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RESEARCH ARTICLE

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Sensory and instrumental textural changes in fillets from Pacú (*Piaractus mesopotamicus*) fed different diets

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Abstract

The influence of two dietary treatments on quality properties, like textural parameters, sensory profile, and nutritional composition of Pacú fillets (*Piaractus mesopotamicus*) were studied. Pacú were fed diets based on plant-meals containing 13 g 100 g^{-1} fish meal (FMD) or bovine plasma protein concentrate (BPPD) as a complete replacement of fish meal. Harvested fish were filleted, kept frozen at −20C for 7 days before analysis. Chemical composition, amino acid and fatty acid profiles, and CIE-Lab parameters of fillets were measured. Sensory characteristics and texture profile analysis (TPA) were conducted for cooked portions. Average values of TPA hardness, chewiness, and deformability modulus were higher in BPPD samples but there was no significant difference in cohesiveness between samples. In accordance with TPA, higher values of firmness and chewiness as well as less flaky muscle were detected in BPPD samples by sensory panel. However, there was no significant difference in the characteristics associated with higher freshness between samples. Total color difference was lower in BPPD samples. Differences in protein, lipid, ash, and moisture content of FMD or BPPD fillets were not found (p > .05). BPPD fillets showed higher basic and sulfur amino acids. Saturated and polyunsaturated fatty acid contents were higher in FMD fillets than BPPD. However, a significantly higher $n-6/n-3$ ratio for FMD fillets was observed. The higher values of textural parameters observed for BPPD cooked fillets and the lower $n-6/n-3$ ratio imply a better sensory and nutritional quality of fillets from fish fed with BPPD.

Practical applications

A complete study is presented on how the source of protein and lipids in feed affect both the sensory profile and the nutritional composition of fillets of Pacú (omnivorous temperate freshwater fish) cultivated in the second stage of fattening. Instrumental texture analysis of the fillets is presented, identifying the indicators that match with sensorial analysis. This analysis can help the industry of aquaculture in the evaluation of new ingredients or diets for fish feeding with impact in the quality of fillets.

KEYWORDS

fish feed, Pacú fillets, sensory properties, texture profile analysis

1 | INTRODUCTION

Due to consumers' recognition of the health effects of fish consumption, the demand for fish has been steadily increasing. Flesh quality, like appearance, taste, texture, odor, and nutritional composition, is important to consumer acceptance (Másílko, Zajíc, & Hlavác, 2015).

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Piaractus mesopotamicus (Pacú) is one of the most frequently reared tropical-climate fish species in Brazil and Argentina (Cian, Bacchetta, Cazenave, & Drago, 2017). In general, it is reared in ponds under intensive system in monoculture or under semi-intensive system in polyculture together with other omnivorous species (Abimorad, Favero, Castellani, Garcia, & Carneiro, 2009). It is a fast-growing warm water fish, with excellent meat taste and consumer acceptance (Jomori, Carneiro, Malheiros, & Portella, 2003).

Since the price of fish meal and fish oil has risen steadily the aquaculture industry has consider other protein sources that are more economical and sustainable (Davidson, Kenney, Barrows, Good, & Summerfelt, 2018). Alternate proteins derived from soy, corn gluten meal, corn, alcoholic yeast, casein, and plasma protein from animal blood produced during slaughtering can be used in Pacú diets (Abimorad, Squassoni, & Carneiro, 2008; Bicudo, Sado, & Cyrino, 2009; Cian et al., 2017; Gonçalves & Cyrino, 2014).

Most studies show that partial or total replacement of fish meal by other protein sources modified physicochemical composition and quality properties of fish fillet. Joseph et al. (2009) found fishmeal-based diet decreased the redness of sunshine bass (*Morone chrysops, Morone saxatilis*) fillets with respect to fillets from sunshine bass fed with poultry by-product meal diet. Moreover, de Francesco et al. (2007) reported fillet from sea bream fed with fish meal diet had higher moisture content (69.6 versus 68.2 g 100 g^{-1}), lower lipid levels (9.1 versus 10.0 g 100 g^{-1}) with higher levels of *n*–3 polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA), than fillet from fish fed with a plant protein diet. Davidson et al. (2018) found red color of *Atlantic salmon* fillets (+*a** CIELab parameter) from fish fed with fish meal diet was lower than those fed without fish meal diet. These results highlight the importance of assessing fillet quality resulting from feeding newly developed diets.

