

Processing yields and chemical composition of fillets from fish fed organic and commercial diets in a polyculture system¹

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ABSTRACT - The aim of this study was to evaluate the processing yields and the chemical composition of fillets from fish reared in a polyculture system, fed organic artisanal diet and conventional commercial diet for 12 months. A total of 168 fish from seven different species, silver catfish (*Rhamdia quelen*), common carp (*Cyprinus carpio*), armored catfish (*Pterygoplichthys joselimaianus*), curimba (*Prochilodus lineatus*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*) and grass carp (*Ctenopharyngodon idella*), were randomly collected at the end of the cultivation period to calculate percentage yields in relation to the whole fish. The following yields were obtained: eviscerated whole fish yield, eviscerated whole fish yield without head, fins, and skin, and fillet yield. Only for silver catfish, abdominal muscle yield and edible parts yield were calculated. Additionally, the percentages of residue (stripped carcass, skin and visceral fat), gonadosomatic index, and hepatosomatic index of the fish were determined. The analysis of the centesimal composition of the fillet was performed for all species. The data obtained were analyzed using Student's T-test ($P < 0.05$). The type of diet did not influence ($P > 0.05$) the yields of most of evaluated cuts. The commercial feed treatment resulted in higher skin yield in curimba and higher hepatosomatic index in silver catfish ($P < 0.05$). The diets did not influence ($P > 0.05$) the centesimal composition of the fillet in any of the evaluated species. These results suggest that organic feed can be used in fish farming without compromising the production process.

Keywords: Sustainable aquaculture. Organic feed. Centesimal composition. Carcass yield.

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INTRODUCTION

Aquaculture is an activity that has been continuously expanding worldwide and currently surpasses global capture fisheries, accounting for the majority of animal protein production derived from aquatic organisms (FAO, 2024). Among the segments encompassed by aquaculture, fish farming stands out as a prominent activity with significant growth potential in Brazil, mainly due to water availability, favorable climate, and the production sector's ongoing pursuit of improved management practices and production technologies (Siqueira *et al.*, 2021).

In Brazilian territory, extensive and subsistence family-based fish farming is widely practiced, contributing to food and nutritional security. Organic fish farming, developed within family farming systems, promotes productive integration through the efficient use and combination of available resources on a small scale and may represent an additional source of income for rural family properties (Borba *et al.*, 2014; Rossignol *et al.*, 2024).

Organic aquaculture in Brazil is regulated by Interministerial Normative Instruction MAPA/MPA No. 28, of June 8, 2011, which establishes technical standards and general requirements addressing environmental, economic, social, and animal welfare aspects, among other criteria, for organic aquaculture production systems (Brasil, 2011). Among the recommendations set forth by IN 28 is the rearing of fish in systems that promote synergistic interactions among species, optimizing nutrient use, as observed in polyculture systems. It is also stipulated that animals raised in organic aquaculture systems must receive precise nutrition derived from high-quality organic sources, and the use of synthetic additives and pigments, as well as genetically modified feed and its derivatives, is not permitted (Brasil, 2011).

This is a highly relevant issue that represents a limitation for the development of organic fish farming in the country, considering that, to date, there is no commercially available organic aquaculture feed on the national market. In this context, there is a clear need for research aimed at evaluating organic feedstuffs and formulations that maximize growth without impairing yield indices and body composition of fish (Remor, Muelbert, and Borba, 2020).

Carcass yield and chemical composition of fish are directly influenced by diet composition and feeding management practices (Santos *et al.*, 2022). Studies on the body composition and yield of farmed fish, especially when addressing species not traditionally cultivated, are of great importance from both economic and production perspectives (Goes *et al.*, 2015). In this regard, the present study aimed to evaluate body yield and the chemical composition of fillets from fish reared in a polyculture system, fed an organic artisanal diet and a conventional commercial diet.

