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BIOMETRIC SAMPLING AND BODY YIELD OF *Cichla kelberi* MARKETED IN THE SEMIARID REGION OF JAGUARIBE-CEARÁ, BRAZIL

AMOSTRAGEM BIOMÉTRICA E RENDIMENTO CORPORAL DE *Cichla kelberi* COMERCIALIZADO NA REGIÃO SEMI-ÁRIDA DE JAGUARIBE-CEARÁ, BRASIL

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Resumo
Ainda é debatido amplamente o padrão corporal do gênero *Cichla*, os tucunarés como conhecidos. Este estudo examinou, para *C. kelberi* introduzido no rio Jaguaribe, CE, uma amostragem biométrica e rendimento corporal. De mercado público no município de Jaguaruana, espécimes (n=5, 338,00±25,65g; 31,2±1,43cm), por procedimentos clássicos amostrados morfologicamente, foram com cabeça filetados e examinados os índices morfométricos (comprimento-cm: total-CT, padrão-CP, cabeça e tronco; e altura-AT-cm) e rendimento corporal (peles, cabeças, olhos, esqueletos ósseos e filés); e, por comparação, a massa intrínsica e resíduos gerados. Para amostras de *C. kelberi* presumiram os aspectos morfológicos e anatômicos, sugerindo o índice com AT no rendimento potencial de filé sem pele (38,13±5,41%; m m^{-1}) e proporção CP/CT (0,91), da filetagem do peixe com cabeça, semelhante aos resíduos produzidos (41,54±5,41%, p>0,05), porém subestimado o residual total (61,67±5,41%, p<0,05; m m^{-1}). Esses achados caracterizaram o perfil anatômico e potencialidades do filé de *C. kelberi* eviscerado, por ferramentas ictiológicas, disponível em um mercado público do Vale do Jaguaribe, CE, em contribuição ao conhecimento do ciclo evolutivo dessa espécie introduzida, desde os anos 70, na bacia do rio Jaguaribe.

Palavras-chaves: Cichlidae; Morfometria; Anatomia descritiva; Tecnologia do pescado; Produto regional.

Abstract
Body standard of the genus *Cichla*, known as peacock bass, is still extensively debated. This study examined a biometric sampling and body yield for *C. kelberi* introduced into the Jaguaribe river, CE. Specimens (n=5, 338.00±25.65g,

31.2±1.43cm) from public market in the municipality of Jaguaruana morphologically sampled by classical procedures were filleted with head and morphometric indices (length-cm: total-TL, standard-SL, head and trunk; and height-HTL-cm) and body yield (%, w w^{-1}: skins, heads, eyeballs, bony skeletons and fillets) examined; and by intrinsic mass comparation and generated wastes. Morphological and anatomical aspects presumed for *C. kelberi* samples with HTL suggesting the index in its potential skinless fillet yield (38.13±5.41%, w w^{-1}) and SL/TL ratio (0.91) similar to produced wastes (41.54±5.41%, $p>0.05$) from filleting with fish' head, but with underestimated total residual (61.67±5.41%, $p<0.05$, w w^{-1}). These findings by ichthyological tools characterized the anatomical profile and potencialities of the fillet of eviscerated *C. kelberi* available in a public market of the Jaguaribe Valley, CE, in contribution to knowledge of the evolutionary cycle of this species introduced into the Jaguaribe river basin since 70s.

Keywords: Cichlidae; Morphometry, Descritive anatomy, Fish technology, Regional product.

Introduction

The semi-arid region in Northeastern of Brazil composes an ichthyofauna with low diversity and available volume compared to other parts of the country, largely due to river damming, anthropogenic pollution, and the loss of riparian vegetation; these factors lead to a decline in natural stocks, affecting both biological recruitment and/or local market (Moreira et al., 2001; Santos et al., 2026). Although some native species were already intended for cultivation in the 1990s, such as 'matrixã' (*Brycon amazonicus* Spix & Agassiz, 1829), 'pintado' (*Pseudoplatystoma corruscans* Spix & Agassiz, 1829), 'piau' (*Leporinus obtusidens* Valenciennes, 1837) and 'piavuçú' (*Leporinus microcephalus* Garavello & Britski, 1988), other were introduced in hydrographic basins by government agencies for the supply and food security of many localities in the 'Caatinga' area, addressing the needs of people living in poverty situation in the semi-arid region (Moreira et al., 2001). Since then, various local communities in Brazil have engaged in fishing for subsistence, regional market and/or, until, for scientific studies using native specimens (Moreira et al., 2001; Borba et al., 2026; Santos et al., 2026). Certain species have also been utilized in "pay-to-fish" operations as a recreational attraction (Sastraprawira et al., 2020), including those of *Cichla* (Bloch and Schneider, 1801) populary consumed due to a flavorful meat (Moreira et al., 2001).

Cichla populations are voracious predators belonging to the family Cichlidae within the order Perciformis including a diverse range of specimens commonly caught by extractive activity, especially to those of Amazon basin in which they are origined primarily (Moreira et al., 2001; Souza and Inhamuns, 2011; Sastraprawira et al., 2020; Cosme et al., 2022). This genus of Neotropical freshwater fish is well-widespread in Brazilian territory as translocated species causing negative impacts on biodiversity (*e.g.*, rivers and reservoirs in the southeastern and northeastern regions) (Gomiero and Braga, 2004; Junior and Gomiero, 2010; Faquim et al., 2022; Klippel et al., 2024) and taxonomic monitoring studies, as a typical consequence in South America, have been developed and examined among different groups (Diamante et al., 2017; Sastraprawira et al., 2020). Populary, they are known as 'tucunarés' or, for the English language, 'peacock bass' gaining relevance worldwide a short period of time due to yield greater fish harvests (Sastraprawira et al., 2020). Their reproductive strategy involves partitioned spawning with bi-parental brood care (Gomiero and Braga, 2004) based on in a typical diet of shrimp and fish (Junior and Gomiero, 2010; Diamante et al., 2017) and, when in captivity, with an artificial food, when conditioned from fingerlings (Moreira et al., 2001). Taxonomic aspects for specimens of *Cichla* have been supported by morphometric indices according to the review of Kullander and Ferreira (2006), although their taxa identification are still considered critical within the scenario of 15 different species (Sastraprawira et al., 2020), requiring complementary molecular' studies since morphology and colour patterns of hybrid specimens have been insufficients to some scientists, even in similar ecosystems (Diamante et al., 2017; Sastraprawira et al., 2020; Faquim et al., 2022).

On this scenario, there are limited biometric databases regarding *Cichla* populations introduced into the Brazilian reservoirs, since body changes could occur or are yet underestimated at biological and commercial levels. From previous studies, Gomiero and Braga (2003) observed an absence of length-weight relationship for *C. ocellaris* (Bloch & Schneider, 1801) and *C. monoculus* (Agassiz, 1831) introducted in Volta Grande Reservoir, Rio Grande, Brazil. In this same water body, these species collected matured or not revealed a significant range in terms of total length during the reproductive stage (Gomiero and Braga, 2004). Kullander and Ferreira (2006) systematically reviewed and described for South American cichlid species of the genus *Cichla*. The phylogenetic analyses pointed out to basal and unresolved groups considering morphometry, meristics, and morphology parameters. More recently, Cosme et al. (2022) determined the best procedure for eviscerated-marketed yellow *Peacock bass* (*C. monoculus*) fillet yield as being by the oblique cut of the head. Although diverse studies have been described on the technological potential using other native Brazilian species, in captivity or not (Santos et al., 2001; Souza and Inhamuns, 2011; Lima et al., 2012; Costa et al., 2014; Araújo et al., 2018; Santos et al., 2025; Borba et al., 2026; Santos et al., 2026), the family Cichlidae has been traditionally consumed in South America as an available animal protein-important option (Moreira et al., 2001; Sastraprawira et al., 2020); however, fish processing-derived rejects also promote chemical/biological/social impacts awakening industrial valorization perspectives (Machado et al., 2020; Sakar et al., 2023; Fernandes et al., 2025) comparing to Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) industry, an African Cichlidae species widely known by its high market demand and well-recognized technological package (Moreira et al., 2001; Sakar et al., 2023; Silva et al., 2025).

