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MORPHOMETRIC CHARACTERISTICS AND BODY YIELD OF *Prochilodus brevis* (Steindachner, 1875) ANALYZED BY SEX

CARACTERÍSTICAS MORFOMÉTRICAS E RENDIMENTO CORPORAL DE *Prochilodus brevis* (Steindachner, 1875) ANALISADOS POR SEXO

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Resumo

Limitados são os dados biométricos para caracterização corporal de *Prochilodus brevis* no desenvolvimento gonadal. Este estudo analisou, de *P. brevis* por sexo, as características morfométricas e rendimento corporal em indivíduos maturados. Machos-M (n=10, 22,80±0,93 cm/156,50±14,14g) e fêmeas-F (n=5, 24,30±2,31 cm/179,67±80,45g), capturados e mantidos em cativeiro, foram submetidos à filetagem por corte reto da cabeça e determinados parâmetros morfométricos (comprimento-cm: total-CT, padrão-CP, furcal, cageça e tronco; e altura-cm) e rendimento corporal (peles, escamas, cabeças, olhos, brânquias, esqueletos ósseos, gônadas, tratos estripados e filés); e, por macrospcopia e índice gonadossomático (IGS), o estágio gonadal. Amostras de cabeças embora diferindo (13,00±2,78%-M vs. 9,20±2,26%-F, p<0,05), não houve, analisado por sexo, relação entre morfometria e rendimento corporal (p>0,05). No estudo gonadal, macroscopia e IGS (0,02±0,01%-M vs. 0,20±0,01%-F) sugeriram relacionadas ao sexo, sem influenciar (p>0,05) o filé sem pele (21,15±5,10%-M vs. 18,84±6,52%-F) do índice CP/CT (0,78±0,02-M vs. 0,80±0,00-F, p>0,05). Assim, de *P. brevis* maturados, ferramentas biométricas não diferiram nos parâmetros corporais entre sexo, como contribuição à biologia reprodutiva e perspectivas industriais.

Palavras-chaves: Peixe reofílico, Partes corporais, Estágio reprodutivo, Biologia comparativa.

Abstract

Biometric data for *Prochilodus brevis* body characterization in gonadal development are limited. This study analyzed the morphometric characteristics and body yield of *P. brevis* by sex in matured individuals. Males-M (n=10, 22.80±0.93 cm/156.50±14.14g) and females-F (n=5, 24.30±2.31 cm/179.67±80.45g) captured and maintained in captivity were submitted to filleting by straight cut of the head and morphometric parameters (length-cm: total-TL, standard-SL, furcal, head and trunk; and height-cm) and body yield (skins, scales, heads, eyeballs, gills, bony skeletons, gonads, gutted tracts and fillets) determined; and gonadal stage by macroscopy and gonadosomatic index (GSI). Although head samples differing (13.00±2.78%-M vs. 9.20±2.26%-F, $p<0.05$), there was no relationship between morphometry and body yield analyzed by sexes ($p>0.05$). In gonadal study, macroscopy and GSI (0.02±0.01%-M vs. 0.20±0.01%-F) suggested related to sex without influencing ($p>0.05$) skinless fillet (21.15±5.10%-M vs. 18.84±6.52%-F) from SL/TL index (0.78±0.02-M vs. 0.80±0.00-F, $p>0.05$). Thus, biometric tools not differed in body parameters of matured *P. brevis* between sex, as contribution to reproductive biology and industrial perspectives.

Keywords: Rheophilic fish, Body parts, Reprodutive stage, Comparative biology.

Introduction

The Neotropical region of the Brazil is well-known for its richness of fish species in several hydrographic basins and good adaptation in captivity (Moreira et al., 2001). The family Prochilodontidae of the order Characiformis is divided into three genera: *Ichthyoelephas* Posada, 1909; *Prochilodus* Agassiz, 1829; and *Semaprochilodus* Fowler, 1941 (Fricke et al., 2024). *Prochilodus* populations have been frequently found in the river basins (Souza and Inhamuns, 2011; Penitente et al., 2025) showing migratory behavior in breeding season and, mostly, recognized as rheophilic species of moderate size with fusiform body shape and presenting a retractable mouth due to detritivore feeding habit (Moreira et al., 2001). The fish common curimatã (*P. brevis* Steindachner, 1875) is an endemic species to the northeast Brazil where its reprodutive biology (Nascimento et al., 2012) related to sperm cryopreservation (Nascimento et al., 2021) and the rational use of processing discards (Santiago et al., 2024; Fernandes et al., 2025) have been investigated for conservation and biotechnological destination, respectively. However, *Prochilodus* are still little-known on the technological aspects aiming at industrialization (Moreira et al., 2001).

In this scenario, the fishing industry of native species has been a challenger sector to integrates the production chain and the comsumption because it involves various complex technological process of market (transport, conservation, etc); besides, specific biological aspects of each species (age, gonadal development, sex, physiology, genetic, etc), cultured or by fishing activity, for the generation of commercial products (fillet or whole fish) (Moreira et al., 2001). The aquaculture of some Brazilian species has already been a current reality offering higher quality fish to fishing centers and consumers by reducing production chains until to commercialization, including time and costs in the availability of fish and its by-products comparing to Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758), a well-known African Cichlidae species by its high market acceptance and technological development over decades (Souza et al., 1999; Moreira et al., 2001), as well as its industrially productible fish-derived products (Sakar et al., 2023).