MATERIAL AND METHODS

Fish and experimental conditions

The present study was conducted at the facilities of the Aquatic Organisms Nutrition Laboratory of the Universidade Federal da Fronteira Sul, Laranjeiras do Sul campus, Paraná, Brazil. Processing yields and proximate composition of fillets were evaluated in 168 specimens from seven different freshwater fish species: silver catfish (*Rhamdia quelen*), common carp (*Cyprinus carpio*), armored catfish (*Pterygoplichthys joselimaianus*), curimba (*Prochilodus lineatus*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), and grass carp (*Ctenopharyngodon idella*). The fish were obtained from a polyculture system in earthen ponds, with a stocking density of 1.5 fish per m², where they were subjected to two dietary treatments, pelleted organic artisanal diet (ORG) and extruded conventional commercial diet (COM), for 12 months, using a randomized complete block design with four replicates. The crude protein (CP) content and particle size of the diets were the same for both Organic and Commercial treatments, with adjustments throughout the culture period to follow the growth of the two main species (*R. quelen* and *C. carpio*). Initially, the fish were fed powdered diets containing 40% CP; subsequently, they were transitioned to 3 mm particles containing 36% CP and, finally, to 5 mm particles containing 32% CP. The commercial diets were purchased from local suppliers, whereas the organic diets were prepared using fish meal, a mineral and vitamin premix, and certified organic ingredients (Gebana Brasil, Campo Largo, Paraná, Brazil). Performance data and other analyzed variables, as well as additional information regarding the culture system, can be found in Muelbert *et al.* (2020).

Processing yield analysis

At the end of the 12-month rearing period, three specimens of each fish species were collected per replicate from both dietary treatments (ORG and COM) (n = 12), euthanized by overdose with clove oil anesthetic (Eugenol[®], 400 mg L⁻¹), and stored at -20 °C until analyses were performed. The experimental procedure was approved by the Ethics Committee on the Use of Animals (CEUA-UFFS) of the Federal University of Southern Frontier, under protocol no. 23205.004905/2016-23.

For each species, the following measurements were obtained: whole fish weight (WFW), eviscerated whole fish weight (EWWF), eviscerated fish weight without head and fins (EWF-HF), fillet weight (FW), stripped carcass weight (SCW), skin weight (SKW), viscera weight (VW), gonad weight (GW), and liver weight (LW). EWWF was obtained by ventral opening of the abdominal cavity, from the urogenital opening to the mandibular bones, followed

by careful removal of the viscera. From the eviscerated whole fish, the head and fins were removed to determine EWF-HF, followed by skin removal (SKW) and fillet extraction (FW) by cutting from the dorsal region, laterally to the fin, extending from the cranial region to the caudal extremity (Carneiro *et al.*, 2004).

Based on the initial whole fish weight and the processed cuts, the following were determined: eviscerated whole fish yield (EWFY %), eviscerated whole fish yield without head, fins, and skin (EWFY-HFS %), and fillet yield (FY %). Additionally, only for silver catfish, abdominal muscle yield (AMY %) and edible parts yield (EPY % = FY + AMY) were calculated. The percentage of residues was also determined, considering stripped carcass (SCY %), skin (SKY %), as well as the gonadosomatic index (GSI % = (gonad weight/body weight) × 100), hepatosomatic index (HSI % = (liver weight/body weight) × 100), and visceral fat percentage (VF % = (visceral fat weight/body weight) × 100).

Proximate composition analysis of the fillet

Fillets obtained from three fish sampled from each species per replicate of the two dietary treatments (12 specimens per species in each treatment; 168 fish in total) were pooled, ground using a meat processor, and homogenized for the determination of proximate composition (moisture, protein, lipid, and ash). Moisture content was determined by drying in an oven at 105 °C until constant weight. Lipid content was determined by ether extraction using the Soxhlet method. Protein content was determined by the micro-Kjeldahl method, using a conversion factor of 6.25 to express total nitrogen as crude protein. Ash content was determined by incineration at 550 °C in a muffle furnace for five hours (AOAC, 2000).

Statistical analysis

Body yield, residue, and fillet proximate composition variables were analyzed using Student's t-test. The assumptions of normality (Shapiro–Wilk) and homogeneity of variances (Levene) were verified prior to the analyses. A significance level of 5% was adopted for all statistical tests.

RESULTS AND DISCUSSION

The final mean weights of the 12 fish sampled per dietary treatment (three specimens per replicate) for each of the seven studied species are presented in Table 1.

Yield of different cuts

The results of the yield analyses of the different cuts from the seven species reared in a polyculture system, fed pelleted organic artisanal diet and extruded conventional commercial diet, are summarized in Table 2.

Regarding the yield of the evaluated cuts, the EWFY-HFS values corroborate those reported in the literature for native species such as curimba (*P. lineatus*) and piavuçu (*Leporinus macrocephalus*), which presented mean clean trunk yields of approximately 61.07% and 58.69%, respectively (Reidel *et al.*, 2004). As the head, fins, and skin are not typically used for consumption, high proportions of these components may lead to reduced meat yield (Reidel *et al.*, 2004). This was clearly observed in bighead carp, as its lower EWFY-HFS compared with the other studied species negatively affected the yield of edible portions such as fillet, supporting the hypothesis of an inversely proportional relationship between head yield and edible parts yield (Contreras-Guzmán, 1994).