The piscivore species *C. kelberi* (Kullander & Ferreira, 2006) is derivates from the Araguaia and Tocantins river basins in Brazil and, due to its voracious behaviour and adaptability to different Neotropical ecoregions, it was also introduced to the population control of other exotic fishes in northeastern (Sastraprawira et al., 2020; Faquim et al., 2022) and southeastern (Júnior and Gomiero, 2010), such as tilapia, as well to other tropical and sub-tropical freshwater regions in the world (Sastraprawira et al., 2020). To our knowledge, their specimens were described, for the first time, as a new species for the Tocantins river basin, of which they were thereafter introduced into the Paraná and Paraíba do Sul rivers and, until, in the semi-arid ones of Brazil, showing specific characters when in adults, but other similar to *C. monoculus* and *C. pleiozona* (Kullander and Ferreira, 2006). These conflicting aspects have been extensively discussed in the literature as a concern for rational identification of *Cichla* sub-groups and to better management strategies aiming at future utilizing given the predatory behavior of this genus in aquatic ecosystems (Sastraprawira et al., 2020; Faquim et al., 2022). Despite these aspects, yellow *Peacock bass C. kelberi* has been marketed by several communities in the Brazilian semi-arid region, and studies on its available biomass would contribute to a better understanding of anatomy aiming at characterizing the artisanal processing-discarded wastes (Cosme et al., 2022), as also infer biological bases *vs. C. monoculus*, a parental *Cichla* variety (Kullander and Ferreira, 2006).

The purpose of this study was to examine a sampling of locally-eviscerated *C. kelberi* from a fish market unit situated in the semi-arid region of the Jaguaribe Valley, recognized with 15 municipalities belonging to the state of Ceará, Brazil (Paula et al., 2006), by determining morphometric indices and anatomical yield (wastes and fillets) using a filleting manual technique with head, as well as analyzing by overall macroscopic observations. Addictionally, all the fish anatomy (external and internal)-derived parts were considered as images to contribute digital biological data this Cichlidae species, introduced into the Northeastern 'Caatinga' rivers since 70s, aiming at its better anatomical knowledge in the organic waste generation and to technological utilization perspectives, as well as adding bases on its evolutionary cycle in this semi-arid region.

Material and Methods

Acquisition of adult C. kelberi and macroscopic characterization

Sampling of eviscerated adult *C. kelberi* was performed from a public market unit located in the municipality of Jaguaruana, which it integrates the semi-arid region of the Jaguaribe Valley, state of Ceará, Brazil. Based on local information, fish intented to sale came from artisanal fishing by traditional fishermen that operate in the Jaguaribe river basin, which is considered as a coastal water intermitent system that flows into estuary areas. This hydrographic basin extends for about 633 km and across several other municipalities in the Valley by through its tributaries and, until, other neighboring states (Paula et al., 2006).

A total of 5 remaining specimens from the establishment were purchased and then tranported in ice (1:1 k biomass: ice ratio) at sialed isothermal boxes to the Marine Biochemical (MarBio) laboratory located at Aquaculture Biotechnology Center, Department of Fisheries Engineering, Federal University of Ceará (FUC), as a management recommended by other studies (Fernandes et al., 2025; Santos et al., 2026). Fish were authorized through our registration with SISGEN-AA4816B (National System for the Management of Genetic Heritage and Associated Traditional Knowledge).

In the MarBio lab, *C. kelberi* samples from the establishment were determined the total / average biomass (kg) and length (cm) before the biometric operations (Table 1) (Fernandes et al., 2025; Santos et al., 2026). Other macroscopic aspects were also considered to characterize this fish following specific literature for the genus *Cichla* (Kullander and Ferreira, 2006; Sastraprawira et al., 2020), as represented in experimental design below.

Table 1. Sampled data from *C. kelberi* fish purchased from a public market unit of Jaguaruana-CE, Brazil.

Parameters*	*C. kelberi*
n (individuals)	5
Total biomass (kg)	1,764.92
Length (cm)	31.2 ± 1.43
Weight (g)	338.00 ± 25.65

* Zootechnique indices determined by rudimentary ichthyometer (cm) and precision balance (g) respectively.

Experimental design

Fish sampling revealed a predominantly yellow large body coloration and, as other main phenotypic features, the presence of three well-highlighted vertical half-body (black) stripes extending to the sideline and other head markings to the macroscopically-analyzed individuals (Kullander and Ferreira, 2006; Sastraprawira et al., 2020) to further determine the body morphometry and respective part processing yield based on Cosme et al. (2022) and Borba et al. (2026), not only to those of external anatomy, but also internal tissues removed from the filleting procedure of the previously eviscerated species (Figure 1) (Santos et al., 2026).

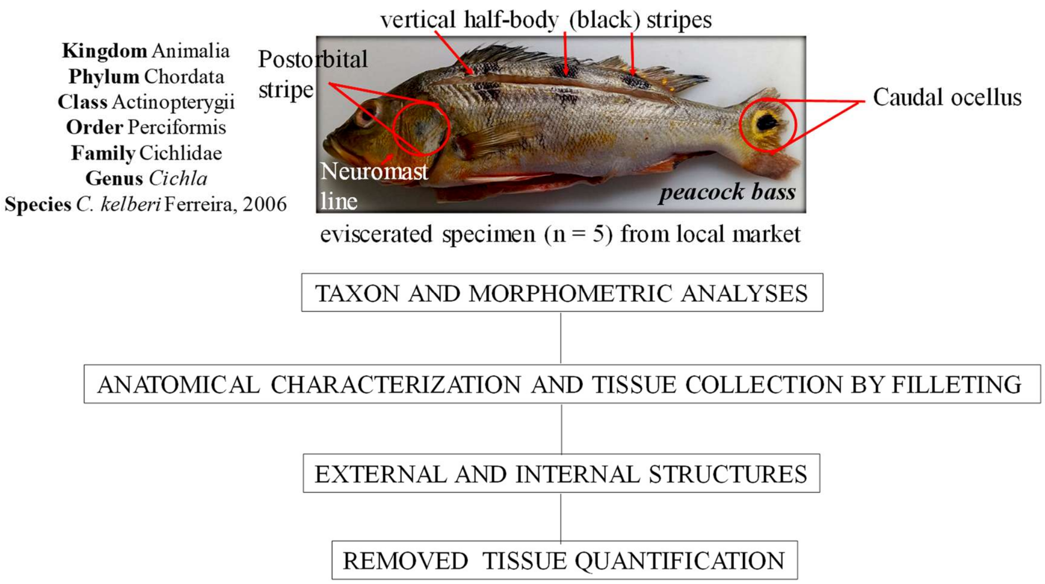


Figure 1. *C. kelberi* body characterization scheme of traditionally marketed individuals from a public market unit in the semi-aride region of Jaguaruana-CE, Brazil and its representative dark markings.

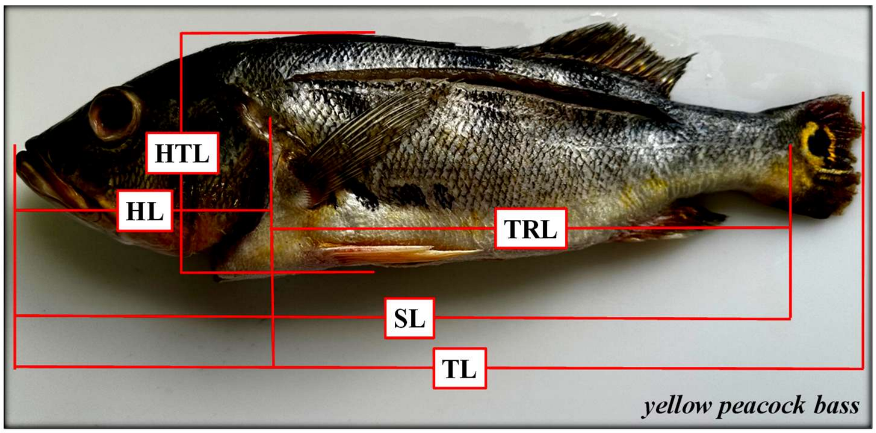
Although with the eviscerated fish head structure, the animal filleting operation was performed because the available specimens presented a longitudinal muscular cut by incision with knife near the dorsal region, a typical practical performed by the local fishermen for some Brazilian regions (Moreira et al., 2001). In parallel, all the fish-removed tissues were recorded and, by integrated images, to contribute digital biological data about the anatomical composition of this Cichlidae species with the aim of future biotechnological and industrial utilization (Figure 1).