On the other hand, littler studies have been reported on the biometric aspects of some promising (wild and/or farmed) freshwater species for the rational utilization aiming at productive potential (Souza et al., 1999; Santos et al., 2001; Lima et al., 2012; Santos et al., 2025). For instance, Costa et al. (2014) evaluated two Amazonian species of “Jaraqui” (*Semaprochilodus taeniurus* Valenciennes, 1817 and *S. insignis* Jardine, 1841) from a local market and found that the method of filleting influenced on the fillet yield, with or absence of skin, and depending on the analyzed scale species. Araújo et al. (2018) observed a correlation between the slaughter weight and the total and the standard length with the fillet weight of wild specimens of “traíra” (*Hoplias malabaricus* Bloch, 1794), a carnivorous species. For ten Amazonian species, belonging to the three orders (Characiformis, Siluriformis and Perciformis), collected in two seasons (flood and drought) Souza and Inhamuns (2011) observed similar yields for gutted body, fillets with or without skin. More recently, Cosme et al. (2022) analyzed the *Peacock bass* (*Cichla monoculus* Spix & Agassiz, 1831) fillet yield and found the best procedure by the oblique cut of the head. For the rheophilic species of the family Prochilodontidae, there are still limited biometric data to introduce the perception that beside industrial utilization from product formulation and fish waste valorization perspectives (Souza and Inhamuns, 2011; Nascimento et al., 2021; Santiago et al., 2024; Fernandes et al., 2025).

The reproductive biology of *Prochilodus* populations is characterized by migratory fish species assuming long displacements supporting wide environmental variations during the trajectory, since at different life stages and hydrological periods (Moreira et al., 2001). In particular, *P. brevis* has a great ecological importance for the hydrographic basins of the northeast region of Brazil; by contrast, no apparent sexual dimorphism there is for its ecological protection and adequate conservation (Nascimento et al., 2012; Leite et al., 2018). Studies have related to experimental culture for better understanding the sex determination (Salmito-Vanderley et al., 2023), the biological characteristics of fish semen for its evaluation by hormone inducers (Vieira et al., 2024) and, until, in cryopreservation using fish waste molecules (Nascimento et al., 2021). However, few data are reported on the body yield of *P. brevis* considerating the sex when submitted to filleting in the reproductive phase aiming at industrial parameters and preservation of specimens (Gurgel et al., 2012; Bomfim et al., 2015).

The scope of this study was to evaluate the morphometric characteristics and body yield (wastes and fillets) using a filleting manual procedure by the straight cut of the head of specimens of Brazilian bocachico *P. brevis*, collected and then adapted in captivity, analyzing by fish sex. Furthermore, its removed tissues generated by filleting from both external and internal anatomies were represented as images to contribute digital biological data this rheophilic species in its reproductive phase aiming at industrial utilization with basis in its conservation and preservation.

Material and Methods

P. brevis collection and its adaptability in captivity

Initially, matured specimens of *P. brevis* males (10 individuals) and females (5 individuals) of a total of 55 animals were selected from a reservoir in the municipality of Canindé-CE, Brazil. These were maintained for about two months in a permanent-recirculation tank of approximately 7,000 L under laboratory conditions (Table 1) (Salmito-Vanderley et al., 2023). Fish were sacrificed by persuasive stunning and then tranported in ice (1:1 k biomass: ice ratio) at sialed isothermal boxes by the Fish Reproduction Biotechnology Laboratory (State University of Ceará, SUC, in Fortaleza city) for the development of this study at the Marine Biochemical (MarBio) laboratory located at Aquaculture Biotechnology Center, Department of Fisheries Engineering, Federal University of Ceará (FUC), in which the Brazilian bocachico has been biotechologically studied (Santiago et al., 2024; Fernandes et al., 2025). Fish were authorized through our registration with SISGEN-AA4816B (National System for the Management of Genetic Heritage and Associated Traditional Knowledge) and approved by the Ethical Committee of the SUC (protocol no. 6699198/2017).

For this experiment, fish were grouped by sexes of the species sampled from the two stages of collect in February 2018 and the second in August of the same year considering its breeding seasons recorded in the reservoir of the region (Salmito-Vanderley et al., 2023). From the sampled specimens, the total biomass and the water parameters in laboratory cultivation were obtained as initial data from the fish sex before the biometric analyses (Table 1).

Table 1. Zootecnical cultivation parameters of *P. brevis* maintained by sexes under laboratory conditions.

Parameters*	Males	Females
n (individuals)	10	5
Total biomass (kg)	1.530,80	1.014,16
Length (cm)	22.80 ± 0.93	24.30 ± 2.31
Weight (g)	156.50 ± 14.14	179.67 ± 80.45
Stocking density (fish L^{-1})	0.20	
Feed rate (%)	1.00	
Temperature (°C)	26.5-29.5	
Dissolved oxygen (mg L^{-1})	7.00	
pH	7.00	
Total ammonia (mg L^{-1})	0.25	
Cultivation system	rectangular fiber tank with aeration system	

* Salmito-Vanderley et al. (2023); Santiago et al. (2024); Fernandes et al. (2025).

Experimental design

With silvery coloration, sampled *P. brevis* with a distinct number of individuals were divided into two groups (males and females) to evaluate the influency of the sexes on the body parameters (morphometry / body yield) to determine the body shape (Nascimento et al., 2012) and yield, not only to skeletal muscle, but also related parts generated from the filletting operation of the species. All the tissues were collected and then recorded in parallel by integrated images to contribute digital biological data about the external and internal anatomy of this rheophilic species aiming at the better biotechnological and industrial utilization during the reproductive stage (Figure 1).