Table 1 - Whole fish weight of the specimens sampled for analysis at the end of 12 months of rearing in a polyculture system, fed organic and commercial diets

Species ²	Weight (g) ¹	
	Organic diet	Commercial diet
<i>R. quelen</i>	431.36 ± 92.31	320.6 ± 76.00
<i>C. carpio</i>	659.41 ± 117.06	580.79 ± 220.35
<i>C. idella</i>	544.51 ± 158.47	465.41 ± 260.34
<i>H. nobilis</i>	373.10 ± 142.58	198.67 ± 57.53
<i>H. molitrix</i>	291.78 ± 102.54	188.03 ± 32.91
<i>P. lineatus</i>	245.57 ± 55.25	238.30 ± 66.08
<i>P. joselimaianus</i>	214.68 ± 19.32	118.13 ± 31.28

¹ Mean ± standard deviation of three fish of each species per replicate (n = 12) for both dietary treatments. ² Proportion of each species in the polyculture system and their respective initial weights: silver catfish, *Rhamdia quelen* (30% of individuals; initial weight 0.23 g); common carp, *Cyprinus carpio* (20%; 0.55 g); grass carp, *Ctenopharyngodon idella* (5%; 0.59 g); bighead carp, *Hypophthalmichthys nobilis* (7.5%; 14.57 g); silver carp, *Hypophthalmichthys molitrix* (7.5%; 1.10 g); curimba, *Prochilodus lineatus* (15%; 5.19 g); armored catfish, *Pterygoplichthys joselimaianus* (15%; 1.04 g)

Table 2 - Yield of different cuts^{1,2} of the seven fish species reared for 12 months in a polyculture system, fed organic or commercial diets

Treatment	Species ³	EWFY	EWFY-HFS	FY	AMY	EPY
		%				
Organic diets	<i>R. quelen</i>	83.93 ± 1.2 a	66.63 ± 2.52 a	34.76 ± 1.56 a	11.57 ± 0.4 a	46.33 ± 1.9 a
	<i>C. carpio</i>	85.92 ± 1.0 a	60.49 ± 10.4 a	39.58 ± 0.84 a		
	<i>C. idella</i>	85.34 ± 0.9 a	67.82 ± 1.28 a	39.71 ± 1.64 a		
	<i>H. nobilis</i>	92.68 ± 0.5 a	61.47 ± 0.95 a	33.90 ± 2.51 a		
	<i>H. molitrix</i>	88.43 ± 4.5 a	65.29 ± 1.38a	35.82 ± 1.32 a		
	<i>P. lineatus</i>	84.14 ± 5.7 a	74.01 ± 1.05 a	42.70 ± 1.11 a		
	<i>P. joselimaianus</i>	82.25 ± 2.2 a	52.80 ± 1.46 a	31.80 ± 2.08 a		
Commercial diets	<i>R. quelen</i>	84.08 ± 0.8 a	65.46 ± 4.60 a	33.75 ± 2.10 a	10.72 ± 0.8 a	44.47 ± 2.8 a
	<i>C. carpio</i>	83.21 ± 3.3 a	64.95 ± 0.56 a	38.53 ± 1.94 a		
	<i>C. idella</i>	84.58 ± 2.7 a	66.15 ± 2.70 a	37.78 ± 2.17 a		
	<i>H. nobilis</i>	93.36 ± 1.9 a	58.18 ± 1.96 b	30.92 ± 1.65 a		
	<i>H. molitrix</i>	90.88 ± 1.8 a	64.05 ± 3.38 a	34.11 ± 1.95 a		
	<i>P. lineatus</i>	85.41 ± 2.9 a	71.98 ± 2.84 a	41.06 ± 3.61 a		
	<i>P. joselimaianus</i>	70.21 ± 23.5 a	46.34 ± 16.26 a	26.72 ± 9.82 a		