From MarBio laboratory, eviscerated fish followed for the manually washing using distillated water baths for removing of solid particules, surface mucus and other abdominal cavity-organic residues before the morphometric and filleting techniques; and then stored in freezer (-20 ± 1°C) until experimental procedures (Fernandes et al., 2025; Santos et al., 2026).

Biometric investigation of *C. kelberi*

Morphometric parameters

Main body indices (length and height) for post-washed specimens were considered in length (cm) (total-TL, standard-SL, head-HL and trunk-TRL) and in height (cm) (HTL) adopting for other neotropical fishes farmed or wild (Kullander and Ferreira, 2006; Costa et al., 2014; Cosme et al., 2022; Santos et al., 2026). For this, each parameter was conducted with a rudimentary ichthyometer (cm) (Fernandes et al., 2025; Santos et al., 2026) and the morphometric relationships (Cosme et al., 2022; Santos et al., 2026) and ratio (SL/TL) calculated as described by Araújo et al. (2018) and Santos et al. (2026) following the figure 2.



Morphometric indices (cm):

TL = from the anterior end of the head to the tip of the caudal fin;
SL = from the anterior end of the head to the last lumbar vertebra;
HTL = from the dorsal region to the ventral part of the fish body;
TRL = from the extremity of the operculum to the insertion of the caudal fin;
HL = from the anterior of the head to the extremity of the operculum.

Figure 2. Schematic illustration on the body morphometry of eviscerated *C. kelberi* and related parameters.

On a relative-metric basis, other adult *C. kelberi* body indices were also considered (HL/SL, HL/TL and HTL/TRL) as previlously determined for eviscerated *C. monoculus*, another yellow peacock bass found in Brazil (Kullander and Ferreira, 2006; Sastraprawira et al., 2020), comparing thus the body profile with that found by Cosme et al. (2022) as an other taxonomic supplement, based on comparative literature, for different *Cichla* populations, in addition to available already data, considering *C. kelberi* grown in a semi-arid region of the Northeast, Brazil.

Body characterization by filleting

Eviscerated adult *C. kelberi* were thereafter submitted to processing by a filleting technique, considering fish head, by a previously trained single operator (Figure 1). Although rarely practiced, this approach was applied as the alternative method from the first-matter origin that revealed locally fishermen-manipulated skin (Figure 2) (Moreira et al., 2001) and, to the complete removing, the skin attached to fish skeletal muscle was manually extracted or, when necessary, using appropriate tools (*e.g.*, clamp and flesh cutter) as for other teleosts (Cosme et al., 2022; Fernandes et al., 2025; Santos et al., 2025; Borba et al., 2026; Santos et al., 2026). Fish head was maintained with the whole trunk during the processing and the dorsal region of skeletal muscle submitted to an incision with a knife where it was extended along the peripheral cut area to better fillet utilization (Moreira et al., 2001; Santos et al., 2026).

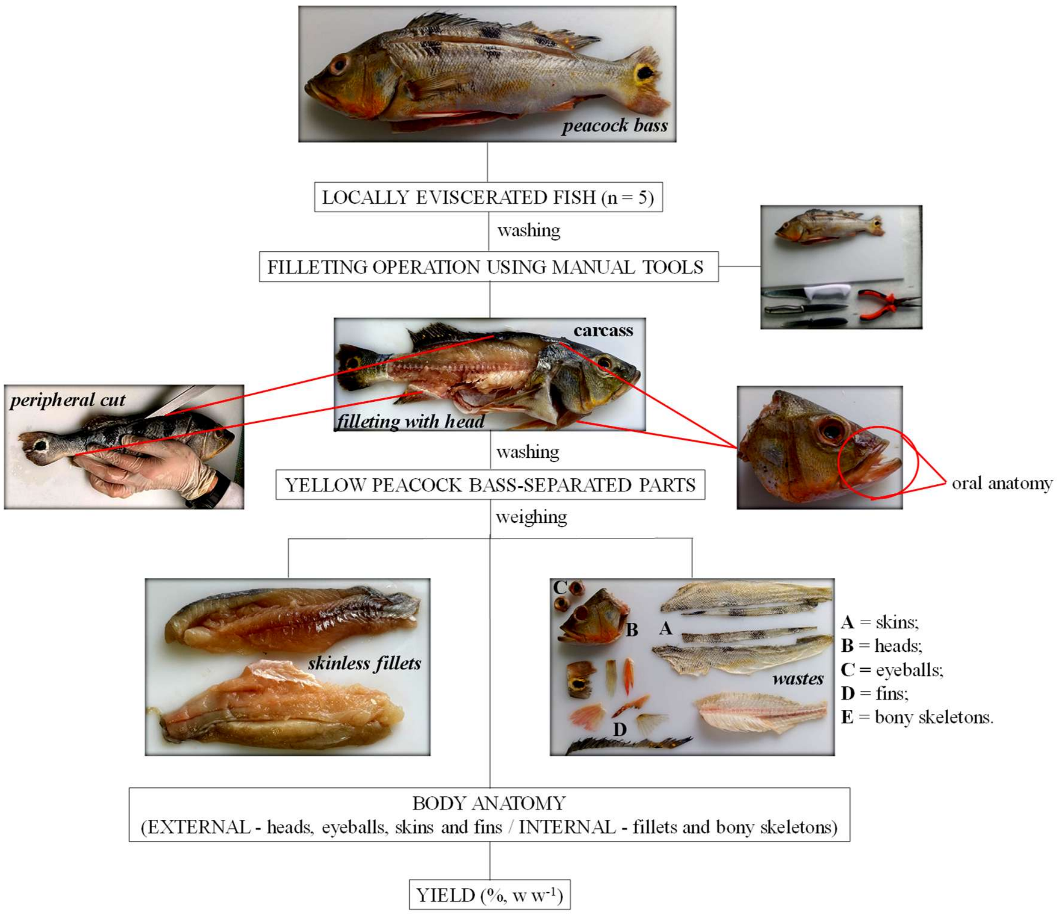


Figure 3. *C. kelberi* filleting operation and processing-sequential steps for selective separation of anatomy (external and internal)-derived tissues and their body mass determination.

The eviscerated fish was filleted with head / fins and its relative mass removed longitudinally and laterally to the dorsal fin, corresponding to the entire length of the vertebral column to the end of the ribs, accessing caudal peduncle extremity (Araújo et al., 2018; Cosme et al., 2022; Santos et al., 2026). At the end of the overall operation, the following parts were considered based on external (heads, eyeballs, skins and fins) and internal (adherent tissues-devoid bony skeletons) anatomies (Santos et al., 2026) from the strippedless carcass (Cosme et al., 2022). From the initial eviscerated fish weight and the carefully processed cuts, all the respective fresh parts were calculated as percentages (%, w w^{-1}) with basis in the total weight of the eviscerated fish (Figure 3) (Cosme et al., 2022; Borba et al., 2026; Santos et al., 2026), according to the Equation 1:

Yield (fillet or waste: %, w w^{-1}) = (part weight eviscerated fish $weight^{-1}$) × 100 (*Eq. 1*)

Relative body taxonomy

To examine relative body indices, wastes comprising the head (eyeballs) and trunk (bony skeletons) (Figure 3) were also submitted to relative rates (%, w w^{-1}) to estimate from each portion generated and as such biological systems could influence on the yield of skeletal muscle in terms of comparative anatomy and, as consequence, for *C. kelberi* filleting-derived by-product utilization (Santos et al., 2026).

