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Flour and fish residue oil in pacamã (*Lophiosilurus alexandri*): performance, apparent digestibility and carcass composition

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ABSTRACT. A study was conducted to assess the impact of partially replacing fish meal and fish oil with fish meal oil and residue in diets for pacamã fry (*Lophiosilurus alexandri*). Eight diets were formulated to be isoproteic and isoenergetic, varying with four levels of fish meal substitution by fish residue meal (0, 10, 20, and 30%), and utilizing two oil sources (fish and fish residue), resulting in a factorial design of 4x2 with three repetitions per treatment. In the first experiment, 192 pacamã fry weighing 12 g ± 2.02 live weight were used, distributed in 24 fiberglass boxes with a capacity of 80 liters of water in a recirculation system. The animals were fed the experimental diets for 60 days and at the end the performance indices and the bromatological composition and fatty acid profile of the carcasses were evaluated. In the second experiment, 8 fish were used per treatment, placed in the same experimental boxes. The fish were fed the same diets, added with chromium oxide as a marker, and underwent 3 periods of feces collection in order to determine the digestibility of the diets. At the end of the experiments, feed and carcass samples were processed and analyzed in the laboratory It was found that fish meal flour can substitute fish meal in pacamã fry diets by up to 30% without compromising performance or carcass characteristics. Furthermore, fish waste oil can completely replace fish oil in pacamã diets.

Keyword: aquaculture; fish farming; vegetal oil; nutrition.

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Introduction

Fish production has become an excellent alternative for obtaining quality food and income for family farmers, as it is an activity that can present high production per area and requires little labor. However, access to inputs often limits the entry of small producers to the activity, with feed being the most limiting, as it corresponds to the largest portion of the production costs of semi-intensive and intensive aquaculture, comprising between 50 and 70% of the total cost (Hertrampf et al, 2012).

Among the noble foods used in fish farming, fish meal stands out for its high amount of protein and excellent amino acid profile, in addition to improving the palatability of the feed. Due to its nutritional qualities, fishmeal has been widely used in aquaculture as a protein source in diets for several cultivated species and is considered one of the best ingredients for the composition of diets for aquatic organisms (National Research Council [NRC], 2011).

An alternative to fishmeal is the fish meal residues (Espe, Sveier, Høgøy, & Lied, 1999). Boscolo and Feiden (2001) reported that fish waste represented about 2/3 of the volume of raw material waste from the fish processing industry, constituting a serious environmental problem when discarded. These residues are generally consisted of heads, carcasses, skins, viscera, fins and trimmings before canning, dark meat and fish that are not fit for consumption. The residues from the fisheries and the fish processing industry can have great potential for use in aquaculture, as long as they are processed correctly (Espe et al., 1999). In refrigerators that process tilapia fillets, 62.5 to 66.5% of the total weight of the fish is discarded as waste (Boscolo et al., 2001).

Other important co-products of the fish industry are fish oils and fish waste. Fish oil can be obtained through the production of fish meal and is composed of 90% neutral lipids (triacylglycerols, free fatty acids) and polar lipids (phospholipids, sphingolipids and oxidized lipids) (Prentice-Hernández, 2011).

Regarding the zootechnical qualities, Pacamã is a species of easy handling and resistant to diseases (Tenório, Santos, Lopes, & Nogueira, 2006); its meat is highly appreciated and does not present intramuscular spines, with high fillet yield (Seabra, 2010). It also presents resistance to long-term handling and transport, as observed by Navarro, Costa, Silva, Silva, and Luz (2017).

This work aimed to evaluate the effect of replacing fish meal with fish residue meal and fish oil with fish residue meal, as well as the interaction between them, in diets for pacamã fry (*Lophiosilurus alexandri*), a native species, with carnivorous eating habits and with potential for aquaculture.

Material and methods

The research was conducted through two experiments carried out in sequence at the Laboratory of Biotechnology in Aquatic Organisms at the University of Brasília - UnB. The experimental procedures were approved by the Animal Ethics Committee of the University of Brasilia (UnBDoc 129101/2015).

Experimental diets

The study was carried out at the Laboratory of Biotechnology in Aquatic Organisms of the Faculty of Agronomy and Veterinary of the University of Brasília, Campus Darcy Ribeiro. Eight isoenergetic and isoproteic diets, were evaluated, with varying levels of substitution of fish meal for fish residue meal (0, 10, 20 and 30%) with two oil sources (fish oil and fish residue oil), each with three replications, representing a 4x2 factorial design. Fish meal flour was composed of leftovers from the processing of tilapia carcasses, consisting of skins, scales, heads, fins and viscera, which underwent cooking and oil removal.