¹ Eviscerated whole fish yield (EWFY); eviscerated whole fish yield without head, fins, and skin (EWFY-HFS); fillet yield (FY); abdominal muscle yield (AMY); and edible parts yield (EPY). ² Mean ± standard deviation of samples from three fish per replicate (n = 12). Within columns, different superscript letters for the same species indicate significant differences (P < 0.05). ³ Silver catfish, *Rhamdia quelen*; common carp, *Cyprinus carpio*; grass carp, *Ctenopharyngodon idella*; bighead carp, *Hypophthalmichthys nobilis*; silver carp, *Hypophthalmichthys molitrix*; curimba, *Prochilodus lineatus*; armored catfish, *Pterygoplichthys joselimaianus*

With regard to the yields obtained from the cuts of *P. joselimaianus*, since this is a poorly studied species and there is limited information on its biology and cultivation, no data were found in the literature regarding carcass yield for this genus of fish. Armored catfish is commonly appreciated as an ornamental species, especially in the juvenile stage (Munson *et al.*, 2024).

For silver catfish, no significant differences were observed between treatments in the analyses of EWFY, EWFY-HFS, FY, AMY, and EPY, suggesting that the type of diet (organic or commercial) does not influence these parameters. The EWFY and FY results are consistent with those reported by Dias *et al.* (2021), who obtained carcass yield of 84.7% and fillet yield of 44.7% for *R. quelen*, values similar to those found in the present study. In this study, carcass and fillet yields for fish fed the organic diet were 83.93 ± 1.2% and 34.76 ± 1.56%, respectively, whereas for those fed the conventional diet, the values were 84.08 ± 0.8% and 33.75 ± 2.10%, respectively.

Regarding EWFY-HFS values, yields of 66.63 ± 2.52% were obtained for the organic diet treatment and 65.45 ± 4.6% for the commercial diet, both higher than those reported by Carneiro *et al.* (2004) (56.06 to 58.45%) for *R. quelen* within a similar weight range to that of the present study, between 400 and 500 g.

These comparatively higher results may be associated with improvements in processing techniques and the composition of the diets used, suggesting that the adoption of balanced feeds contributes to greater utilization of the edible portion. This evidence reinforces the importance of considering not only fillet yield but also the overall utilization of the carcass as an indicator of production efficiency.

In the processing of silver catfish, in addition to the fillet, the abdominal muscle, popularly known as “barriguinha” (literally “little belly”), is also removed. This product is marketed by the industry as a snack and shows good market acceptance (Goes *et al.*, 2015). In the present study, abdominal muscle yield (AMY) values of 11.57 ± 0.45% and 10.72 ± 0.82% were found for the organic and commercial diet treatments, respectively, with no significant differences observed. These percentages are very close to those reported for *R. quelen* in a study by Carneiro *et al.* (2004), in which AMY ranged from 9.34 to 11.22%. In contrast, a study conducted with *R. voulezi* in size classes between 100 and 400 g reported lower abdominal muscle yields, ranging from 5.02 to 5.59% (Goes *et al.*, 2015). In other siluriform species, such as the marine catfish *Sciades herzbergii* and the native species *Pimelodus britskii*, abdominal muscle is also separated, with AMY values of 7.0% and 7.28%, respectively, both

lower than those obtained in the present study for silver catfish (Almeida *et al.*, 2018; Vasconcelos-Filho *et al.*, 2017). However, this product has lower commercial value than fillet, and its proportion in the carcass yield may inversely influence fillet yield (Carneiro *et al.*, 2004).

Regarding the carps, with the exception of bighead carp, all other species showed very similar yield indices. For common carp, Corrêa *et al.* (2009) reported EWFY values ranging from 83.21 to 86.15%, which are very close to those observed in the present study for the same species ($83.21 \pm 3.31\%$ to $85.92 \pm 1.07\%$). For grass carp, EWFY values ranged from $84.58 \pm 2.74\%$ to $85.34 \pm 0.91\%$, also very similar to those reported by Veiverberg *et al.* (2010), who found carcass yields between 81.2 and 83.7% for this species. For silver carp and bighead carp, no carcass yield data were found in the literature surveyed.