Statistical analysis

All the values were expressed as mean ± standard deviation. Body yield and related variables were investigated by comparison among the eviscerated fish-removed parts, using one-way ANOVA, followed by Tukey's test, applying $p < 0.05$ as significant. For combined characterization, it was also adopted *Student*'s *T*-test, at level of 5% ($p < 0.05$), when applied. 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

Anatomical aspects of C. kelberi: macroscopy vs. morphometry

This study examined the body shape of Brazilian samples of eviscerated adult *C. kelberi* from a popular market unit located in the municipality of Jaguaruana-CE belonging to the Jaguaribe Valley, a semi-arid region of Brazil, in which the specimens were purchased and came from artisanal fishing to the commercial establishment by native fishermen that carryied out the activity in the Jaguaribe river basin, which is characterized as a water intermitent body (Paula et al., 2006).

Initially, sampled individuals were evaluated on the anatomical aspects (macroscopy and morphometry) with basis in the qualitative methods because the genus *Cichla* has a high adaptability and dominance on other species as a translocated piscivorous (Sastraprawira et al., 2020; Gomiero and Braga, 2004; Faquim et al., 2022; Klippel et al., 2024). Studies have also pointed to hybrid variations, including in morphology and colour patterns as phenotypic features, of this genus in certain localities already introduced (Diamante et al., 2017; Sastraprawira et al., 2020).

On the macroscopic scenario, specimens were recognized as a ‘yellow peacock bass’ with large body having distinct body markings (bands and blotches) along the trunck/head (Sastraprawira et al., 2020), as more specifically vizualized in figure 4 comparing two specimens. Both eviscerated individuals showed common three black bands in the snake-like skin, from the dorsal region to the body sideline; besides, the presence of ocellated marking at the base of the caudal fin (Figure 4) as described for *Cichla* species having a bass-like shape based on descriptive reviews of the genus (Kullander and Ferreira, 2006; Sastraprawira et al., 2020).

Conflicting results were to the presence or not of irregular abdominal blotches close to the pectoral fin and postorbital markings between both images (Figures 1, 4), even remaining the vertical black bands as well-defined from the examined *C. kelberi* specimens; possibly, they could be perharps the result of different populations by genetic introgression (Diamante et al., 2017) colonizing the Jaguaribe river and its connected tributaries considered a complex neotropical ecosystem (Paula et al., 2006), but investigations related to this theme are recommended (Faquim et al., et al., 2002).

Figure 4. *C. kelberi* showing different colour patterns and black markings within the same sampling unit. In left, a specimen showing postorbital markings in the head (A), while irregular abdominal blotches close to the pectoral fin highlighting from another animal with more colourful body patterns, in right (B).

Anatomical changes could lead to differences at level of colour patterns and variable markings from the specimens as a result of reproductive processes and/or adaptation to environment conditions (Gomiero and Braga, 2004; Junior and Gomiero, 2010) because of its aquatic translocation (Sastraprawira et al., 2020) since 70s by Brazilian government agencies (Moreira et al., 2001) could generate regional variations (Diamante et al., 2017; Sastraprawira et al., 2020).

Previous studies revealed that *C. kelberi* is distinct from other *Cichla* species by showing small light spots on pelvic and anal fins, and lower lobe of caudal fin similar to our study, considering observations for Araguaia and Tocantins river basin samples according to Kullander and Ferreira (2006) whom reported, for the first time, this Brazilian species. Although merist characters could not be considered to this study due to the degraded state of the specimens' fins (Figure 4), observations evidenced marked differences *vs. C. monoculus* because it should to be continuous vertical bands as those illustrated by Cosme et al. (2022) analyzing its fillet yield from marketed samples in the municipality of Altamira-PA, Brazil. Collectivelly, the biological aspects for hobbyists as ornamental attraction and fish aggression in fishing activity have been stimulating attractions to sport fishermen in the Jaguaribe river as recreational area similar to other regions of the world (Sastraprawira et al., 2020), although their impacts on local biodiversity be challenging in extensive and diverse areas (Klippel et al., 2024).

Despite the small fish sample (Table 1), biometric parameters were evaluated to analyze the body composition in terms of shape and size of the *Cichla* specimens (Table 2) (Araújo et al., 2018; Cosme et al., 2012; Santos et al., 2026) estimating the indirect potential of skeletal muscle-derived fillet (Moreira et al., 2001) and other relative percentages of filleting-generated wastes for various *C. kelberi* utilization perspectives based on the circular economy principles (Machado et al., 2020; Sarkar et al., 2023; Fernandes et al., 2025; Silva et al., 2025).

Body morphometric composition

From a total of 5 Jaguaribe region (CE, Brazil)-analyzed *C. kelberi* samples, a size range of 29-33 cm (31.20 ± 1.43 cm) (Table 2) was measured within of average weight for matured individuals (30-60 cm) (Sastraprawira et al., 2020) as an important biological base during the reproductive period for the genus *Cichla* introduced into other Brazilian reservoirs (Gomiero and Braga, 2003; Gomiero and Braga, 2004; Junior and Gomiero, 2010), but not from other native neotropical species (22.80 ± 0.93 cm-males *vs.* 24.30 ± 2.31 cm-females), such as for reproducers of *Prochilodus brevis*, a Characiformes teleost (Santos et al., 2026).

Relative average size among individuals in this study, demonstrating relative homogeneity, could be perhaps determined by reproductive biology (Santos et al., 2026) since for some *Cichla* spp. (*C. ocellaris* and *C. monoculus*) the width of the length class determined the population structure between females (28-36 cm *vs.* < 22 cm) and males (10-54 cm *vs.* > 30 cm), respectively, in Volta Grande Reservoir, Rio Grande-MG/SP, Brazil (Gomiero and Braga, 2003); and average size 36.32 ± 2.24 cm from morphometrically-analyzed *C. monoculus* samples obtained in municipality of Altamira-PA, Brazil (Cosme et al., 2022).

Considering HTL, SL, TRL and HL ratio (Table 2), these indices characterized the general morphological pattern for *C. kelberi* similar to that of 'peacock bass' body shape of *C. monoculus* by Cosme et al. (2022), with ~750-800 g average weight range, and by Souza and Inhamuns (2011), using the same species (589.80 ± 97.00 g-699.8 ± 201.00 g) from different seasons. Taking with literature data, both *Cichla* species have quite clear morphometric similarity, but *C. kelberi* frequently displays black blotches behind the pectoral fin base as discretely visualized here (Figure 4), even in a poor state of preservation of the specimens' fins, possibly resulting from the fishing and preparation of fish for sale challenging its identification (Kullander and Ferreira, 2006). Other species of neotropical fish, such as *Semaprochilodus* spp. (Costa et al., 2014), *H. malabaricus* (Araújo et al., 2018) and *Prochilodus nigricans* (Souza and Inhamuns, 2011), when processed, showed morphometric differences independent or not of the season, but, in reproductive period, for *P. brevis* had no body size chances analyzed by sexes (Santos et al., 2026) (Table 2).

Table 2. Morphometric indices of *C. kelberi* in comparison with other species.