Conversely, texture is an important element of food quality that affects not only acceptability but also the mechanical processing of fillets. Texture includes a group of physical properties (structural, mechanical, and surface) of the foods perceived through the senses (Szczesniak, 2002). Several factors, like intrinsic structure of fish muscle, properties of the flesh, storage time, pH value, temperature, among others, might have an influence on textural characteristics (Lin, Zeng, Zhu, & Song, 2012; Veland & Torrisen, 1999). In addition, freshness is a multifaceted quality attribute of fish that notably affects the eating quality and further influences consumer acceptability (Cheng, Sun, Han, & Zeng, 2014).

Surprisingly, most of the studies that have evaluated the feasibility of alternate-ingredient formulations for Pacú diets have not thoroughly described the resulting fillet quality attributes. In this context, the aim of this work was to evaluate the effect of fish meal replacement by bovine plasma protein concentrate (BPPD) in plant meal-based diets on instrumental and sensory textural characteristics as well as nutritional composition as important contributors to the quality of Pacú fillets.

2 | MATERIALS AND METHODS

2.1 | Fish production and processing

The experiment was conducted in the Northeast Institute of Ichthyology (INICNE), School of Veterinary Sciences (Corrientes, Argentina). Juvenile Pacú (*Piaractus mesopotamicus*) were obtained from INICNE fish culture facilities from breeders. Fish were placed in 16 m^2 outdoor tanks. At the start of the feeding experiment, 40 Pacú (initial body weight 565.0 ± 13.0 g) were randomly stocked into four tanks with 10 fish per tank (average density of 0.60 individual's m^2 surface). Water parameters (temperature, pH, and dissolved oxygen) were checked daily. They remained stable throughout the acclimation and experimental periods (water temperature: 24.2 ± 0.22C; pH: 7.03 ± 0.02, and dissolved oxygen: 6.68 ± 0.4 mg/L) according to the values recommended by Urbinati, Gonçalves, and Takahashi (2010) for Pacú.

Fish were either fed a diet based on vegetable meals containing 13 g 100 g^{-1} fish meal (FMD) or the same diet containing BPPD as a complete replacement for fish meal. The replacement of fish meal by BPPD produced a decrease in the lipid content of BPPD formulations. For this reason, 3 g 100 g^{-1} of canola oil was added to BPPD to reach the same level of lipids as the FMD. Chemical analysis confirmed diets supplied a similar amount of macronutrients. Composition of formulated diets in dry base was: crude protein: 27.9 ± 0.6 g 100 g^{-1}, fat: 3.7 ± 0.4 g 100 g^{-1}, total starch: 44.0 ± 0.9 g 100 g^{-1}, ash: 4.4 ± 0.1 g 100 g^{-1}, and moisture: 10.1 ± 0.3 g 100 g^{-1}.

Two tanks were allocated for each diet. A ration of 2.5% from body weight was supplied daily throughout the experimental period (85 days). At 3 times points (33, 48, and 63 day), all fish were weighed (± 0.1 g) and measured (standard length ± 0.1 cm) individually to evaluate the growth and adjust the feeding level in each tank. Also, the feed supplied was adjusted weekly considering a simple growth model proposed by Hepher (1993).

At the end of the feeding trial, fish from each diet treatment (final body weight 985.4 ± 136.6 g and 999.2 ± 182.42 g for FMD and BPPD, respectively) were killed through pithing, and filleted immediately. Fillets from each diet were stored at −20C until further analysis.

2.2 | Performance sensory sessions and texture profile analysis of fillets

2.2.1 | Cooking conditions

Sensory analysis was performed on fillet portions of approximately 30 × 10 × 10 mm of thickness. In the case of texture profile analysis (TPA), the fillet portions were 1,000 mm^3. The portions were cooked in a preheated grill for 6 min (4 min on one side and 2 min more on the other side), reaching an internal temperature of 60C. Portions were cooked without seasoning. In all cases, samples were wrapped in aluminum foil after cooking and served to panelists. Portions from the same sample batch were cooked together.