Fillet is considered the most widely marketed type of cut and therefore has an advantage in terms of consumer acceptance (Goes *et al.*, 2015). Native species generally show higher fillet yields compared to the main exotic species currently commercialized in the country, Nile tilapia (*Oreochromis niloticus*), whose fillet yield ranges from 33 to 38% (Reis *et al.*, 2023). For several native species, fillet yield percentages are even higher, as observed in curimba, ranging from 40 to 46% (Machado; Foresti, 2009); trahira (*Hoplias malabaricus*), with ~44%

(Santos *et al.*, 2001); piraicanjuba (*Brycon orbignyanus*), with ~40% (Santamaria; Antunes, 1999); and tambaqui (*Colossoma macropomum*), with values ranging from 35.40 to 36.61% and from 42.96 to 44.21% for skinless and skin-on fillet yields, respectively (Garcia; Maciel, 2021). In contrast, for pintado (*Pseudoplatystoma corruscans*) and *R. quelen*, fillet yield percentages are slightly lower, ranging from 33 to 35% and 29 to 35%, respectively (Frasca-Scorvo *et al.*, 2008), as well as for *R. voulezi*, which ranges from 25.09 to 29.36% in fish weighing between 100 and 400 g (Goes *et al.*, 2015). In the present study, curimba showed the highest fillet yield values, ranging from $41.06 \pm 3.61\%$ to $42.7 \pm 1.11\%$ for the organic and commercial feed treatments, respectively, with no significant differences between them ($P > 0.05$). However, this species has Y-shaped intramuscular bones, which reduces its acceptance by consumers (Pretto *et al.*, 2017).

Residue yield

The results of the residue yield analyses for the fish species fed pelleted organic artisanal diet and extruded conventional commercial diet are presented in Table 3.

No differences ($P > 0.05$) were observed between treatments for stripped carcass yield (SCY) in any of the evaluated species. The values obtained (9.95 – 10.28%) were lower than those reported by Carneiro *et al.* (2004),

Table 3 - Residue yield^{1,2} of the seven fish species reared for 12 months in a polyculture system, fed organic or commercial diets

Treatment	Species ³	SCY	VCY	VF	SKY	HSI	GSI
		%					
Organic diets	<i>R. quelen</i>	9.95 ± 0.46 a	15.60 ± 1.58 a	7.00 ± 2.10 a	4.95 ± 0.20 a	0.98 ± 0.17 b	4.60 ± 3.15 a
	<i>C. carpio</i>	15.92 ± 5.70 a	13.39 ± 1.47 a	3.82 ± 2.97 a	6.99 ± 0.56 a	1.08 ± 0.19 a	-
	<i>C. idella</i>	13.33 ± 0.34 a	15.05 ± 1.40 a	6.70 ± 2.00 a	8.13 ± 0.39 a	1.35 ± 0.31 a	-
	<i>H. nobilis</i>	13.32 ± 1.10 a	4.53 ± 1.18 a	-	6.44 ± 0.46 a	-	-
	<i>H. molitrix</i>	13.03 ± 1.09 a	6.54 ± 2.20 a	-	6.92 ± 0.69 a	-	-
	<i>P. lineatus</i>	16.59 ± 1.44 a	12.87 ± 2.12 a	1.73 ± 0.68 a	8.96 ± 0.19 b	1.04 ± 0.26 a	-
	<i>P. joselimaianus</i>	-	15.46 ± 3.52 a	-	17.21 ± 2.84 a	-	-
Commercial diets	<i>R. quelen</i>	10.28 ± 0.58 a	15.36 ± 1.13 a	4.76 ± 1.27 a	5.49 ± 0.46 a	1.57 ± 0.40 a	4.96 ± 1.26 a
	<i>C. carpio</i>	13.61 ± 1.35 a	13.77 ± 1.59 a	3.48 ± 1.79 a	7.60 ± 0.63 a	1.15 ± 0.20 a	-
	<i>C. idella</i>	12.75 ± 0.65 a	14.68 ± 3.26 a	6.55 ± 3.65 a	7.99 ± 0.45 a	1.02 ± 0.40 a	-
	<i>H. nobilis</i>	13.58 ± 0.82 a	4.61 ± 2.82 a	-	5.89 ± 0.48 a	-	-
	<i>H. molitrix</i>	12.97 ± 1.37 a	6.56 ± 2.02 a	-	6.65 ± 0.80 a	-	-
	<i>P. lineatus</i>	15.59 ± 0.50 a	13.88 ± 2.95 a	2.05 ± 1.09 a	10.04 ± 0.60 a	1.31 ± 0.31 a	-
	<i>P. joselimaianus</i>	-	13.52 ± 5.53 a	-	14.19 ± 3.95 a	-	-