Parameters (cm)	Specimen (n)	Origin	Males (M)	Females (F)	Reference
TL HTL SL TRL HL	*C. kelberi* (5 - purchased in local market, sex not indentified, without cut of the head)	Jaguaribe river-CE	31.20 ± 1.43 8.70 ± 0.76 28.50 ± 0.5 17.90 ± 3.65 9.00 ± 0.28		This study
TL HTL SL TRL	*P. brevis* (10-M / 5-F, captured and	Canindé reservoir-CE	22.80 ± 0.93 5.65 ± 0.32 18.70 ± 0.64 10.38 ± 0.68	24.30 ± 2.31 5.80 ± 0.66 19.63 ± 1.20 11.43 ± 0.3	Santos et al. (2026)

HL	adapted in		4.55 ± 0.16	4.47 ± 0.34	
FL	captivity)		20.85 ± 0.59	21.63 ± 1.14	
TL	*C. monoculus*		36.32 ± 2.24 / 35.27 ± 1.55		
HTL	(60 - purchased,		9.65 ± 0.49 / 9.22 ± 0.52		
SL	sex not informed,	Altamira-PA, local market	31.75 ± 2.04 cm / 30.20 ± 1.40		Cosme et al. (2022)
TRL	oblique/straight		21.30 ± 2.51 / 19.52 ± 1.10		
HL	cut of the head)		7.55 ± 0.91 / 7.30 ± 1.07		
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)		
SL	*P. nigricans* (20 - sex not informed	Amazon river, fishing terminal	29.8 ± 3.00 (flood) 22.1 ± 4.00 (drought)		Souza and Inhamuns (2011)
	C. monoculus (20 - sex not informed		28.60 ± 4.00 (flood) 31.00 ± 4.00 (drought)		

The morphometric profile in terms of HL/SL (0.31) and HTL/TRL (0.48), SL/HL (3.16) and SL/TRL (1.59) suggested related to the *Cichla* species (Cosme et al., 2022), therefore, exhibiting typical body characteristics for 'peacock bass fish' as confirmed by the SL/HL and SL/TRL indices, since the *Cichla* head exhibits as a relevant portion (Kullander and Ferreira, 2006; Sastraprawira et al., 2020) distinguishing from that of fusiform body shape fish (Santos et al., 2026) because the biology influence on the success of most tropical fish species (Sastraprawira et al., 2020), including the adaptation in captivity (Moreira et al., 2001; Borba et al., 2026). For *P. brevis*, Santos et al. (2026) found morphometric indices similar for males and females (HL/SL: 0.24 vs. 0.22; HTL/THL: 0.54 vs. 0.50; SL/HL: 4.10 vs. 4.39; SL/TRL: 3.30 vs. 3.38), captured and then maintained in captivity, unrelated to its gonadal maturing stage. Therefore, teleost body shape could determine, by slaughter weight (Araújo et al., 2018), cut of the head (Cosme et al., 2022) and other related factors (Santos et al., 2025), indirect technological and industrial values to the consumer market, as well-established for tilapia fish, an economically-important Cichlid' species, at global level (Moreira et al., 2001; Sakar et al., 2023).

As there is a connection between morphometry and body yield (Moreira et al., 2001; Araújo et al., 2018; Cosme et al., 2022; Santos et al., 2026), the further step was to examine the generation of wastes and skinless fillet by a filleting manual technique with head of *C. kelberi*.

Body yield composition: external anatomy-derived wastes

On a quantitative basis, *C. kelberi* was submitted to a processing with head in order to evaluate both external and internal anatomies from the eviscerated fish samples (Figure 5). Under our filleting conditions, *C. kelberi*-removed fresh parts produced a substancial volume of biomass (total/average) considering both anatomical regions from the available fish total biomass weight (1.764,96 kg / 338.00 ± 25.65 g, Table 1). Overall, total residual masses varied from 151.93 g (30.39 ± 8.12 g) to 457.55 g (91.51 ± 13.52 g) for clean bony skeletons and heads, respectively, whose respective rates corresponded to 8.60% and 25.92% from the total biomass (%, w w^{-1}), in line with other related studies where the major discarded proportions were for carcass and head by-products (Moreira et al., 2001; Cosme et al., 2022; Santos et al., 2025; Santos et al., 2026), while eyeballs (33.37 g / 6.67 ± 0.45 g), skins (49.91 g / 9.98 ± 2.96 g) and fins (55.74 g / 11.15 ± 0.54 g) represented lower percentages (Santos et al., 2026). Therefore, *in natura* biomasses of both bony skeleton and head wastes totaled, together, 81.41% from the total fish biomass weight (kg). Machado et al. (2020) evaluated the discarded proportions for processed fish residues from a public market segment of State of São Paulo, Brazil, and found significant volume for whole (fin+carcass+whole head) and isolated (skin) parts from different species. As a rule, higher quantitites of head negatively affect the fillet yield as an edible component (Borba et al., 2026) and could be indirectly associated with the previously analyzed *C. kelberi* head size (Table 2) (Cosme et al., 2022).

For examine this hypothesis, the relative proportions of external anatomy-derived wastes were firstly determined as a *C. kelberi* body function (Santos et al., 2026), as shown in figure 5. Thus, the eviscerated fish revealed a waste composition for external anatomy varying from eyeballs (1.88 ± 0.07%) to head (25.37 ± 2.83%), respectively ($p < 0.05$), considering animal external region, therefore, head-related wastes had a preponderant participation within other sampled tissues (2.75 ± 0.70% - skins and 3.15 ± 0.09% - fins) that no differed among their masses ($p > 0.05$) (Santos et al., 2026).

Obviously, these data reflected a small sample universe for a better understanding of the body biology of *C. kelberi* from the semi-arid region of the Jaguaribe river, since several factors could affect the population structure in biomass availability (Table 3) (Gomiero and Braga, 2003; Gomiero and Braga, 2004; Junior and Gomiero, 2010; Souza and Inhamuns, 2011), among them, overfishing (Santos et al., 2026). Studies on the comparative biology of exotic species to the hydrographic basins in Brazil have been underestimated not only in species hybridization, but also regarding changes in the genetic inheritance among populations, and these taxonomic units must be monitored (Diamante et al., 2017) and new tested models (Klippel et al., 2024) combining information at the fish body composition level as well over time (Sastraprawira et al., 2020; Cosme et al., 2022; Santos et al., 2026).

Figure 5. Yield (%, w w^{-1}) of filleting-separated fresh pasts of *C. kelberi* (eviscerated) marketed in the municipality of Jaguaruana, CE, Brazil (A). Different letters on the bars indicate significative differences at level of 5% (ANOVA, Tukey's test, $p < 0.05$, $n = 5$). Fresh parts: snake-like skin and their three black vertical markings (B); head without eyeballs (C); fins with small light spots on pelvic and anal structures, as well a caudal ocellus (D); and clean bony skeleton highlighting the vertebral structure (E).

On this baseline, fish skin is preponderantly present in the trunk and acts as a protective physical barrier covering the animal's body, composed of the epidermis and dermis, with patterns, coloration and biochemical composition that vary according to the studied species (Moreira et al., 2001; Sarkar et al., 2023; Fernandes et al., 2025; Santos et al., 2026). *C. kelberi* skin samples indicated diverse coloring (primarily yellow and black, besides with a grayish hue), but with an irregular structure among the analyzed specimens (Figure 4), although well-defined in terms of pattern of black vertical bars resembling a snake (Figure 5B). Cell pigmentation (chromatophores) adapts to the environment, becames it more intense during reproduction and group formation (Moreira et al.., 2001). Teleost fish skin composition has been implicated for tanning for handicrafts (Moreira et al., 2001), extracting of molecules (Fernandes et al., 2025) and clinical medicine (Sarkar et al., 2023).

C. kelberi yielded an overall relative rate of fresh skin, at least, 1.66-fold lower that other Brazilian freshwater fish species (Table 3), including parental *C. monoculus* species (7.12 and 66.33% from the 1,075-699.80 g whole fish weight - Souza and Inhamuns (2011) / 5.00 and 5.65% from the 700-800 g eviscerated fish weight - Cosme et al., 2022), except for matured *P. brevis* skin samples (1.89 and 1.52% for whole males and females, respectively) maintained in captivity (Santos et al., 2026). Besides, the average level found for *C. kelberi* skin samples was to also be 2.72-fold lower than that of teleosts (~7,5, w w^{-1}), including adult Nile tilapia fish (5.1%, w w^{-1}) (Moreira et al., 2001). The fish skin mass depends not only on the species (Machado et al., 2020), but also by feed dynamic (Borba et al., 2026; Santos et al., 2026) and season of the year (Souza and Inhamuns, 2011).

Table 3. Anatomical composition (%, w w^{-1}) obtained by filleting from other Brazilian fish species.