2.2.2 | Sensory analysis

Ten assessors (seven female and three male) from the Instituto de Tecnología de los Alimentos (Universidad Nacional del Litoral, Argentine) were recruited to the sensory panel. They had experience in quantitative descriptive analysis of different food products.

During preliminary training sessions, fillets of *Hoplias malabaricus* ("Tararira"), and Pacú were purchased at the local market. Portions of approximately 1 kg were obtained as fresh catch (1–2 days of freezing) and others after 4–5 months of freezing. Thawing was carried out at 4C for 24 hr and thereafter at 22–23C for 2 hr. Assessors selected the list of descriptors and sample evaluation procedures, specific cooking and serving conditions, and defined the score sheet. Ten centimeters unstructured line scales with different anchor words were used for the analysis. The list of attributes, definitions, and references

TABLE 1 List of descriptors used for sensory analysis of cooked fillets from Pacú

Descriptor	Definition	Anchor points
Odor intensity	The initial total impact of aroma (unwrap the sample and inhale immediately and deeply the odor).	1 = low 9 = high
Fresh odor	The aromatics associated with cooked fresh fish.	1 = low[a] 9 = high
Foreign odor	Atypical odor.	1 = low 9 = high
Color	Attribute of products inducing the color sensation (cut the sample with the help of a fork and observe the color inside the piece).	1 = white 9 = yellowish gray
Flavor intensity	The initial total impact of flavor.	1 = low 9 = high
Fresh flavor	The flavor associated with cooked fresh fish.	1 = low[a] 9 = high
Foreign flavor	Atypical flavor.	1 = low 9 = high
Easy to cut	The easiness of breaking the fish in half with a fork.	1 = it breaks down into multiple pieces when cut. 9 = clean cut (without dispersion of layers).
Firmness	The force required to compress the sample between the molar teeth.	1 = little (soft) 9 = A lot (firm)
Chewiness	Number of chews required to masticate a solid product into a state ready for swallowing.	1 = little 9 = A lot
Juiciness	The total impression of succulence in the mouth just prior to swallowing.	1 = little 9 = A lot
Oily mouth coating	The perceived degree of oil left on the teeth, tongue, and palate after swallowing.	1 = little 9 = A lot

[a]Associated with the "Catch of the day": references as a fish that has not more than 1 or 2 days of freezing after it was catched.

are shown in Table 1. The cooked samples were served in aluminum foil and coded with three digital random numbers. Mineral water and unsalted toasts were served as palate cleanser. A defined protocol was used in which the order of assessment of attributes was established (Carbonell, Izquierdo, & Costell, 2002). A first sample was used to evaluate the intensity of the descriptors for odor, appearance, and taste; a second one, for texture.

During performance sessions, fillets of Pacú fed with FMD or BPPD were used. These samples were kept frozen at −20C for 7 days before sensory analysis. At this time, the pieces were thawed and cooked as describe above. Assessors were placed in individual taste standardized booths, with a room temperature of 24C and cool white light (ISO, 1988). The evaluation was repeated twice and different code numbers were used for each session.

2.2.3 | Texture profile analysis

TPA of cooked fillet pieces of FMD and BPPD (2.2.1) was conducted at the same time of sensory analysis using the procedure described by Bourne (1978). A texture analyzer TA-XT Plus (Stable Micro Systems Ltd., Godalming, UK) equipped with a 5 kg force load cell was used. A double compression cycle was carried out with a rest period of 5 s between the first and second cycles. Optimized test conditions were: 20 mm diameter of cylinder plate of the probe; 2 mm/s test speed; and each piece was compressed 50% transversally in relation to muscle fibbers (Ashton, Michie, & Johnston, 2010). Data collection was accomplished using Texture Exponent 32 software (Stable Microsystems). Compression curves were recorded (force versus time) and texture properties expressed as hardness, cohesiveness, springiness, chewiness, resilience, and deformability modulus according to Ashton et al. (2010). Eight replicates were measured on each sample.

2.3 | Chemical composition of fillets

Crude protein, crude lipid, ash, moisture, and phosphorus contents of fillets from Pacú fed with FMD or BPPD diets were determined following the AOAC (2000) method. Iron, zinc, and calcium contents were measured by atomic absorption spectroscopy after dry mineralization.