¹ Stripped carcass yield (SCY); viscera yield (VCY); visceral fat yield (VF); skin yield (SKY); hepatosomatic index (HSI); gonadosomatic index (GSI). ² Mean ± standard deviation of samples from three fish per replicate (n = 12). Within columns, different superscript letters for the same species indicate significant differences ($P < 0.05$). ³ Silver catfish, *Rhamdia quelen*; common carp, *Cyprinus carpio*; grass carp, *Ctenopharyngodon idella*; bighead carp, *Hypophthalmichthys nobilis*; silver carp, *Hypophthalmichthys molitrix*; curimba, *Prochilodus lineatus*; armored catfish, *Pterygoplichthys joselimaianus*

who observed SCY of 14.88% for silver catfish under similar weight conditions. This discrepancy may be related to methodological differences in processing, such as criteria for skin and bone removal, or to variations in body composition influenced by diet and management practices. Studies also indicate that sex, in addition to slaughter weight, may significantly affect processing yields in silver catfish (Goes *et al.*, 2015). In this context, the results of the present study reinforce the need for standardization of processing methods and evaluation of body composition, in order to enable more consistent comparisons among different production systems.

Regarding viscera yield (VCY), Carneiro *et al.* (2004) reported lower percentages than those obtained in the present study, with an inversely proportional relationship between SCY and VCY observed in both studies. Echevengua *et al.* (2008) found VCY values ranging from 13.46 to 18.10% in Hungarian carp, which are very close to those observed in the present study for common carp, with values of 15.92% for fish fed organic diet and 13.61% for those fed commercial diet.

Regarding the gonadosomatic index (GSI), only silver catfish presented developed gonads suitable for reproduction, as this species reaches sexual maturity at around one year of age in both sexes (Montanha *et al.*, 2011). However, no difference ($P > 0.05$) was observed for this variable between treatments, with GSI values of $4.60 \pm 3.15\%$ for fish fed organic diet and $4.96 \pm 1.26\%$ for those fed commercial diet.

Fat can be deposited in different locations in fish, including visceral, intramuscular, and subcutaneous sites (Weil; Lefevre; Bugeon, 2013). Excess nutrient intake may lead to dietary imbalance, resulting in undesirable lipid deposition in the viscera and muscle tissue, since increasing lean mass (protein) is the primary goal in fish finishing systems (Quirino *et al.*, 2024). In the present study, no significant differences were observed between treatments for visceral fat yield (VF) in any of the evaluated species. However, some species (bighead carp, silver carp, and armored catfish) did not deposit visceral fat and showed low lipid content in their fillets. Studies by Alahmad *et al.* (2021) and Gabriela, Daniel, and Mircea (2019) corroborate these findings, reporting low body fat levels in *H. nobilis* (1.07%) and *H. molitrix* (1.65%). Considering that excess fat may reduce meat quality due to rancidity caused by fatty acid oxidation during storage (Geraldo *et al.*, 2021), these species appear to have advantages over others regarding shelf life. On the other hand, based on Table 3, the low fat deposition may be associated with the lower final weight observed in these species under both dietary treatments (Muelbert *et al.*, 2020).

The hepatosomatic index (HSI) represents the percentage of liver mass in relation to body weight and is used as an indicator of energy reserves in the liver (Sharma; Ram, 2020). Amino acids not used for protein

synthesis may be deaminated and converted into lipids (lipogenesis) or glycogen (gluconeogenesis), which are then deposited in the liver, increasing HSI values (Peres; Oliva-Teles, 2008). Changes in endogenous reserves can be assessed through HSI and VF, which reflect the energy balance in fish (Jobling *et al.*, 2001). In the present study, the only species that showed a significant difference in HSI was silver catfish, with values of 0.98 ± 0.17 for fish fed organic diets and 1.57 ± 0.40 for those fed commercial feed. Due to liver damage caused by the freezing and thawing process in bighead carp, silver carp, and armored catfish, it was not possible to calculate HSI for these species, which is why these data are not presented in Table 5.

According to Contreras-Guzmán (1994), skin represents, on average, 7.5% of fish body weight. Regarding skin yield (SKY) in the present study, most species showed values close to those reported by this author. Only curimba exhibited a significant difference ($P < 0.05$) between dietary treatments, with SKY values of $8.96 \pm 0.19\%$ for fish fed organic diet and $10.04 \pm 0.60\%$ for those fed commercial diet.

Proximate composition of the fillet

The results of the proximate composition analyses of fillets from the seven fish species reared in a polyculture system, fed organic and commercial diets, are presented in Table 4.