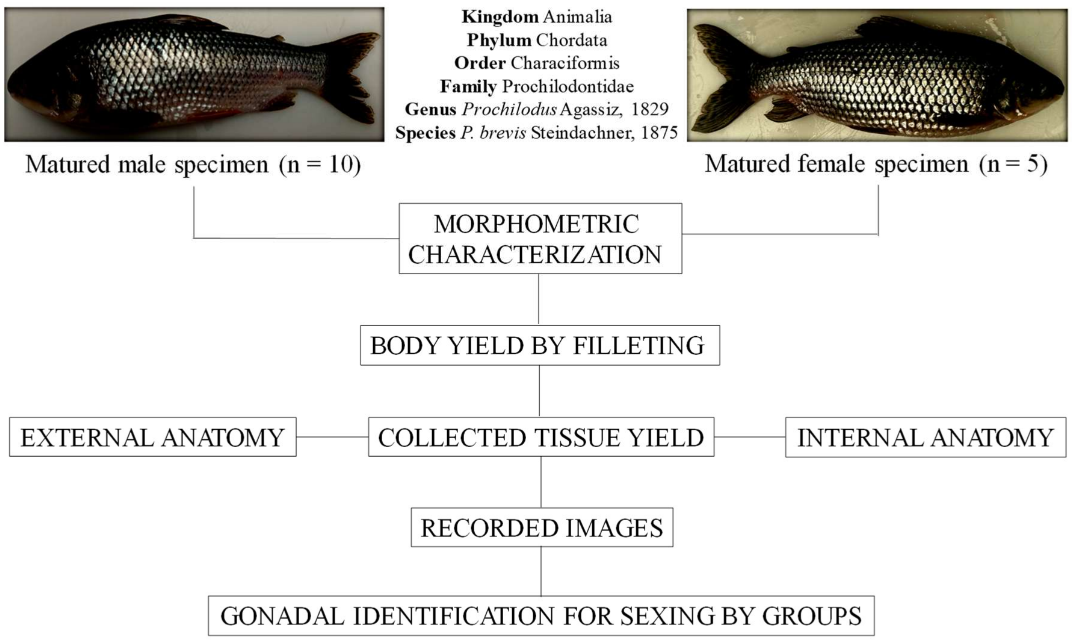

Figure 1. *P. brevis* body characterization scheme categorized by sexes of previously collected individuals and then maintained in captivity during the reproductive phase.

Upon arriving at the MarBio laboratory, whole fish were manually washed with distillated water for removing of solid particules and surface mucus before the morphometric and filleting procedures; and then stored in freezer (-20 ± 1°C) until experimental analyses (Santiago et al., 2024; Fernandes et al., 2025).

Biometric characterization

Morphometric analysis

Pos-washed whole fish were analyzed for main body parameters (length and height), considering length (cm): total-TL, standard-SL, furcal-FL, head-HL and trunk-TRL; and height-HTL (cm) (Gurgel et al., 2012; Nascimento et al., 2012; Costa et al., 2014; Souza et al., 1999; Cosme et al., 2022), which were determined with a rudimentary ichthyometer (cm) (Santiago et al., 2024; Fernandes et al., 2025) and their bodily relations and ratio (SL/TL) calculated subsequently (Araújo et al., 2018), according to the figure 2.

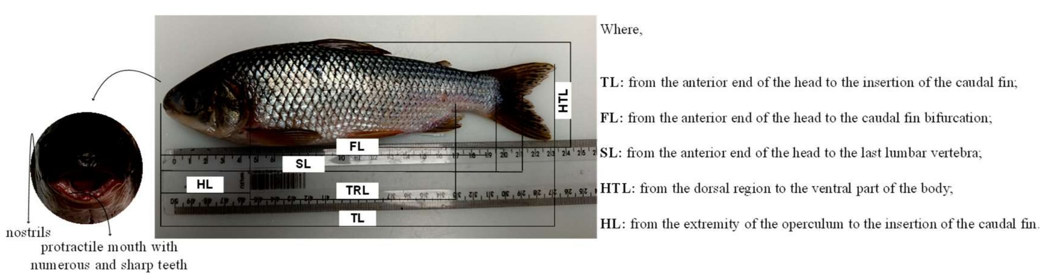

Figure 2. Illustrative representation of the body morphometry of *P. brevis* adulthoods using a rudimentary ichthyometer and related parameters.

Other relative parameters were also considered (HL/SL, HL/TL and HTL/TRL) from the sampled specimen of adult *P. brevis* body (Cosme et al., 2022) for the complementary morphometric measurements of both the sexes according to Gurgel et al. (2012).

Body analysis by filleting

Matured *P. brevis* filleting was performed by a single operator from the eviscerated specimen divided into two groups (Figure 1), applying the method by complete removing of the skin attached to skeletal muscle (Souza et al., 1999; Cosme et al., 2022; Santos et al., 2025). Fish head was separated by straight cut from the whole trunk and the dorsal region of skeletal muscle submitted to an incision with a knife that extended along the peripheral cut area (Moreira et al., 2001).

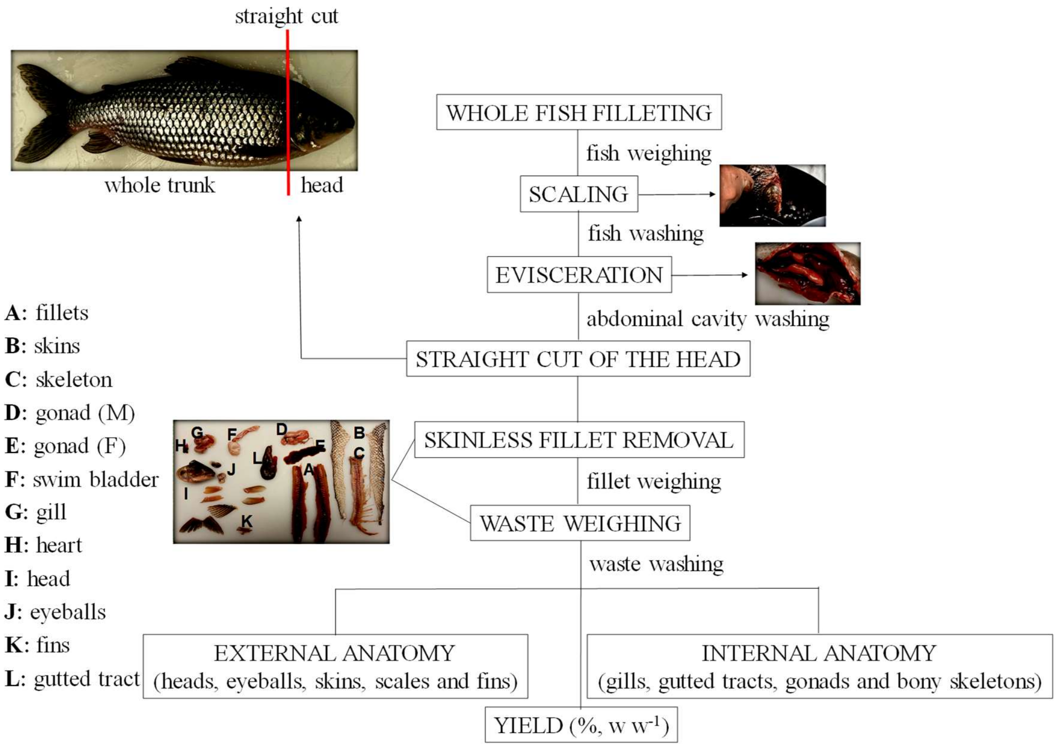

Figure 3. *P. brevis* filleting procedure and related steps for obtaining of anatomy-derived wastes and their body mass quantification.