2.4 | Amino acid and fatty acid profiles of fillets

Amino acids were determined after derivatization with diethyl ethoxymethylenemalonate by high-performance liquid chromatography (HPLC), according to Alaiz, Navarro, Giron, and Vioque (1992), using D,L-α-aminobutyric acid as an internal standard. The HPLC system consisted of a Perkin Elmer Series 200 pump, with Perkin Elmer 785A UV/vis detector, equipped with a 300 × 3.9 mm i.d. reversed-phase column (Novapack C18, 4 m; Waters).

Fatty acids were determined by gas chromatographic quantification of their methyl esters prepared according to Masson et al. (2015).

2.5 | pH analysis of fillets

The pH of fish fillets was determined according to Strange, Benedict, Smith, and Swift (1977). One gram of sample was dispersed in 5 ml deionized water using a tissue homogenizer (PRO250-Homogenizer, PRO Scientific Inc., Oxford, CT) and the pH of the homogenate was determined with a pH-meter (IQ Scientific Instruments).

2.6 | Instrumental color evaluation

Instrumental color of fillet was measured using a colorimeter (MINOLTA CM-508D), with an angle of observer: 10°, illuminate: D65, and specular component excluded. A CIE-Lab color scale was used to measure the degree of lightness (L^*), redness ($+a^*$) or greenness ($-a^*$), and yellowness ($+b^*$) or blueness ($-b^*$) of fillets. Total color difference ($\Delta E^* = [L^{*2} + a^{*2} + b^{*2}]^{0.5}$) was calculated according to Cian, Caballero, Sabbag, González, and Drago (2014). All determinations were performed in triplicate.

2.7 | Statistical analysis

The mean and standard deviation of each group of data were calculated. One-way ANOVA was applied to chemical composition, amino acid and fatty acid profiles, scores of each attribute, and textural parameters. To determine the significance among the means in each group, post hoc tests (LSD) were carried out using Statgraphics Plus 4.1 software package at 5% level of significance.

3 | RESULTS AND DISCUSSION

3.1 | Sensory analysis, color, and texture profile analysis

Values of sensory descriptors of FMD and BPPD cooked fillets are shown in Figure 1. In general, consumers expect Pacú fillets to be un-pigmented (i.e., white color) and without any strong odor. In this study, the score for odor was significantly higher in FMD samples and color has a tendency to be lower in BPPD samples, but for both treatments the intensities for both descriptors were very low. In agreement, total color difference (ΔE^*) of BPPD fillets was lower than that of FMD fillets (77.5 ± 0.5 versus 81.6 ± 0.6 for BPPD and FMD fillets, respectively). Similarly, de Francesco et al. (2004) found that fillets from rainbow trout fed with a plant protein-based diet had less odor intensity than trout fed with a fish meal-based diet. There were no significant differences in the characteristics associated with high freshness (odor and flavor) between diets. However, a foreign flavor was found in BPPD fillets and it may be the result of slight increase in intensity of initial total impact of flavor. However, the intensities were very low and can be masked by seasoning.

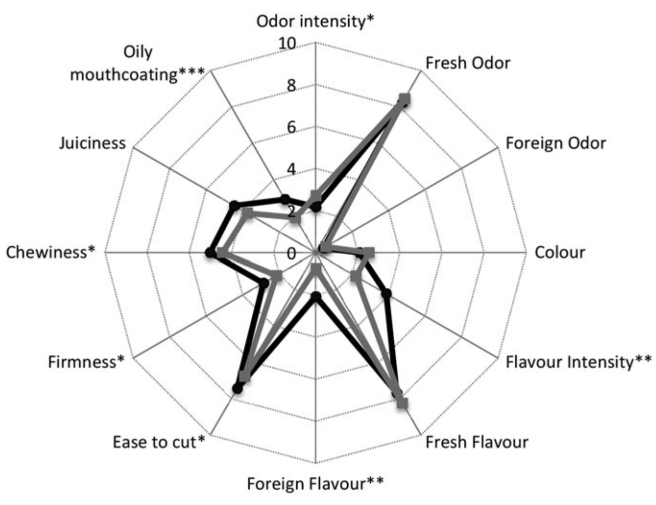

FIGURE 1 Spider diagram of the sensory parameters of cooked fillets from Pacú fed with FMD (gray lines) or BPPD (black lines). Symbols mean significant differences between samples at different p values (*$p < .05$; **$p < .01$; ***$p < .001$)

Appearance, color, freshness, and odor of fillets from cultured fish are of vital importance to consumers, who associated them with quality. Thus it is important that these parameters not be negatively affected by diet formulation.