Although the composition of fish is well established in terms of its predominant constituents, the proportion among them is variable (Ahmed *et al.*, 2022). The organoleptic and nutritional characteristics depend on the chemical composition of the fish, which in turn may be affected by factors such as genetics, sex, spawning type and season, environmental conditions, and diet (Tachibana; Leonardo; Baccarin, 2013). In the present study, however, proximate composition analysis showed that the type of diet (organic or conventional commercial) did not influence the chemical composition of the fillet (Table 6). This result is supported by studies on other fish species, such as European seabass (*Dicentrarchus labrax*) (Trocino *et al.*, 2012), silver catfish (*R. voulezi*), Nile tilapia, and pacu (Boscolo *et al.*, 2013), in which fish fed organic or conventional diets also did not differ in terms of fillet moisture, protein, lipid, and ash contents.

In the present study, an inverse relationship was observed between moisture and lipid percentages among the different species (Table 4), a pattern widely reported in numerous studies conducted with fish under different feeding, growth, and reproductive conditions (Ahmed *et al.*, 2022). The determination of these variables is important, as they directly influence food preservation time (shelf life), particularly because fish contain high levels of unsaturated fatty acids, which may accelerate rancidity and product deterioration (Ahmed *et al.*, 2022).

Table 4 - Proximate composition of the fillet1 of the seven fish species reared for 12 months in a polyculture system, fed organic or commercial diets

Treatment	Species ²	Moisture	Protein	Lipids	Ash
		%			
Organic diets	<i>R. quelen</i>	73.22 ± 1.88	17.95 ± 1.01	10.22 ± 0.49	1.07 ± 0.02
	<i>C. carpio</i>	73.57 ± 2.36	17.41 ± 1.43	8.98 ± 0.11	1.03 ± 0.08
	<i>C. idella</i>	77.34 ± 1.12	17.43 ± 0.62	5.97 ± 0.13	0.94 ± 0.04
	<i>H. nobilis</i>	80.43 ± 1.56	17.68 ± 1.02	1.62 ± 0.11	1.12 ± 0.04
	<i>H. molitrix</i>	80.17 ± 0.66	16.62 ± 1.02	1.82 ± 0.13	1.10 ± 0.02
	<i>P. lineatus</i>	76.07 ± 0.71	19.23 ± 1.06	3.27 ± 0.12	1.16 ± 0.03
	<i>P. joselimaianus</i>	80.75 ± 0.84	17.28 ± 0.67	1.34 ± 0.03	0.99 ± 0.05
Commercial diets	<i>R. quelen</i>	73.80 ± 2.89	18.10 ± 1.32	8.18 ± 0.28	1.06 ± 0.04
	<i>C. carpio</i>	74.93 ± 1.43	18.51 ± 1.56	7.91 ± 0.19	0.93 ± 0.05
	<i>C. idella</i>	77.84 ± 2.06	16.69 ± 1.61	5.50 ± 0.08	0.94 ± 0.02
	<i>H. nobilis</i>	81.87 ± 1.14	17.57 ± 0.92	1.36 ± 0.10	1.07 ± 0.03
	<i>H. molitrix</i>	80.78 ± 0.71	16.68 ± 0.48	3.24 ± 0.17	1.07 ± 0.02
	<i>P. lineatus</i>	76.95 ± 1.51	19.16 ± 0.81	3.06 ± 0.18	1.11 ± 0.07
	<i>P. joselimaianus</i>	80.28 ± 1.06	17.67 ± 1.20	1.01 ± 0.06	1.09 ± 0.04

¹ Mean ± standard deviation of pooled fillet samples from three fish per replicate (n = 12). No significant differences were observed between treatments ($P > 0.05$). ² Silver catfish, *Rhamdia quelen*; common carp, *Cyprinus carpio*; grass carp, *Ctenopharyngodon idella*; bighead carp, *Hypophthalmichthys nobilis*; silver carp, *Hypophthalmichthys molitrix*; curimba, *Prochilodus lineatus*; armored catfish, *Pterygoplichthys joselimaianus*

The lipid and protein contents of the fillets from the secondary species in the polyculture system (grass carp, bighead carp, silver carp, curimba, and armored catfish) observed in the present study (Table 4) classify them within category A, comprising fish with low fat content (< 5%) and high protein content (15 – 20%) (Stansby, 1962). Among the secondary species, only grass carp showed a fat content slightly above this classification range. In contrast, silver catfish and common carp, the main species in the culture system, which directly benefited from the supplied feed, exhibited higher fillet lipid contents than the secondary species, reaching $10.22 \pm 0.49\%$ and $8.98 \pm 0.11\%$, respectively, under the organic diet treatment, and $8.18 \pm 0.28\%$ and $7.91 \pm 0.19\%$ under the commercial feed treatment.

