo L., 2011 [Initial diet composition affects weight gain and total length of Pacu (*Piaractus brachypomus*) larvae]. Revista Colombiana de Ciencias Pecuarias 24(1):48-54. [in Spanish]
De Schryver P., Crab R., Defoirdt T., Boon N., Verstraete W., 2008 The basics of bio-flocs technology: The added value for aquaculture. Aquaculture 277(3-4):125–137.
Ebeling J. M., Timmons M. B., Bisogni J. J., 2006 Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. Aquaculture 257(1-4):346-358.
Ekasari J., Maryam S., 2012 Evaluation of biofloc technology application on water quality and production performance of red tilapia *Oreochromis* sp. cultured at different stocking densities. Hayati Journal of Biosciences 19(2):73-80.
Emerenciano M., Córdova-Martínez L., Martínez-Porchas M., Miranda-Baeza A., 2017 Biofloc Technology (BFT): a tool for water quality management in aquaculture. In: Water quality. Tutu H. (ed), pp. 91-109, IntechOpen.
Prieto-Guevara M., Atencio-García V., 2008 [Zooplankton in larviculture of neotropical fishes]. Revista Medicina Veterinaria y Zootecnia Córdoba Colombia 13(2):1415-1425. [in Spanish]
Lim L., Dhert P., Sorgeloos P., 2003 Recent developments in the application of live feeds in the freshwater ornamental fish culture. Aquaculture 227(1-4):319-331.
Loureiro K. C., Wilson W. J., Abreu P. C., 2012 The use of protozoan, rotifers and nematodes as live food for shrimp raised in BFT system. Atlantica Rio Grande 34(1):5-12.
Mendoza M. A., Comas-Corredor J., Romero-Hurtado C. S., 2013 [Histological study of the digestive system at different stages of development of the white cachama (*Piaractus brachypomus*)]. Revista Medicina Veterinari 25(1):21-38. [in Spanish]
Mesa-Granda M. N., Botero-Aguirre M., 2007 [White cachama (*Piaractus brachypomus*), a potential species for genetic improvement]. Revista Colombiana de Ciencias Pecuarias 20(1):79-86. [in Spanish]
Mirzakhani N., Ebrahimi E., Hossein-Jalali S. A., Ekasari J., 2019 Growth performance, intestinal morphology and nonspecific immunity response of Nile tilapia (*Oreochromis niloticus*) fry cultured in biofloc systems with different carbon sources and input C:N ratios. Aquaculture 512:734235.
Monroy-Dosta M. del C., De Lara-Andrade R., Castro-Mejía J., Castro-Mejía G., Coelhe-Emerenciano M. G., 2013 [Composition and abundance of microbial communities

associated with biofloc in a tilapia farming system]. Revista Biología Marina y Oceanografía 48(3):511-520. [in Spanish]
Prieto M. J., Logato-Rosa P., Moraes G., Okamura D., Araújo F., 2006 [Types of preys on growth and survival of pacu (*Piaractus mesopotamicus*) pos-larvae]. Ciência e Agrotecnologia (Brasil) 3:1002-1007. [in Portuguese]
Saha J., Hossain M. A., Mamun M. A., Islam M. R., Alam M. S., 2022 Effects of carbon-nitrogen ratio manipulation on the growth performance, body composition and immunity of stinging catfish *Heteropneustes fossilis* in a biofloc-based culture system. Aquaculture Reports 25:101274.
Sandoval-Vargas L. Y., Jiménez-Amaya M. N., Rodríguez-Pulido J., Guaje-Ramírez D. N., Ramírez-Merlano J. A., Medina-Robles V. M., 2020 Applying biofloc technology in the culture of juvenile of *Piaractus brachypomus* (Cuvier, 1818): Effects on zootechnical performance and water quality. Aquaculture Research 51(9):3865-3878.
Ueno-Fukura M., Aya-Baquer E., Collazos-Lasso L. F., 2020 Biofloc application in larviculture of *Pterophyllum scalare* at different stocking densities. AACL Bioflux 13(5):3028-3036.
Wang G., Yu E., Xie J., Yu D., Li Z., Luo W., Qui L., Zheng Z., 2015 Effect of C:N ratio on water quality in zero-water exchange tanks and the biofloc supplementation in feed on the growth performance of crucian carp, *Carassius auratus.* Aquaculture 443:98-104.
Zaniboni-Filho E., 1992 [Incubation, larviculture and fry raising of tambaqui (*Colossoma macropomum* CUVIER 1818)]. PhD thesis, Universidade Federal de São Carlos, Doutorado em Ciências, 222 p. [in Portuguese]
Zúñiga-Upegui P. T., Villa-Navarro F. A., García-Melo L. J., García-Melo J. E., Reinoso-Flórez G., Gualtero-Leal D. M., Ángel-Rojas V. J., 2014 [Ecological aspects of *Chaetostoma* sp. (Siluriformes: Loricariidae) in the upper Magdalena River, Colombia]. Biota Colombiana 15(2):81-94. [in Spanish]

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