According to Rasmussen (2001), consumers prefer firm and elastic fish flesh. A significant increase in firmness and less flaky muscle in BPPD cooked fillets was observed, which implied a higher number of chews required to swallowing BPPD samples. These results could be associated with the lower pH of BPPD than FMD fillets (5.99 ± 0.09 versus 6.24 ± 0.06, respectively). Fish fillets with low pH were described as firm, a little tough, while the texture of fillets with a higher pH is softer and very tender (Hyldig & Nielsen, 2001). Conversely, the higher chewiness could induce oily mouth-coating sensations due to the longer time the sample is inside the oral cavity, but did not significantly affect juiciness.

Table 2 shows texture parameters of cooked fillets from Pacú fed with FMD or BPPD. No significant differences in cohesiveness and resilience of FMD and BPPD cooked fillets were observed. However, in accordance with sensory descriptors, instrumental hardness, chewiness, and deformability modulus values were higher in BPPD cooked fillets than those obtained for FMD fillets. Since soft flesh tends to have reduced acceptability by both the consumers and the processing industry (Fuentes et al., 2013), the higher values of textural parameters observed for BPPD cooked fillets implies a better sensory quality when Pacú were fed with diet containing BPPD as a complete replacement for fishmeal.

3.2 | Chemical compositions, amino acid, and fatty acid profiles of fillets

Table 3 shows the chemical composition of fillets from Pacú fed with FMD or BPPD. No difference in the protein, lipid, ash, and moisture contents of fillets from Pacú fed with FMD or BPPD were found ($p > .05$). Moreover, there were not significant differences in calcium, phosphorus, iron, and zinc contents between FMD and BPPD fillets ($p > .05$). Lima, Mujica, and Lima (2012) found for Pacú fillets a protein, lipid, ash, and moisture content of 17.0 ± 0.2, 5.0 ± 0.3, 0.9 ± 0.1, and 76.9 ± 0.8 g 100 g^{-1}, respectively. Ogawa and Maia (1999) reported Pacú fillets can contain 60 to 85 g 100 g^{-1} moisture, approximately 20 g 100 g^{-1} protein, 1 to 2 g 100 g^{-1} ash, and 0.6 to 36 g 100 g^{-1} lipids. These results indicated that fish meal replacement by bovine plasma proteins did not exert any influence on the proximal composition of Pacú fillets, probably due to the same level of proteins and fat in both diets. In agreement, Joseph et al. (2009) found that two diets with different protein sources (30% fish meal or 30% poultry by-product meal), but with the same level of protein and fat, did not alter protein and lipid content of sunshine bass fillets.

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TABLE 2 Texture parameters of cooked fillets from Pacú fed with FMD or BPPD

Fillets	Hardness (*N*)	Chewiness (*N*)	Cohesiveness	Resilience	Deformability modulus (*N*/s)
FMD	4.91 ± 0.64[a]	1.65 ± 0.25[a]	0.46 ± 0.05	0.17 ± 0.02	1.70 ± 0.21[a]
BPPD	9.44 ± 0.82[b]	3.82 ± 0.37[b]	0.44 ± 0.04	0.15 ± 0.02	3.73 ± 0.32[b]

Notes. FMD: plant based diet with fish meal; BPPD: plant based diet with bovine plasma protein concentrate as a complete replacement of fish meal. Different letters mean significant differences between samples ($p < .05$).

TABLE 3 Chemical composition of fillets from Pacú fed with FMD or BPPD

Components	FMD (g 100 g^{-1})	BPPD (g 100 g^{-1})
Crude protein	19.6 ± 1.7	19.1 ± 0.8
Crude lipid	9.5 ± 5.2	13.9 ± 4.2
Ash	1.22 ± 0.25	1.16 ± 0.07
Moisture	71.5 ± 2.8	70.2 ± 2.5
Minerals	**FMD (mg 100 g^{-1})**	**BPPD (mg 100 g^{-1})**
Calcium	16.1 ± 4.7	16.7 ± 3.9
Phosphorous	194.2 ± 24.0	179.7 ± 10.3
Zinc	0.7 ± 0.1	0.7 ± 0.3
Iron	0.4 ± 0.1	0.5 ± 0.1

Notes. Chemical composition expressed as mean ± *SD* (n = 8). There were not differences between samples ($p > .05$). FMD: plant based diet with fish meal; BPPD: plant based diet with bovine plasma protein concentrate as a complete replacement of fish meal.