The diets provided to fish influence their chemical composition, particularly lipid content and even fatty acid profiles (Xu *et al.*, 2020). Although secondary species may have occasionally consumed some of the feed distributed in the ponds, their primary food source was likely natural feed, which generally contains lower levels of gross energy and lipids compared to artificial aquaculture diets. Similar results for silver catfish, and slightly higher values for common carp, were reported by Corrêa *et al.* (2009), who, when evaluating biculture of silver catfish and Hungarian carp, found lipid contents of 10.27% and 10.68%, respectively.

Regarding crude protein (CP) content in the fillets of the seven evaluated species, the highest percentage was observed in curimba under both dietary treatments. Values very close to those found in the present study have been reported in other studies involving fish of the genus *Prochilodus* sp. from both natural environments (rivers) and aquaculture systems (Contreras-Guzmán, 1994; Machado; Foresti, 2009). Fish of the genus *Prochilodus* are iliophagous, meaning they feed on bottom sediments from lakes, rivers, or ponds, which consist of algae (especially diatoms), plant detritus, and sand particles (Godoy, 1975).

In the present study, protein contents for curimba were $19.23 \pm 1.06\%$ and $19.16 \pm 0.81\%$ under organic and commercial diets, respectively. Regarding lipid content, this species is classified as low-fat (< 5%), with values of $3.27 \pm 0.12\%$ for the organic diet treatment and $3.06 \pm 0.18\%$ for the commercial diet treatment.

Ash is the residue obtained after complete incineration of the organic matter in the analyzed sample. Fish generally present total mineral content in muscle (wet basis) ranging from 0.6% to 1.5% of total body weight (Ahmed *et al.*, 2022). In the present study, ash content in the fillets of the seven evaluated fish species ranged from 0.93% to 1.16%, with no significant differences ($P > 0.05$) between treatments.

Organic aquaculture is a rapidly expanding sector worldwide, based on sustainability, animal welfare, and the reduction of environmental impact. Organic production involves the integration of traditional methods, modern technology, and scientific knowledge to protect the environment, promote fair and equitable relationships, and improve quality of life (Tefal *et al.*, 2023).

Brazilian agriculture is characterized by the predominance of small-scale producers, especially in the Southern region, where family farming plays a central role in the rural economy (Trentin, 2023) and accounts for the largest number of organic producers in the country (Finatto; Eduardo; Konrad, 2024; Lucion, 2025). National regulations for organic aquaculture production establish that aquatic organisms must be fed organic feed originating from the production unit itself or from another certified organic production system (Brasil, 2011). In this context, organic fish farming represents an activity with high development potential in Brazil, considering that fish production integrated with agroecological and organic systems is advantageous, enabling value addition to products and diversification of income sources within family farming (Rossignol *et al.*, 2024).

In fish farming, nutrition and feeding are key factors. Research focused on the development and evaluation of organic aquaculture diets, aiming to improve the competitiveness of organic fish farming, is crucial for the growth of the sector (Gambelli *et al.*, 2019). The diversity of production and processing methods for organic feed may lead to variations in composition and biological value compared to conventional feeds (Boscolo *et al.*, 2012). Therefore, optimizing organic diet formulations may be necessary to improve and maximize efficiency (Tefal *et al.*, 2023).

According to Boscolo *et al.* (2012), the proper formulation of organic diets allows their use as a substitute for conventional diets without impairing productive performance, yield, or proximate composition of fish. This finding is supported by Muelbert *et al.* (2020), who observed superior zootechnical performance in fish reared in polyculture systems fed organic diets compared to those fed commercial diets. The present study is consistent with these findings, demonstrating that processing yields for most species in the polyculture system and fillet chemical composition were not influenced by dietary treatment.

CONCLUSION

The type of diet used (organic artisanal or conventional commercial) did not significantly influence the yield of most evaluated cuts, with the exception of eviscerated whole fish yield without head, fins, and skin in bighead carp, which was higher in fish

fed organic diet. Regarding residues, the commercial diet treatment resulted in higher skin yield in curimba and a higher hepatosomatic index in silver catfish. The diets did not influence the proximate composition of the fillets in any of the evaluated species. These results suggest that organic feed can be used in fish farming without compromising the production process, indicating that fish rearing in organic systems represents an activity with high development potential in Brazil.

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DATA AVAILABILITY STATEMENT

The research data are available upon request to the corresponding author.

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