Eight rations were produced using an extruder at the Unesp Aquaculture Center (Caunesp) in Jaboticabal, São Paulo State, as shown in Table 1.

The rations produced constituted granules with approximately 4 mm in diameter and were stored in a freezer at a temperature of -18°C for conservation before being used for animal feeding. physico-chemical characteristics. The experimental diets were analyzed and their chemical-bromatological composition is described in Table 2.

Nutrient contents did not show statistical difference between treatments. The observed protein content was higher than that calculated, but within the recommended range for carnivorous fish fry: 40 to 48.6% CP for pirarucu (Ituassú et al., 2005; Del Risco et al., 2008); 40% for painted (Zanardi, Boquembuzo, & Koberstein, 2008) and 43% CP for African catfish (Ali et al., 2005) and close to the 47.4% CP used for pacamã fry in an experiment conducted by Santos, Silva, Amorin, Balen, and Meurer (2003).

Test species

To assess the diets, 202 pacamã fry (Lophiosilurus alexandri) were utilized, with an average initial live weight of 12 g ± 2.02; total length of 9.9 cm and standard length of 8.5 cm. These fry were sourced from the Aquaculture sector of the Veterinary School of the Federal University of Minas Gerais. The fish were randomly distributed in 24 fiberglass boxes each with a capacity of 80 L. Each experimental unit consisted of a box with eight fish. These boxes were integrated into a recirculation system, where water from the boxes underwent mechanical and biological filtration in a glass box. The water was then passed through a disc filter and an ultraviolet filter in sequence to ensure water quality. Constant aeration was provided to the boxes through an air blower equipped with a porous stone diffuser. Water for the system was sourced from the Companhia de Saneamento Ambiental do Distrito Federal (Caesb) and was pre-dechlorinated before use. Perforated acrylic supports were placed in the boxes with conical bottoms to allow the fish to rest comfortably.

Performance evaluation

The fish went through an adaptation period of 15 days to get used to the feeding routine and the experimental environment. After that period, they started to receive the experimental diets in an amount adjusted every two weeks to 3% of the live weight for 60 days. The feed was supplied through automatic feeders at 20:00 pm and at 4:00 am. The water quality parameters were monitored, with temperature checked daily and dissolved oxygen, ammonia, and pH checked weekly. To maintain water quality, in addition to constant filtration, siphons and water drains from the bottom of the boxes were carried out every 3 days.

At the end of the experimental period, the fish were fasted for 24 hours and, after this period, individual measurements of weight (g) and length (cm) of the fish in each experimental unit were performed.

Table 1. Centesimal composition of experimental diets.

Ingredient (%)	Levels of substitution of fish meal by fish residue meal with inclusion of fish oil				Levels of substitution of fish meal for fish waste meal with the inclusion of fish waste oil			
	0%	10%	20%	30%	0%	10%	20%	30%
Soybean meal	34.90	36.47	38.05	39.62	34.90	36.47	38.05	39.62
Wheat bran	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40
Fish waste meal	0.00	3.38	6.78	10.14	0.00	3.38	6.78	10.14
Fish flour	33.38	30.00	26.60	23.24	33.38	30.00	26.60	23.24
Corn	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90
Maize starch	5.00	3.43	1.85	0.28	5.00	3.43	1.85	0.28
Rice crackers	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Fish waste oil	0.00	0.00	0.00	0.00	3.00	3.00	3.00	3.00
Fish oil	3.00	3.00	3.00	3.00	0.00	0.00	0.00	0.00
BHT Antioxidant[1]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Supplement (vit + min.) [2]	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Common salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Chromium oxide	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Diets were formulated based on the average tabulated values of food nutrients. Values based on dry matter. Isoproteic diets containing 36% of crude protein (Souza et al., 2013) and isoenergetics (4,340 kcal kg^{-1} of EB). [1]Butyl-Hydroxy-toluene (antioxidant); [2]Vitamin and mineral supplement (composition per gram of the product): Vit. A, 1,200,000 IU; Vit. D3, 200,000 IU; Vit K3, 2,400 mg; Vit B3., 4,800 mg; Vit B2, 4,800 mg; Vit B6, 4,000 mg; Vit B12, 4,800 mg; Folic acid, 1,200 mg; Calcium Pantothenate 12,000mg; Vit. C, 48,000 mg; Biotin, 48 mg; Choline, 108,000 mg; Niacin, 24,000 mg; Fe, 50,000 mg; Cu, 3,000 mg; 20,000 mg; Mn, 20,000 mg; Zn, 3,000 mg; I, 100 mg; Co, 10 mg; If, 100 mg.