Species (fresh/marine)	Origin	Fish (g)	External anatomy				Internal anatomy		Ref.
			Skin	Head	Eyeball	Fin	Bone	Fillet	
P. nigricans	Amazon (AM) river	598.60	6.59	14.14	-		-	29.54	Souza and Inhamuns (2011)
S. insignis		215.70	9.49	14.86	-		-	32.38	
B. amazonicus		621.60	12.83	15.80	-		-	38.68	
C. macropomum		1,071.2	6.89	25.29	-		-	29.08	
P. fasciatum		1,075	7.12	12.74	-		-	25.48	
C. monoculus (whole)		699.80	6.33	25.29	-		-	31.63	
P. mesopotamicus (whole)	Porto Nacional (TO) farm	1,320.3	4.57	20.80	-	-	17.51	30.17	Lima et al. (2012)
H. malabaricus (whole)	Boa Vista (RR) reservoir	400 -550 / 600 -800	-	-	-	-	-	34.62 (161.00 g) 34.76 (234.99 g)	Araújo et al. (2018)
C. monoculus (eviscerated)	Altamira (PA) local market	750 - 800	5.00	29.72	-	-	-	46.52 (347.23 g)	Cosme et al. (2022)
			5.65	34.24				42.96 (306.49g)	
S. herzbergii (whole)	Sirinhaé (PE) reservoir	367.70	7.10	35.70	-	-	15.80	22.50	Santos et al. (2025)
		360.00	10.40	41.20					
P. brevis (whole)	Canindé (CE) reservoir	156.50	1.89	13.00	1.29	-	5.19	21.15 (28.31 g)	Santos et al. (2026)
		179.67	1.52	9.20	1.07		4.78	18.84 (37.62 g)	
C. carpio (eviscerated)	Laranjeiras do Sul (PR) culture - organic or artificial diet)	85.92	6.99	-	-	-	-	39.58	Borba et al. (2026)
		83.21	7.60	-	-	-	-	38.53	
P. lineatus (eviscerated)		84.14	8.96	-	-	-	-	42.70	
		85.41	10.04	-	-	-	-	41.06	

Fresh parts calculaded from the fish weight; - not informed. Fish were obtained from natural habitat or culture.

Fish head represents one of the largest residual rates streams from processing at local market (Machado et al., 2020) and industrial (Moreira et al., 2001; Sarkar et al., 2023) levels. *Cichla* populations produce significant rates in terms of head mass and size (Table 3), similar to our findings for Jaguaribe river-sampled specimens (Figure 5A). In fact, their highlighted anatomy by a robust mandibular structure offer a challenge to the sport fisherman, since *C. kelberi* is also a voracious predator that hunts and swallows their prey entirely (Sastraprawira et al., 2020) including in reproductive period (Gomiero and Braga, 2003; Gomiero and Braga, 2004) and showing feeding dynamics (Junior and Gomiero, 2010) within ecological (Klippel et al., 2024) and taxonomic (Kullander and Ferreira, 2006) variables. *C. kelberi* head samples, having bright colorations and black markings (Figures 4, 5C), indicated highest percentages within all the wastes obtained (Figure 5A), as expected for the genus *Cichla*, but the fresh mass would depend on the processing adopted and fish weight, even using same species (Table 3); therefore, the yield of its eyeballless carcass could also be underestimated (Santos et al., 2026) compared over others regarding fish market-derivated discards (Machado et al., 2020).

Fish eyeballs are structures for animal peripheral vision located on both sides of the head (Moreira et al., 2001) being natural sources of molecules (mainly hyaluronic acid) for topical destination (Sakar et al., 2023), although rarely quantified from teleost fish (Fernandes et al., 2025). In this study, *C. kelberi* eyeball samples are important ocular structures in terms of diameter and mass, compared to the few species of these residues already examined, whose fresh mass-recovered yield showed to be, at least, 1.75-fold higher than that of *P. brevis*, a detritivorous species of fusiform body shape (Santos et al., 2026). Fish waste composition and their body proportions between different species could suggest specific biological characters within industrial utilization for the rational use of the native ichthyofauna (Moreira et al., 2001; Machado et al., 2020; Sarkar et al., 2023; Fernandes et al., 2025).

Body yield composition: internal anatomy-derived wastes

On the internal-residual mass, fish carcass generated post-filleting, together with head and viscera, constitute as the main rejects depending on the fish anatomy (Table 3) (Moreira et al., 2001; Machado et al., 2020; Sakar et al., 2023). Although showing potential for development of feasible technologically coproducts (*e.g.*, silage, fish meal and meatball) (Moreira et al., 2001; Sakar et al., 2023; Silva et al., 2025), its fleshing resulted body trunk made of vertebral spines (neural and pleural) related to the architecture of the ventral cavity (Figure 5E), since spines may still remain on the edible mass after filleting procedure (Moreira et al., 2001). In this study, these bone by-products yielded 8.38 ± 1.91% (w w^{-1}) from the eviscerated *C. kelberi* weight (Figure 5A), an estimated value to be, at least, 1.88-fold lower for that from characin *P. mesopotamicus* (whole fish) (Lima et al., 2012) and from marine catfish *S. herzbergii* (Santos et al., 2025), when both whole fishes, respectively; but, comparing to the whole *P. brevis* fusiform fish, *C. kelberi* bony skeletons resulted in a more important percentage (Table 3). Combined observations denoted that the mineralyzed (adherent tissuesless) mass yield vary based on the analyzed fish weight and size and, on this scenario, *C. kelberi* derived-bone tissue could be an interesting first-matter for mineral (calcium and magnesium)-based product prospection (Sakar et al., 2023), although with masses similar to other external anatomy-related wastes, except for head one (Figure 5A).

As there is direct connection between head size and body profile by evaluated cut (Moreira et al., 2001; Santos et al., 2025; Santos et al., 2026; Borba et al., 2026), our study extended to determine the eviscerated *C. kelberi* skinless fillet, as also shown in figure 5A. On this conceptual basis, fillet samples ranged from 107.04 g to 233.08 g for the respective fish weight (335.19-395.66 g), with average edible rate for 38.13 ± 5.41% (136.7 ± 24.55 g) from the fish weight (w w^{-1}). The skin-devoid product, but maintaining the head attached to the bone carcass, could be comparable with other teleosts, although with technical variations (Table 4). Its apparence revealed to be white meat with discrete peripheral red coloration in caudal loin, and with considerable thickness along its elongated shape, it also influenced in profile due to the animal's height (Table 2), as a marked biometric indice (Kullander and Ferreira, 2006) for *Cichla* fillet yield (Souza and Inhamuns, 2011; Cosme et al., 2022). Another factor was to the moderate presence of intramuscular spines when handled as common for carnivorous (Moreira et al., 2001; Araújo et al., 2018) and detritivores (Santos et al., 2026) species, challenging the production-cost for a more elaborated product (Moreira et al., 2001; Sakar et al., 2023; Santos et al., 2026).

As can be seen in table 3, somatic factors have been related to influence or not the edible production post-filleting (Moreira et al., 2001). Among them have the sex (Santos et al., 2001), body weight and size (Cosme et al., 2022), anatomical structure (Araújo et al., 2018; Santos et al., 2026), head size (Cosme et al., 2022) and the weight of viscera, skin, and fins (Moreira et al., 2001; Costa et al. 2014; Santos et al., 2025; Santos et al., 2026). Inverse proportions of such factorial components would lead to smaller fillet yields (Borba et al., 2026). Cosme et al. (2022) determined the oblique cut of the head as better strategy against that by straight one for the eviscerated yellow *Peacock bass* (*C. monoculus*) fillet yield (46.52 vs. 42.96%, respectively). The sazonal/locality (Souza and Inhamuns, 2011) and technological (Moreira et al., 2001) aspects are also relevant to the fish fillet utilization (Sakar et al., 2023), even under polyculture conditions (Borba et al., 2026).

As the body proportions determine the anatomy of the *Cichla* species, since the environmental differences and species behavior govern inter-intraspecific relationships, which are also determined by genetic, body chances occur as a adaptative-function supporting the systematic (Kullander and Ferreira, 2006; Sastraprawira et al., 2020). So, relative body indices for head and trunk were analyzed as complex biological systems in terms of intrinsic comparative anatomy for *C. kelberi*, as tempted by Santos et al. (2026) studying the rheophilic fish *P. brevis* during its reproductive stage.

Relative body taxonomy: external vs. internal composition

Body profile of *C. kelberi* between both external and internal anatomies, as well their relative configurations for wastes (eyeballs vs. heads) and edible part (bony skeletons vs fillet and fillet vs wastes) are shown in figure 6.