After that, fish fillet was removed longitudinally (Araújo et al., 2018; Souza et al., 1999), since the entire length of the vertebral column to the end of the ribs, including caudal peduncle (Cosme et al., 2022). Further, whole fish-processing parts were also removed and, when necessary, with clamp and flesh cutter, since those from the external anatomy (heads, eyeballs, skins, scales and fins) such as those of internal (gills, gutted tracts, gonads and adherent tissues-devoid bony skeletons) one, being the respective fresh parts calculated as percentages (%, w w^{-1}) in relation to the total weight of the fish (Figure 3) (Santos et al., 2025), according to the Equation 1:

$$\text{Yield (fillet or waste: \%, w w}^{-1}\text{)} = (\text{part weight whole fish weight}^{-1}) \times 100 \quad (Eq.\ 1)$$

Gonadal maturation aspects

Besides fresh tissue determination (Figure 3), the gonadal maturation was macroscopically analyzed by qualitative method of sexual visualization and quantitative one considerating gonado somatic index (GSI) (Equation 2) based on Nascimento et al. (2012) and Gurgel et al. (2012), respectively. Photographic images on the determining the gonadal maturation of each fish were also recorded from a portable device with a resolution of 50 megapixels (Fernandes et al., 2025).

$$\text{GSI} = (\text{gonad weight whole fish weight}^{-1}) \times 100 \quad (Eq.\ 2)$$

Statistical analysis

All the values were expressed as mean ± standard deviation. Morphometric study was investigated by *t-Student* test, with $p < 0.05$ as significant. For yield comparison among the removed parts, statistical analysis was conducted by *Student' T*-test or one-way ANOVA, followed by Tukey' test, applying $p < 0.05$ as significant. For GSI, the *t*-Student test was adopted to apparently determine differences between the gonadal maturation of males and females. The statistical analyses were performed using the GraphPad Prism® version 5.01 for Windows (GraphPad Software, 1992-2007, San Diego, CA; www.graphpad.com).

Results and discussion

In this study, *P. brevis* males and females collected and maintained in laboratory conditions were divided into two experimental groups to evaluate the influency of the reproductive phase on the body aspects of matured specimens as analyzed by the quali-quantitative methods (Tables 1, 2).

Table 2. Comparison of body lengths and weights of some *Prochilodus* populations in Brazilian reservoirs.

***Prochilodus* populations (n)**	**Origin**	**Males (M)**	**Females (F)**	**Reference**
P. brevis (10-M / 5-F)	Canindé (CE)	21.10-24.20 cm 126.00-182.14 g	20.60-27.10 cm 137.91-320.94 g	this study
P. nigricans (20-M and F)	Amazonia (AM)	22.10±4.00-29.80±3.00 cm	314.60±67.00-598.60±212.00 g	Souza and Inhamuns (2011)
P. brevis (26-M / 17-F)	Gargalheiras (RN)	23.50-28.00 cm 204.20-322.40 g	23.00-30.00 cm 215.60-513.20 g	Nascimento et al. (2012)
P. brevis (136-M / 121-F)	Piranhas-Assu (RN)	5.30-28.70 cm 5.00-385.00 g	6.50-32.80 cm 5.00-416.50 g	Gurgel et al. (2012)
P. brevis (137- M / F)	Macaíba (RN)	not informed		Bomfim et al. (2015)
P. lineatus (148)	Paraná (PR)	not informed		Penitente et al. (2025)

Sampled fish revealed the predominance of males (10) than females (5) from the examined sexually individuals, after extraction of the gonads by longitudinal abdominal incision (Bomfim et al., 2015), ranging in lengths and weights (Tables 1, 2), whose data were collected the first in February 2018 and the second in August of the same year based on breeding seasons recorded in the reservoir of the region (Salmito-Vanderley et al., 2023).

Male body parameters (21.10 to 24.20 cm and 126.00 to 182.14 g) differed only in average weight (about 1.15-fold lower, Table 1, $P < 0.05$) than those of females (20.60 to 27.10 cm and 137.91 to 320.94 g) revealing the majority presence not only adult individuals during the period of sampling from the reservoir in Canindé-CE, but also indicating a biological imbalance of the species similar to other localities in which *P. brevis* occured frequently (Nascimento et al., 2012). The higher frequency of males and the sex ratio for 2 M:F in this study would also suggest the dynamic reproductive period of *P. brevis* according to the season of the year (Gurgel et al., 2012; Bomfim et al., 2015), with mean size for reproducers (16 to 23 cm) (Leite et al., 2018). *Prochilodus* populations usually has low genetic variation (Penitente et al., 2025) and are overexplored by extractive fishing (Souza and Inhamuns, 2011), motivating studies regarding their conservation and management (Gurgel et al., 2012; Bomfim et al., 2015; Leite et al., 2018; Salmito-Vanderley et al., 2023; Vieira et al., 2024), non-edible by-product utilization (Santiago et al., 2024; Fernandes et al., 2025) and for their better ecological knowledge (Nascimento et al., 2012; Bomfim et al., 2015).

In this scenario, as the morphometry represents the body variation in shape and size of the fish (Araújo et al., 2018; Cosme et al., 2012), it was further employed to evaluate the reproductive biology on the indirect potential of fillet production and other relative rates of by-products (wastes) for different fish utilization perspectives (Moreira et al., 2001; Souza et al., 1999).