Table 2. Chemical composition on the diets.

Constituent (%)	Levels of substitution of fish meal by fish residue meal with inclusion of fish oil				Levels of substitution of fish meal for fish waste meal with the inclusion of fish waste oil				Medium	DP
	0%	10%	20%	30%	0%	10%	20%	30%		
Dry matter	92.96	92.76	93.34	92.81	93.23	92.58	93.34	93.04	93.01	0.28
Organic matter*	88.05	87.73	87.88	87.82	88.18	88.08	87.67	87.51	87.87	0.23
Crude protein*	45.84	46.59	46.63	46.21	45.52	45.83	46.67	46.04	46.51	1.16
Ether extract*	8.82	8.33	9.01	7.65	8.64	8.52	7.97	9.77	8.59	0.65
Crude fiber*	13.12	11.33	15.39	11.75	15.31	14.44	11.65	11.92	13.11	1.71
Ash*	11.95	12.27	12.12	12.18	11.82	11.92	12.33	12.49	12.14	0.23
Calcium*	4.64	5.47	5.27	5.09	4.82	4.64	4.54	5.06	4.94	0.33
*Phosphorous**	2.06	2.28	2.31	2.25	2.12	1.96	2.27	2.12	2.17	0.12

*Values expressed as a percentage of the total dry matter of the feed.

The following zootechnical indexes were evaluated:
Daily weight gain - DWG(g) = final weight (g) - ln initial weight (g)/ days;
Relative weight gain - RWG (%) = 100 [final weight (g) - initial weight (g)/ initial weight (g)];
Specific growth rate - SGR (%) = [(ln final weight - ln initial weight)/ days of cultivation] x 100;
Weight gain - WG (g) = final weight (g) - initial weight (g).

For the evaluation of the carcasses, 10 fish were sacrificed at the beginning of the experiment to form a sample composed of initial carcasses. At the end of the experimental period, samples composed of carcasses from each treatment were collected, with two carcasses per experimental unit. For the collection of carcass samples, the fish were desensitized through an immersion bath in a container containing eugenol diluted in water at a concentration of 100 mg L^{-1} and then slaughtered. Then they underwent ventral laparotomy to remove the viscera, and then weighed without viscera, to determine the yield of the carcass with head. The liver was also weighed to determine the hepatosomatic index (IHS) and the viscera to determine the viscera-somatic index. Weighing with 0.001 g precision electronic scales was used to weigh the viscera. After collection, the samples were frozen.

To determine these indices, the following formulas were used:
Yield of carcass with head (%) = (weight carcass/ weight of fish) * 100;
Hepatosomatic index - IHS (%) = (liver weight/ fish weight) * 100;
Viscero-somatic index - VSI (%) = (weight of the viscera[1]/ weight of the fish) * 100;
Fat deposition rate - FDR (mg day^{-1}) = (weight of fat in the final carcass - weight of fat in the initial carcass)/ number of days;
Protein deposition rate - PDR (mg day^{-1}) = (protein weight in the final carcass - protein weight in the initial carcass)/ number of days;

Percentage of protein in weight gain - PPWG (%) = DWG = [(CP x Pf) - (CPi x Pi)] x 100/ (Pf - Pi);
Percentage of fat in weight gain - PFWG (%) = GGP = [(Gf x Gf) - (Gi x Gi)] x 100/ (Gf - Gi).

[1]Viscera = liver, gonads, empty gastrointestinal tract and mesenteric fat.

The carcass samples were dried, ground, and analyzed to obtain their composition of minerals, crude protein and total fat (ether extract) according to procedures described by Silva (1990).

The data obtained related to water quality, performance, and carcass characteristics were subjected to analysis of variance and polynomial regression. Subsequently, the parameters that eventually showed significant differences had their averages compared by the Tukey test, at 5% probability (Zar, 1996). Data analysis was performed using the Assistat 7.7 statistical program.