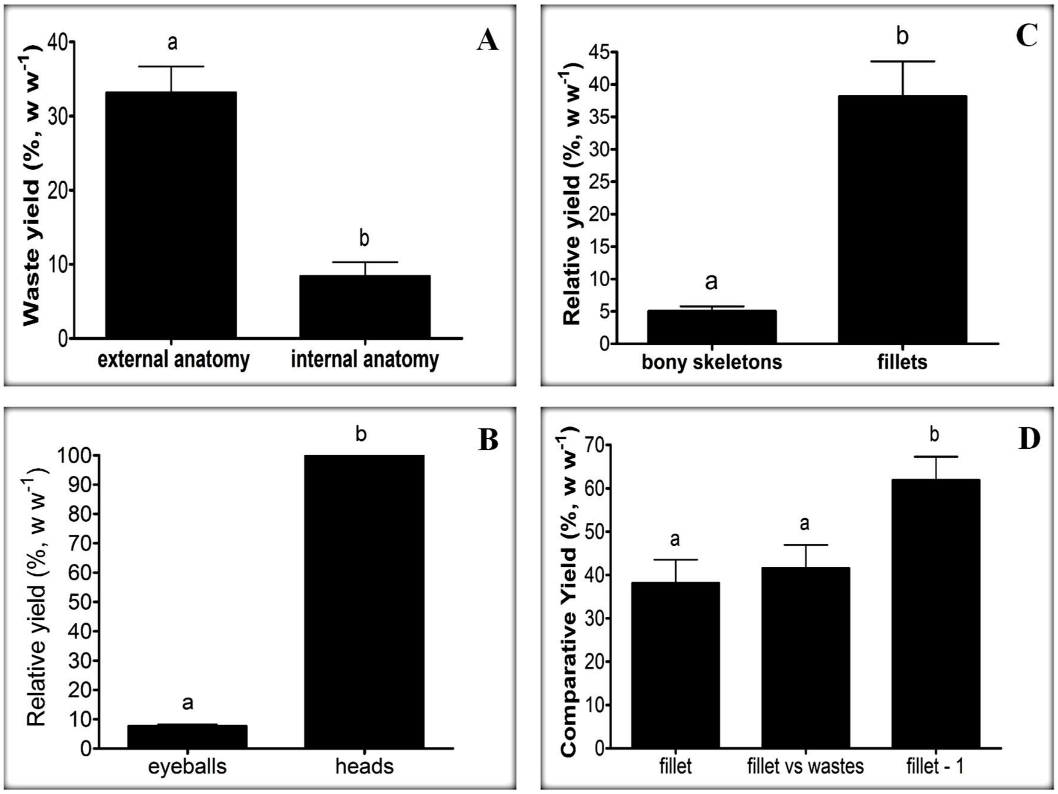


Figure 6. *C. kelberi* raw biomass yield (%, w w^{-1}): comparative anatomical analysis of total volume (A), relative residual portions (B, C) and impact of filleting between fillet and reject production (D). Different letters on the bars indicate significative differences at level of 5% (*Student*'s *T*-test or ANOVA, $p < 0.05$, n =5).

Using our technical conditions, the filleting operation produced a more significant residual rate from the external composition as already mentioned (Figure 5A); but, 22.83% reaching within the generated raw volume (Figure 6A), therefore, ~3.95-fold higher of the discarded total raw material, as expected since head waste corresponded to the highest amount within all ones (Moreira et al., 2001; Souza and Inhamuns, 2011; Machado et al., 2020) because anatomical structure of *C. kelberi* significantly influenced, contrasting to that of *P. brevis* having a fusiform body shape recently examined by our group (Santos et al., 2026).

For gillless head-integrating data (figure 6B), eyeballs composed 7.59 ± 0.56% for the *C. kelberi* samples, whose value was marginally different that those found for males and females (9.13 ± 2.17% and 10.88 ± 4.36%, respectively) of *P. brevis* (Santos et al., 2026), therefore, distinct relative masses between freshwater teleost species as a result depending on the fish head shape (Moreira et al., 2001). Even fillet vs bone skeleton ratio (Figure 6C), whose average values were 38.13 ± 5.41% vs 5.02 ± 0.75%, respectively, it represented 7.59-fold higher for edible part, since the bony skeleton-attached fillet was separated from the eviscerated fish trunk (Figure 3), and this basic operation allowed a comparatively higher SL/TL index (0.91) than those obtained for *P. brevis* (0.78 ± 0.02 -males vs. 0.80 ± 0.00 - females) (Santos et al., 2026) and *H. malabaricus* (0.82 vs 0.85, for two weight classes, respectively) (Araújo et al., 2018), confirming *C. kelberi* as a good producer of skinless fillets, even when compared to those from eviscerated *C. monoculus* samples (0.87 and 0.86), although presenting a different sample size (Cosme et al., 2022). Nile tilapia yields a 32-35% (w w^{-1}) fillet rate according to the literature over time (Moreira et al., 2001).

In fact, when fillet vs wastes were analyzed, there was similar relative percentage (38.13 ± 5.41% for skinless fillet and 41.54 ± 5.41% for fillet vs wastes, $p > 0.05$) between themselves (Figure 5D) under our experimental conditions applying filleting with fish head (Figure 3). Since the discards traditionally occur with whole carcass (Moreira et al., 2001; Machado et al., 2020), our total residual rate, when the eviscerated fish, it was estimated to be 61.67 ± 5.41% ($p < 0.05$, w w^{-1}) (Figure 6D), a lower total residual level that other studied Neotropical teleost fish species (Souza and Inhamuns, 2011; Cosme et al., 2022), although this study yet presenting an underestimated volume and small sample size. Studies on the fishing rejects have been crucial themes for the development of public politicies in Brazil (Machado et al., 2020).

Understanding the body variability and intra- and interspecific maintenance of *Cichla* populations is an interesting theme within the biological structure and somatic factors involved that influence their environmental dynamic intercropped with native species in the Jaguaribe river, CE. More recently, a reclassification was indicated for different *Cichla* from 16 to 9 species based on genetic studies (Willis et al., 2012). In the ichthyology world, there are three schools of thought regarding the description of a given species: taxonomy (morphological differences, such genetic), evolution (speciation, including evolution) and conservation (sustainable management, including preservation) (Kullander and Ferreira, 2006; Sastraprawira et al., 2020). Hybridization of the individuals introduced into the Brazilian reservoirs has revealed common patterns, even with morphological and marking differences, but considering as sub-species to other scientists. Therefore, studies are still conflicting on the genus *Cichla* and the body patterns could characterize different populations (or sub-species) for given region, as a result of their environmental adaptation. Our study contributed to the descriptive body examining of Brazilian samples of *C. kelberi* introduced into the Jaguaribe river basin, in which it occurs as a non-native species since 70s.

Conclusion

Eviscerated *Cichla* specimens introduced into the Jaguaribe river and purchased from a fish public market in the municipatility of Jaguaruana, CE, presumed *C. kelberi* by classic morphological standards of body shape and coloration (markings). The available biometric tools seemed by fish' indices to an association between the body height with the well-elaborated skinless fillet yield unrelated to the head size as an alternative technique within weight range and apparent fish conditions. Use of relative body analyses allowed identify more specific anatomical standards regarding their particulated residual portions and estimated production of organic rejects, as additional supplements in the evaluation of the fillet and discarded total raw materials aiming at better development of public politicies, therefore, within the concept of the bioeconomy in fishing wastes; in addition, as biological base to understand the evolutionary cycle of the species in the Jaguaribe river basin for sustainable fishing use by the region's consumer and to future industrial alternatives based on its eco-friendly management.