Table 4 shows the amino acid profile of fillets from Pacú fed with FMD or BPPD. Except for proline, methionine, cysteine, and lysine, there were not significant differences in amino acid profile between FMD and BPPD fillets ($p > .05$). Fillets from Pacú fed with BPPD showed higher levels of methionine, cysteine, and lysine; but lower content of proline than fillets from FMD Pacú ($p < .05$). Methionine, cysteine, and lysine content of fillets from Pacú fed with BPPD were similar to that reported by Bicudo et al. (2009) for juvenile Pacú (2.8, 0.8, and 10.0 g 100 g^{-1} protein, respectively). Moreover, the sum of basic and sulfur amino acids was higher for BPPD fillets than FMD fillets (basic amino acids: 19.5 ± 1.0 versus 24.1 ± 0.5 g 100 g^{-1}; sulfur amino acids: 4.0 ± 0.1 versus 4.7 ± 0.0 g 100 g^{-1} for FMD and BPPD fillets, respectively). Cian et al. (2017) reported that BPPD had higher lysine content than FMD. Moreover, BPPD is an excellent lysine source and may contribute up to 10 g 100 g^{-1} lysine, whereas fish meal may only contribute 2.5 g 100 g^{-1} digestible lysine (Abimorad et al., 2008). Thus, the protein source of the diet modified the amino acid profile. De Francesco et al. (2007) reported amino acid content of fillet from sea bream fed with plant protein or fish meal diet. They found that fillets had higher levels of threonine, glutamic acid, alanine, and leucine. Moreover, the main difference was observed for lysine (about 2 times higher) when these fish were fed with plant protein diet compare to fish meal feed.

Fatty acid profile of fillets from Pacú fed with FMD or BPPD is shown in Table 5. Fillets presented a predominance of unsaturated fatty acids of the C16 and C18 series (C16:1 9c, C18:1 9c, and C18:2 9c 12c). Monounsaturated fatty acid content of BPPD fillets was higher than FMD fillets (49.74 ± 2.09 versus 42.86 ± 3.08 g 100 g^{-1}). Fillets from Pacú fed with FMD showed higher content of saturated (38.07 ± 2.48 versus 33.66 ± 1.35 g 100 g^{-1}) and polyunsaturated fatty acids (15.70 ± 1.20 versus 11.77 ± 0.99 g 100 g^{-1}) than BPPD fillets ($p < .05$). However, n−6 content of FMD fillets was

TABLE 4 Amino acid profile of fillets from Pacú fed with FMD or BPPD

	Total amino acids (g 100 g^{-1} protein)*	
Amino acids	**FMD**	**BPPD**
Asp + Glu	18.25 ± 0.51	19.93 ± 0.34
Ser	4.31 ± 0.09	5.18 ± 0.48
His	3.78 ± 0.12	3.99 ± 0.22
Gly	5.67 ± 0.38	5.72 ± 0.07
Thr	4.27 ± 0.05	4.57 ± 0.44
Arg	6.97 ± 0.02	7.36 ± 0.26
Ala	4.89 ± 0.24	5.59 ± 0.84
Pro	23.94 ± 0.76[b]	13.33 ± 1.2[a]
Tyr	5.16 ± 0.02	5.23 ± 0.31
Val	4.61 ± 0.01	4.95 ± 0.23
Met	2.96 ± 0.01[a]	3.30 ± 0.03[b]
Cys	1.07 ± 0.06[a]	1.35 ± 0.03[b]
Ile	4.53 ± 0.12	4.89 ± 0.24
Leu	9.25 ± 0.34	9.93 ± 0.64
Phe	6.79 ± 0.36	6.73 ± 0.25
Lys	8.72 ± 1.1[a]	12.72 ± 0.58[b]

Notes. Total amino acids content expressed as mean ± *SD* (n = 8). Different letters in a row mean significant differences between samples ($p < .05$). FMD: plant based diet with fish meal; BPPD: plant based diet with bovine plasma protein concentrate as a complete replacement of fish meal.