Body morphometry

Matured specimens of adult *P. brevis* divided by sexes and the predominance of males did not result for significant morphometric differences compared to sampled females, considerating TL, HTL, SL, TRL, HL and FL (Table 3). For TL, combined observations supported the predominance of 16-24 cm ranges during the reproductible period of *P. brevis* males and females (Gurgel et al., 2012; Nascimento et al., 2012; Bomfim et al., 2015), as well as demonstrating relative homogeneity in terms of fish size for its induced reproduction (Leite et al., 2018).

Other related parameters simiraly indicated in fusiform body size between sexes with the reproductive cycle (Table 3), reinforcing absence sexual dimorphism (Bonfim et al., 2015; Leite et al., 2018). Sampled specimens of *Semaprochilodus* spp. (Costa et al., 2013), *H. malabaricus* (Araújo et al., 2018), *Cichla monoculus* (Cosme et al., 2022) and other native Brazilian species (Souza and Inhamuns, 2011) had important morphometric differences when processed, as well as independent of the season.

In fact, the morphometric relations in terms of HL/SL (0.24-M vs. 0.22-F) and HTL/THL (0.54-M vs. 0.50-F), as well as SL/HL (4.10-M vs. 4.39-F) and SL/TRL (3.30-M vs. 3.38-F) also not were related to the fish's sex, therefore, not exhibiting any relative sexual characteristic in the reproductive phase (Bomfim et al., 2015) when the specimens were collected in two well-defined periods (February vs. August) since the environmental conditions can define the reproductive success of most fish species, including *P. brevis* (Leite et al., 2018).

Overall, these data contrasted to other teleost fish with different relatively body indexes for head and profile as a result of their body shapes considerating slaughter weight (Araújo et al., 2018) and cut of the head (Cosme et al., 2022). The knowledge of the morphological patterns of fish species is important for evaluate novel technological and industrial potentials aiming at the consumer market, as has already been for tilapia fish at international level (Souza et al., 1999; Moreira et al., 2001; Sakar et al., 2023).

Table 3. Morphometric indexes of *P. brevis* in comparison with other species.

Parameters (cm)	Specimen (n)	Males (m)	Females (f)	Reference
TL	*P. brevis*	22.80 ± 0.93^{a}	24.30 ± 2.31^{a}	this study
HTL	(10-M / 5-F)	5.65 ± 0.32^{a}	5.80 ± 0.66^{a}	
SL		18.70 ± 0.64^{a}	19.63 ± 1.20^{a}	
TRL		10.38 ± 0.68^{a}	11.43 ± 0.3^{a}	
HL		4.55 ± 0.16^{a}	4.47 ± 0.34^{a}	
FL		20.85 ± 0.59^{a}	21.63 ± 1.14^{a}	
TL	*C. monoculus*	36.32 ± 2.24 / 35.27 ± 1.55		Cosme et al. (2022)
HTL	(60 - sex not	9.65 ± 0.49 / 9.22 ± 0.52		
SL	informed,	31.75 ± 2.04 cm / 30.20 ± 1.40		
TRL	oblique/straight	21.30 ± 2.51 / 19.52 ± 1.10		
HL	cut of the head)	7.55 ± 0.91 / 7.30 ± 1.07		
TL	*P. brevis* (26-M / 17-F)	23.50 - 28.00	23.00 - 30.00	Nascimento et al. (2012)
TL	*P. brevis* (136-M / 121-F)	20.00 ± 5.30	19.20 ± 6.50	Gurgel et al. (2012)
HL	*Semaprochilodus* spp. (30 - sex not informed)	5.21 ± 0.06 (fine scale) 5.36 ± 0.07 (coarse scale)		Costa et al. (2014)
SL		24.50 ± 0.29 (fine scale) 24.22 ± 0.27 (coarse scale)		

Therefore, data on *P. brevis* lengths / weights estimated by sexes (Table 2) were in line for reproducers, considerating commercial fish farm perspectives (Leite et al., 2018).

Waste yield

Filleted *P. brevis* allowed us to examine the body aspects on the quantitative biomass yield per fish-separated part based on processing technique applied comparing sexes (Figure 3). Under our conditions, males (M) and females (F)-derived residues firstly resulted in a substantial difference of total/average biomass (g) between both the external (211.32/20.52 ± 3.32-M vs. 97.46/19.74 ± 7.55-F = heads, 19.62/1.81.52 ± 0.51-M vs. 10.65/2.05 ± 0.63-F = eyeballs, 31.07/2.99 ± 0.94-M vs. 14.87/2.47 ± 1.22-F = skins and 72.57/4.52 ± 4.17-M vs. 59.45/13.43 ± 5.14-F = scales; without fins) and internal (39.65/3.88 ± 0.71-M vs. 23.04/4.47 ± 1.07-F = gills, 63.67/6.11 ± 0.96-M vs. 35.40/7.18 ± 2.59-F = gutted tracts, 35.15/3.32 ± 1.37-M vs. 134.84/25.51 ± 21.11-F = gonads, 81.83/8.59 ± 1.71-M vs. 48.18/9.73 ± 3.87-F = bone skeletons) anatomies, totaling 335.21 g-M vs. 182.43 g-F, but when considering the gonadless gutted tracts had no differences between the sexes in terms of average volumes (32.46 ± 1.60 / 18.39 ± 0.75 g-M vs. 37.49 ± 6,19 / 21.32 ± 3.26 g-F, $p > 0.05$) for each anatomic region, respectively.

Obviously, these results reflected the sample size of both sexes collected and maintained in captivity since the population structure of *P. brevis* could vary according to the season of the year (Leite et al., 2018). Low biomass availability, exacerbated by overfishing, threatens biological recruitment and industrial potential; consequently, cultivation and the development of techniques to assess biomass in relation to the reproductive cycle of *P. brevis* are fundamental approaches for the species' survival (Moreira et al., 2001; Nascimento et al., 2012; Gurgel et al., 2012; Bonfim et al., 2015).

Based on external-relative mass (Table 4), head samples of *P. brevis*, with average fish weight ranging from 156.50 to 179.67 g, differed (13.00 ± 2.78%-M vs. 9.20 ± 2.36%-F, $p < 0.05$) between the sexes comparing other analyzed-filleting wastes with similar masses ($p > 0.05$).