References

ARAÚJO, K. C., CIRNE, L. G. A., SOUZA, W. S., SILVA, J. R., FELTRAN, R. B., MELO, D. R., MELO, P. R. R., & MACIEL, E. S. (2018). Características morfométricas, rendimento de filé e composição química da traíra. Agroecossistemas, 10(2), 25-36. DOI: http://dx.doi.org/10.18542/ragros.v10i2.5198

BORBA, M. R., LUCZINSKI, T. G., NASCIMENTO, L. B. A., WEINGARTNER, M., SADO, R. Y., & MUELBER, B. (2026). Processing yields and chemical composition of fillets from fish fed organic and commercial diets in a polyculture system. Revista Ciência Agronômica, 57, e202594987. DOI: https://doi.org/10.5935/1806-6690.v57e202594987

COSME, S. S., SANCHESB, A. G., SILVA, M. B., MOREIRA, E. G. S., & CORDEIRO, C. A. M. (2022). Rendimento do filé de tucunaré (Cichla cf. monoculus) Osteichthyes, Cichlidae em diferentes cortes da cabeça. Journal of Biotechnology and Biodiversity, 10(1), 061-067. DOI: https://doi.org/10.20873/jbb.uft.cemaf.v10n1.cosme

COSTA, T. V., MACHADO, N. J. B., BRASIL, R. J. M., & FRAGATA, N. P. (2014). Caracterização físico-química e rendimento do filé e resíduos de diferentes espécies de jaraqui (Semaprochilodus spp.). Boletim do Instituto de Pesca, 40(1), 35-47.

DIAMANTE, N. A., OLIVEIRA, A. V., PETRY, A. C., CATELANI, P. A., PELICICE, F. M., PRIOLI, S. M. A. P., & PRIOLI, A. J. (2017). Molecular analysis of invasive Cichla (Perciformes: Cichlidae) populations from neotropical ecosystems. Biochemical Systematics and Ecology, 72, 15e22. DOI: http://dx.doi.org/10.1016/j.bse.2017.03.004

FAQUIM, R. C. P., BRAGA-FERREIRA, R. S., CASTRO, T. G., SILVA, L. C. F., & TELLES, M. P. C. (2022). Genetic diversity in Cichla piquiti and cross-amplification for Cichla kelberi in the Serra da Mesa reservoir, Goiás, Brazil. Acta Scientiarum. Biological Sciences, 44, e58294. DOI: https://doi.org/10.4025/actascibiolsci.v44i1.58294

FERNANDES, F. G. M.; RODRIGUES, J. A. G., SANTIAGO, L. M., QUEIROZ, I. N. L., FEITOSA, J. P. M., SOARES, S. A., SALMITO-VANDERLEY, C. S. B., NETO, O. P. P., & ARAÚJO, I. W. F. (2025). Biochemical prospection of glycosaminoglycans in fish wastes aiming at circular economy. Revista Brasileira de Engenharia de Pesca, 16(3), 18-33. DOI: https://doi.org/10.18817/repesca.v16i3.4116

GOMIERO, L. M., & BRAGA, F. M. S. (2003). Relação peso-comprimento e fator de condição para Cichla cf. ocellaris e Cichla monoculus (Perciformes, Cichlidae) no reservatório de Volta Grande, rio Grande - MG/SP. Acta Scientiarum: Biological Sciences, 25(1), 79-86. DOI: https://doi.org/10.4025/actascibiolsci.v25i1.2119

GOMIERO, L. M., & BRAGA, F. M. S. (2004). Reproduction of species of the genus Cichla in a reservoir in southeastern Brazil. Brazilian Journal of Biology, 64(3B), 613-624. DOI: https://doi.org/10.1590/S1519-69842004000400008

JUNIOR, G. A. V., & GOMIERO, L. M. (2010). Feeding dynamics of Cichla kelberi Kullander & Ferreira, 2006 introduced into an artificial lake in southeastern Brazil. Neotropical Ichthyology, 8(4), 819-824. DOI: https://doi.org/10.1590/S1679-62252010000500000

KLIPPEL, G., MACÊDO, R. L., ANA CLARA S. FRANCO, A. C. S., HAUBROCK, P. J., LORINI, M. L., & SANTOS, L. N. (2024). Future invasion risk assessment of the peacock bass in Neotropical ecoregions: a conceptual and testable model. Global Ecology and Conservation, 55, e03227. DOI: https://doi.org/10.1016/j.gecco.2024.e03227

KULLANDER, S. O., & FERREIRA, E. J. G. (2006). A review of the South American cichlid genus Cichla, with descriptions of nine new species (Teleostei: Cichlidae). Ichthyological Exploration of Freshwaters, 17(4), 289-398.

LIMA, M. M., MUJICA, P. I. C., & LIMA, A. M. (2012). Caracterização química e avaliação do rendimento em filés de caranha (Piaractus mesopotamicus). Brazilian Journal of Food Technology, IV, 41-46. DOI: http://dx.doi.org/10.1590/S1981-67232012005000031

MACHADO, T. M., CATAPRETA, L. C., FURLAN, E. F., & NEIVA, C. R. P. (2020). Economia circular e resíduo de pescado. Revista Brasileira de Ciências Ambientais, 55(4), 525-535. DOI: https://doi.org/10.5327/Z2176-947820200677

MOREIRA, H. L. M., VARGAS, L., RIBEIRO, R. P., & ZIMMERMANN, S. (2001). Fundamentos da moderna aqüicultura. Canoas: Ulbra, 200p.

PAULA, D. P., MORAIS, J. O., & PINHEIRO, L. S. (2006). Análise geoambiental do estuário do Rio Jaguaribe-CE: tensores naturais e antrópicos, UECE.

SANTOS, N. M., & OLIVEIRA-FILHO, P. R. C. (2025). Rendimento corporal do bagre marinho Sciades herzbergii submetido a dois métodos de filetagem. Revista brasileira de Engenharia de Pesca, 16(1), 12-21. DOI: https://doi.org/10.18817/repesca.v16i1.1621

SANTOS, S. M., RODRIGUES, J. A. G., DAMIÃO, R. P., SALMITO-VANDERLEY, C. S. B., & ARAÚJO, I. W. F. (2026). Morphometric characteristics and body yield of Prochilodus brevis (Steindachner, 1875) analyzed by sex. Revista Brasileira de Engenharia de Pesca, 17(1), 367-385, 2026. DOI: https://doi.org/10.18817/repesca.v17i1.4644

SARKAR, S. I., KHAN, M., HASAN, M. M., ISLAM, A. A., PAUL, S. K., HOSSAIN, S., GOLAM RASUL, G., & KAMAL (2023). Exploring fish in a new way: a review on non-food industrial applications of fish. Heliyon, 9, e22673. DOI: https://doi.org/10.1016/j.heliyon.2023.e22673

SASTRAPRAWIRA, S. M., RAZAKB, I. H. A., SHAHIMIA, S., PATIA, S., EDINURD, H. A., JOHNF, A. B., AHMADB, A., KUMARANG, J. V., MARTINB, M. B., CHONGB, J. L., CHOWDHURYH, A. J. K., & NELSONA, B. R. (2020). A review on introduced Cichla spp. and emerging concerns. Heliyon, 6, e05370. DOI: https://doi.org/10.1016/j.heliyon.2020.e05370

SILVA, A. R., COSTA, J. F., CASTRO, J. S., BITU, L. A., MENEZES, M. L. A., RODRIGUES, J. A. G., SILVA, L. M. R., FARIAS, A. C. S., ANDRADE, A. P. C., & ARAÚJO, I. W. F. Elaboração, composição centesimal e estabilidade oxidativa de almôndegas de carne de tilápia separada mecanicamente adicionada de extrato de alho. Nutrivisa Revista de Nutrição e Vigilância em Saúde, 12(1), e15710, 2025. DOI: https://doi.org/10.52521/nutrivisa.v12i1.15710

SOUZA, A. F. L., & INHAMUNS, A. J. (2011). Análise de rendimento cárneo das principais espécies de peixes comercializadas no Estado do Amazonas, Brasil. Acta Amazonica, 41(2), 289-296. DOI: https://doi.org/10.1590/S0044-59672011000200015

WILLIS, S. C., MACRANDER, J., FARIAS, I. P., & ORTÍ, G. (2012). Simultaneous delimitation of species and quantification of interspecific hybridization in Amazonian peacock

cichlids (genus Cichla) using multi-locus data. BMC Evolutionary Biology, 12:96, 2-14.
DOI: https://doi.org/10.1186/1471-2148-12-96