TABLE 5 Fatty acids profile of fillets from Pacú fed with FMD or BPPD

	Fatty acids (g 100 g^{-1} crude lipid)*	
Fatty acids	**FMD**	**BPPD**
C14:0	2.08 ± 0.13	2.27 ± 0.20
C16:0	25.14 ± 1.89	23.18 ± 1.10
C16:1 9c	4.27 ± 0.49[a]	5.33 ± 0.39[b]
C18:0	10.63 ± 0.45[b]	8.21 ± 0.53[a]
C18:1 9c (oleic acid)	38.59 ± 2.78[a]	44.41 ± 1.78[b]
C18:2 9c 12c (linoleic acid)	11.40 ± 0.41[b]	7.81 ± 0.62[a]
C 18:3 9c 12c 15c (linolenic acid)	0.56 ± 0.06[a]	1.30 ± 0.12[b]
C20:4 n−6 (arachidonic acid)	1.86 ± 0.44	1.74 ± 0.78
C20:5 n−3 (eicosapentaenoic acid)	N.d.	N.d.
C22:5 (docosapentaenoic acid)	0.22 ± 0.04	0.25 ± 0.09
C22:6 (docosahexaenoic acid)	1.70 ± 0.54	1.12 ± 0.52

Notes. Fatty acid content expressed as mean ± *SD* (n = 8). Different letters in a row mean significant differences between samples ($p < .05$). N.d.: not detected. FMD: plant based diet with fish meal; BPPD: plant based diet with bovine plasma protein concentrate as a complete replacement of fish meal.

higher than BPPD fillets and there were not significant differences in fillet n–3 content between diets (p > .05). The average value was 2.5 g 100 g^{-1}. Therefore, a significant increase in n–6/n–3 ratio for FMD fillets was observed (5.7 ± 0.2 versus 3.9 ± 0.6 for FMD and BPPD fillets, respectively). Lipids used in fish diets are primarily derived from fish oils to maintain n–3 fatty acid content, particularly EPA and DHA (Davidson et al., 2018). However, the use of canola oil in the BPPD effectively maintained the n–3 fatty acid levels in BPPD fillets. Thus, BPPD resulted in a balance of fillet fatty acids conducive to human health and nutrition, with a good dietary n–6/n–3 ratio. This ratio is substantially lower than the estimated ratio for the Western diet, which could be as high as 15–17/1 (Simopoulos, 2002).

Possibly, the different amino acid and fatty acid profile can be related with the foreign flavor described by panelists (de Francesco et al., 2004; Johansson, Kiessling, Kiessling, & Berglund, 2000).

4 | CONCLUSION

Total replacement of fish meal by plasma protein concentrate and canola oil did not modify the characteristics associated with high freshness (odor and flavor) of fillets from Pacú. However, the sensory quality of fillets from Pacú consuming the diet without fish meal was improved since less color and more firm, chewy and easy to cut cooked fillet were obtained. Additionally, results of instrumental texture were in accordance with sensory descriptors, which can help the aquaculture industry in searching for new ingredients or diets for fish feeding.

The diet changed the chemical composition and nutritional properties of fish fillet. Amino acid and fatty acid profiles were modified, with higher basic and sulfur amino acids, higher monounsaturated, but lower saturated and n–6/n–3 ratio (at the same level of n–3) than fillets from Pacú fed a fish meal diet. These changes are associated with a better nutritional profile. Thus, changing the fish feed improves nutritional quality of freshwater fish meat. This is very important to take into account since the best combination between textural, sensory, and nutritional characteristics in the final product is what the consumer is looking for at the time of choosing a food.

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ETHICAL STATEMENTS

Conflict of Interest: The authors declare that they do not have any conflict of interest.

Ethical Review: The procedures adopted with the animals in this research were in accordance with the ethical principles of animal experimentation, and approved according to protocol No. 114 0001/14–2011-02827 by the Ethics and Biosafety Committee of School of Veterinary Sciences of the Northeast National University (UNNE) of Argentina.

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