Table 4. External wastes generated by filleting of *P. brevis* in comparison with other species.

Reference	Species	Fish weight (g)	External anatomy (%, w w^{-1})*			
			Heads	Eyeballs	Skins	Scales
this study	*P. brevis*	156.50-M	13.00 ± 2.78[a]	1.29 ± 0.35[a]	1.89 ± 0.81[a]	3.57 ± 2.16[a]
		179.67-F	9.20 ± 2.36[b]	1.07 ± 0.41[a]	1.52 ± 0.29[a]	6.49 ± 2.09[a]
Souza and Inhamuns (2011)	*P. nigricans*	598.6	16.31/14.14	-	7.67/6.59	-
	S. insignis	215.7	14.10/14.86	-	8.90/9.49	-
	B. amazonicus	621.6	13.54/15.80	-	9.46/12.83	-
	C. macropomum	1071.2	23.68/25.29	-	6.29/6.89	-
	P. fasciatum	1075	27.23/12.74	-		-
Lima et al. (2012)	*P. mesopotamicus*	1,320.3	20.80	-	~4.57	3.57
Cosme et al. (2022)	*C. monoculus*	~750-800	29.72 ± 2.21	-	5.00 ± 0.56	-
			34.24 ± 7.59		5.65 ± 0.47	
Santos et al. (2025)	*S. herzbergii*	367.7	35.7 ± 6.9	-	7.1 ± 3.4	-
		360.0	41.2 ± 4.8		10.4 ± 3.9	

*residues calculaded from the whole fish; different letters indicate statistical significance in the waste between sexes at level of 5% (*t*-Student test, $p < 0.05$); (-) not informed.

Species of the genus *Prochilodus* have revealed rates for heads varying from 13.7 (*P. lineatus*, ~250 g) (Moreira et al., 2001) to 16.31% (*P. nigricans*, ~600 g) (Souza and Inhamuns, 2011) from the whole fish, similar to our findings for males only, although with animals showing relatively lower body weights (< 200 g) (Table 4). This peculiar characteristic for *P. brevis* in the reproductive period showed to be unrelated to its morphometric indexes (Table 3) since there is a direct relationship between head size and body yield determining the technological aspects (Moreira et al., 2001; Lima et al., 2012; Cosme et al., 2022; Santos et al., 2025). Possibly, endogenous and environmental factors could be involved in the body composition of this rheophilc species, during the reproductive cycle and/or the locality/season of the collect (Souza and Inhamuns, 2011), even under cultivation (Leite et al., 2018).

Eyesballs are peripheral vision-related functional structures that integrate the external anatomy of the head (Moreira et al., 2001), only yielding 1.29 ± 0.35%-M vs. 1.07 ± 0.41%-F ($p > 0.05$) based on other parts separated from the whole fish (Table 4). On a head-integrating basis, eyeballs represented 9.13 ± 2.17% and 10.88 ± 4.36% for males and females, respectively ($p > 0.05$), therefore, same relative mass between sexes. The quantification of isolated components in specific fish products has not been common; however, the global demand for natural products is growing across various economic sectors, in line with circular economy principles (Fernandes et al., 2025).

The body wall of some teleost fish consists of scale and skin structures acting as physical barrier to stress agents and as a sensorial system to environmental variations (Moreira et al., 2001). These raw residues have been sources of minerals and molecules for biotecnological (Sakar et al., 2923; Fernandes et al., 2025), human (Moreira et al., 2001) and non-food industrial (Sakar et al., 2923) applications. Both raw by-products, after filleting operation, are also variably discarded according to the species and its body characteristics, like from 5.00 ± 0.56 (*C. monoculus* - Cosme et al., 2022) to 10.4 ± 3.9% (*S. herzbergii* - Santos et al., 2025) for skins and from 3.57% (*P. mesopotamicus* - Lima et al., 2012) for scales.

In this study, *P. brevis* males and females were smaller sources in such wastes (1.89 ± 0.81%-M vs. 1.52 ± 0.29%-F = skin / 6.49 ± 2.09%-M vs. 3.57 ± 2.16%-F = scales) (Table 4), whose fusiform shape of this species did not influence the body indexes between both sexes (Table 3), being the fish skin-recovered rate at 3.96-fold lower than the average level found for teleosts (~7,5, $w\ w^{-1}$) (Moreira et al., 2001).

As the internal anatomy generates residue with various technological utilization (*e.g.,* silage and fish meal) (Moreira et al., 2001; Sakar et al., 2023), respective *P. brevis* raw wastes were also considered between the sexes and analyzed for their relative percentages as showed in table 5.

Table 5. Internal wastes generated by filleting of *P. brevis* in comparison with other species.

Reference	Species	Fish weight (g)	Internal anatomy (%, w w^{-1})*			
			Gills	Gutted tracts	Gonads	Bone skeletons
this study	*P. brevis*	156.50-M	2.47 ± 0.46^{a}	4.36 ± 0.77^{a}	2.20 ± 0.90^{a}	5.19 ± 0.96^{a}
		179.67-F	2.26 ± 0.32^{a}	3.26 ± 0.87^{a}	16.74 ± 8.44^{b}	4.78 ± 0.87^{a}
Souza and Inhamuns (2011)	*P. nigricans*	598.6	-	91.28/79.70	-	-
	S. insignis	215.7	-	89.01/83.49	-	-
	B. amazonicus	621.6	-	83.18/88.20	-	-
	C. macropomum	1071.2	-	82.34/84.51	-	-
	P. fasciatum	1075	-	92.59/79.41	-	-
Lima et al. (2012)	*P. mesopotamicus*	1,320.3	-	15.54	-	17.51
Santos et al. (2025)	*S. herzbergii*	367.7 360.0	-	10.1 ± 3.5	-	15.8 ± 6.3

*residues calculaded from the whole fish; different letters indicate statistical significance in the waste between sexes at level of 5% (*t*-Student test, $p < 0.05$); (-) not informed.

Environmental factors also determine the internal structure and functionality of bony fish (Osteichtyes), since the cartilaginous organs until those more specialized involved in the reproduction (Moreira et al., 2001; Leite et al., 2018; Santiago et al., 2024; Fernandes et al., 2025). In this study, the inedible parts removed from both *P. brevis* sexes, especially from the abdominal cavity, revealed similary among the themselves, considering their relative rates ($p > 0.05$) ranging from 2.26 ± 0.32% (gills) to 5.19 ± 0.96% (bone skeletons) and could reflect the fusiform body shape adaptated to detritivore feeding habit and reproductible ecology (Moreira et al., 2001). Collectively, both combined analyses lead us to infer that the anatomical composition of *P. brevis* had no relevant changes in terms sexual dimorphism among the sampled individuals, except for the increased gonadal volume in females that highlighted against that of males as an apparent result of different animal maturation stages (Bonfim et al., 2015).

Related studies to filleting-discarded adherent tissues-free bone structure/total viscera and their integrating parts have gastrointestinal tract and carcass as the main wastes depending on the fish weight (Moreira et al., 2001), such as the species listed in table 5. Except for *P. brevis* gonads that showed a significant difference in terms of *in natura* waste (2.20 ± 0.90%-M vs. 16.74 ± 8.44%-F) between the sexes, whose gonadal mass was about 7.61-fold higher occupying near all the coelomic cavity for matured females. For relative data, gonads represented 31.42 ± 10.32% and 80.73 ± 24.13% for males and females, respectively, therefore, with important difference between the sexes from the total viscera depending on the sampled fish weight.

Based on macroscopic observations (Figure 4), they confirmed the reproductible status from a total of 15 specimens of sampled *P. brevis* adulthoods, as gonadal structures characterized by a bluish-gray coloration and a milky-pink one for females and males, respectively (Gurgel et al., 2012; Nascimento et al., 2012; Bonfim et al., 2015). In this stage, of each fish registered the weight of the gonad and the respective sex, it was observed a gonadal maturation that, in females, ovaries occupied a greater volume of the abdominal cavity, to a greyish-green color and well-vascularized. For males, the testicles suggested to their maximum development, with pink or milky white color, near the spermiation (Bonfim et al., 2015). Taking with literature data, these combined observations can also be noted in captivity from well-treated animals presenting good physiological response, but unable to release sperm, even with water physicochemical parameters suitable for reproduction (Leite et al., 2018; Salmito-Vanderlei et al., 2023).

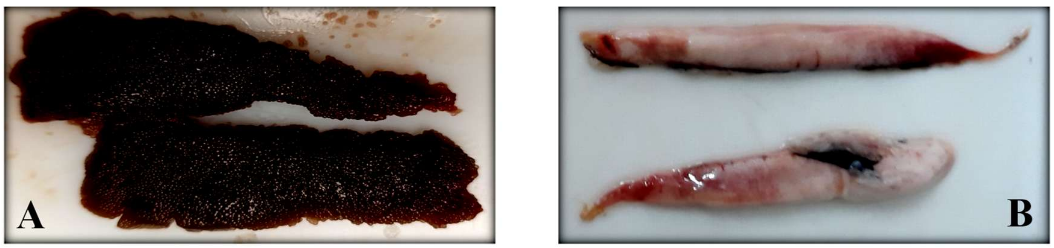

Figure 4. Female (A, n = 5) and male (B, n = 10) gonads of *P. brevis* adulthoods in captivity from the mature stage. In females, the ovaries are bigger and richly vascularized, whereas a maximum development showing tumescent shape and pink or milky color to spermiation in males.

As can be seen, all the individuals showed also be mature in accordance with the analysis of GSI, as a biological indicator of the reproductive period, in which revealed a relatively higher rate for matured females than males (0.02±0.01%-M vs. 0.20±0.01%-F, $p < 0.05$), since the body length/weight of adult individuals (Table 3) indicated similar to other studies analyzing the reproductive cycle of this species (Nascimento et al., 2012; Bonfim et al., 2015). Previous reports demonstrated that the first gonadal maturity was estimated as average 19.2 ± 0.21 cm for females and 18.6 ± 0.07 cm for males, although the frequency of mature specimen varying along of the year (Gurgel et al., 2012; Nascimento et al., 2012; Bonfim et al., 2015). As *Procholodus* populations have a hormonal cascade stimulated by migration (Moreira et al., 2001), studies on the reproductive ecology (Leite et al., 2018), techniques of artificial reproduction (Salmito-Vanderley et al., 2023; Vieira et al., 2024) and quality of cryopreserved sperm (Nascimento et al., 2021) have been analyzed to its better conservation and commercial culture (Moreira et al., 2001), although molecular studies of fish gonad are still littler-explored fields (Fernandes et al., 2025).

Macroscopic characterization and fillet yield

Subsequently, the skeletal muscle devoid of skin was removed from the *P. brevis* body (Figure 5) and the technique by the straight cut of the head revealed an edible product yield comparable with other teleosts, as seen in table 6.

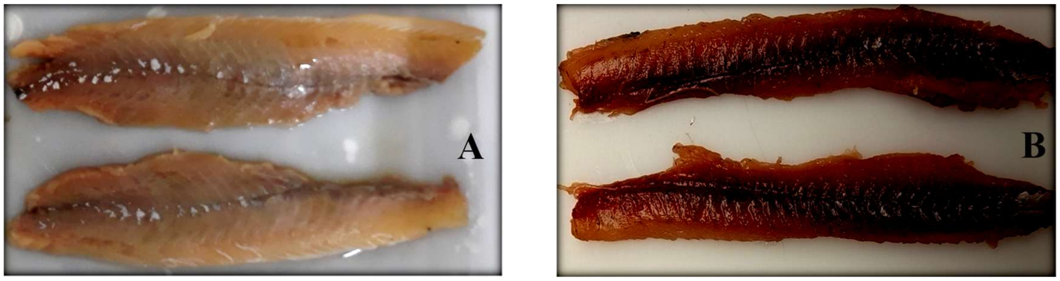

Figure 5. Skinless fillet of *P. brevis* (female-A and male-B) adulthood in captivity from the mature stage.

The edible part revealed to be a white meat with central brownish/red coloration of slim fillet based on its elongated shape (Figure 5), overall characterizing the *Prochilodus* genus (Moreira et al., 2001). The separation of the edible part resulted in a lowest yield of whole fillet from both fusiform sexes (18.84 ± 6.52%-F vs. 21.15 ± 5.10%-M, $p > 0.05$) compared to other teleosts with significatively higher fillet mass (Table 6), where the anatomical structure, head size, and the weight of viscera, skin, and fins were determined by species (Moreira et al., 2001; Araújo et al., 2018; Cosme et al., 2022; Santos et al., 2025).

On a sex-to-sex basis, Santos et al. (2001) found a relative difference between the *H. malabaricus* fillet from females (48.635) vs. males (46.12%) in gonadal development stage. Sexual factor may influence the structure of the edible part (Moreira et al., 2001), contrasting the specimens with similar body weight/size in this study where had no impact on the yield of flesh, as also observed for *H. malabaricus* fillets, although with different weights (Araújo et al., 2018). The commercial diet could be supplemented the performance of *P. brevis* during the captivity (Moreira et al., 2001; Leite et al., 2018), although the marginally lower female fillet weight (Table 6).

Table 6. Fillet yield of *P. brevis* in comparison with other species.

Reference	Species	Average fish weight	Fillet*	SL/TL
this study	*P. brevis*	156.50g-M	21.15 ± 5.10%^{a} (28.31 ± 9.16 g)	0.78 ± 0.02^a
		179.67g-F	18.84 ± 6.52%^{a} (37.62 ± 9.47 g)	0.80 ± 0.00^a
Souza and Inhamuns (2011)	*P. nigricans*	598.6 / 314.6g	32.52-29.54%	-
	S. insignis	215.7 / 178.2g	30.91-32.38%	-
	B. amazonicus	621.6 / 365.4g	39.00-38.68%	-
	C. macropomum	1071.2 / 1229g	25.70-29.08%	-
	P. fasciatum	1075 / 1536g	28.01-25.48%	-
Lima et al. (2012)	*P. mesopotamicus*	1320g	30.17%	-

Costa et al. (2014)	*Semaprochilodus* spp.	185.24-447.94g	34.92-44.31% (101.44-114.28g)	
Araújo et al. (2018)	*H. malabaricus*	400-550 / 600-800g	34.62-34.76% (161.00-234.99g)	0.82 / 0.85
Cosme et al. (2022)	*C. monoculus*	750 / 800g	46.52-42.96% (347.23-306.49g)	-
Santos et al. (2025)	*S. herzbergii*	367.7g	22.50%	-

*fillet calculaded from the whole fish; similar letters no statistical significance in the waste between sexes at level of 5% (t-Student test, p > 0.05); (-) not informed.

Obviously, intrinsic/technological factors also cause influency on the fish fillet yield in industrial utilization (Moreira et al., 2001). From table 6, Costa et al. (2014) evaluated two commercially-important Amazonian species of "Jaraqui" (*S. taeniurus* and *S. insignis*) and observed that, depending on the analyzed scale species, the strategy of filleting influenced on the fillet yield (34.92-44.31%), with or absence of skin. Araújo et al. (2018) found a correlation between the slaughter weight and the total and the standard length with the fillet weight of wild specimens of "traíra" (*H. malabaricus*). For ten Amazonian species (Characiformis, Siluriformis and Perciformis) collected in two seasons (flood and drought), Souza and Inhamuns (2011) revealed similar yields (25.70-39%) for fillets with or without skin. Cosme et al. (2022) analyzed the eviscered *Peacock bass* (*C. monoculus*) fillet yield (46.52-42.96%) and found the best procedure by the oblique cut of the head.

Although presenting a different head size (Table 4), this parameter had no impact on the skinless fillet yield of cultured *P. brevis*, as well as considering the SL/TL index (0.78 ± 0.02-M vs. 0.80 ± 0.00-F, p > 0.05) as an important value for pos-filleting-generated fillet estimation (Araújo et al., 2018), therefore, making it less attractive to industrial production that requires a more elaborated product, but could be utilized as other food products (*e.g.,* nuggets, breaded items) (Moreira et al., 2001; Sakar et al., 2023), although firstly requiring knowledge of its nutritional attributes (Araújo et al., 2018; Santos et al., 2001; Cosme et al., 2022).

Overall, both matured specimens (females and males) of *P. brevis* showed skinless fillet percentage unrelated to body weight and morphometric indexes (TL and HTL), especially by the SL/TL ratio, as a result of its particular fusiform anatomy contrasting other commercially-important *Prochilodus* species (*e.g.*, *P. nigricans*, 32.52-29.54% - Souza and Inhamuns (2011)). Therefore, for the rheophilic species of the family Prochilodontidae, there are still limited biometric data to introduce the perception that beside industrial utilization from product formulation and fish waste valorization perspectives (Souza and Inhamuns, 2011; Nascimento et al., 2021; Santiago et al., 2024; Fernandes et al., 2025).

On the other hand, current investigation brings, for the first time, more refined data on the body profile of *P. brevis* in its mature phase and additional studies could provide new biological bases for their better ecological preservation, and how their by-products would generate benefits of the rational use of fishery resources as a promising candidate to the Brazilian semi-arid region. An in-depth study regarding its possible body changes associated with the biochemical composition during ontogenetic development is in progress.

Conclusion

Sampling of *Prochilodus brevis* (females and males) adulthood collected during reproductive period and maintained in captivity suggested no morphometric association with the body weight and waste and skinless fillet yield after filleting operation by the straight cut of the head. On this particular biological basis, both specimens in maturing stage predicted with a satisfactory degree of confidence by both macroscopic and gonadosomatic index analyses, unrelated to the relative production of edible mass under cultivation conditions. Use of biometric tools to determine the body mass could be an effective strategy of evaluating of fish status inside the reproductive season and to identify possible bodily variations at level of cost-impact in the production chains, contributing to knowledge not only in reproductive biology, but also as new alternatives of native species by processing and handicrafts industries

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