Digestibility evaluation

The experiment to evaluate the digestibility of diets was conducted out at the Laboratory of Biotechnology in Aquatic Organisms (Laboa) of the Faculty of Agronomy and Veterinary of the University of Brasília, Campus Darcy Ribeiro.

The experiment was carried out in a randomized block design, with eight treatments, in a factorial scheme (4x2), composed of 4 levels of fish meal substitution for fish residue flour and 2 types of oil. The experiment took place in three stages of fecal collection in which each stage constituting a repetition. To enable the determination of digestibility, the same diets from the first experiment containing chromium oxide (Cr2O3) were used to serve as an indicator in the proportion of 0.5% of the total dry matter of the diet.

A total of 64 pacamã fry with a live weight of 30.24 ± 5.01 g were used, randomly distributed in 8 fiberglass boxes with a capacity of 80 L each. The experimental unit consisted of a box with 8 fish. The boxes were installed in a closed water renewal system with mechanical and biological filtration, and constant aeration was provided through an air blower with a porous stone diffuser. Perforated acrylic supports were placed in boxes with a conical bottom to allow the fish to rest. In addition to the 8 boxes where the fish remained being fed, there were 8 boxes for the collection of fecal matter, totaling 16 boxes.

The experiment took place in three stages, each lasting 30 days, totaling a 90-day experimental period with 7 days of adaptation in each stage to the experimental units. After each adaptation period, stool collections were initiated. A methodology similar to that of Furuya et al. (2001) was employed, where the fish stayed two days in the food boxes and 14 hours in the feces collection boxes. The feces collection boxes were identical to the feeding boxes and equipped with a falcon tube collector where, through gravity, the feces were stored. During the collection, the falcon tubes remained surrounded by a polystyrene box with ice to decrease bacterial action and light degradation of nitrogen compounds. At the end of each collection period, after transferring the fish, the boxes were cleaned. During the feces collection period, the water filtration system was turned off to prevent loss of waste.

The water quality parameters were monitored on alternate days where the temperature, dissolved oxygen, ammonia and pH were measured. To maintain water quality in addition to constant filtration, siphoning and drainage of the water from the bottom was performed at each fish transfer. The rations were supplied twice a day during the dark period. The photoperiod was adjusted to 12 hours of light and 12 hours of darkness.

The following formula was used to calculate apparent digestibility:

Da(a) = 100 - [100 (%Cr203r/%Cr203f) x (%Nf/%Nr)]

where:

Da (n) = Apparent digestibility;

Cr2O3r = % chromium-III oxide in the feed;

Cr2O3f = % chromium-III oxide in feces;

N r = Nutrients in the feed;

Nf = Nutrient in feces.

After each collection, the feces were separated from the excess water by centrifuging the falcon tubes and then collected, stored in opaque plastic pots and frozen at −20.0°C. At the end of each collection period (block), the stool samples were dehydrated in an oven with forced ventilation at 55.0°C for 48 hours. Bromatological analyzes (CP, DM, EE, CE) of food, feed and feces were performed at the Food Laboratory of the Faculty of Agronomy and Veterinary Medicine at UnB.

To determine the concentration of chromium oxide in the feces and in the rations, the samples were taken to a muffle for heating at 600°C until completely burned. The burning residue was weighed and the percentage of mineral matter in the samples was determined. Part of the mineral residue from the samples was sent to the Analytical Chemistry Laboratory of the Chemistry Institute of UnB so that the amount of chromium oxide could be determined by atomic absorption spectrophotometry, according to the methodology described by Williams, David, and Iismaa (1962).

The data obtained were subjected to analysis of variance and polynomial regression. Subsequently, the parameters that eventually showed significant differences had their averages compared by the Tukey test, at 5% probability (Zar, 1996). Data analysis was performed using the Assistat 7.7 statistical program.

Results

Performance

The water quality parameters measured remained constant during the experimental period, with no difference between treatments ($P > 0.05$) as shown shown in Table 3.

For the survival rate there was a significant difference ($P < 0.05$) between the types of oil used, with fish fed diets containing fish oil and fish waste oil obtained an average of 100% and 88.54 respectively (Table 4). However, there was no significant difference between the substitution levels.

The average values related to the performance parameters are contained in Table 5 and 6. Analysis of variance was performed for the variables related to the performance: Weight Gain, Relative Weight Gain, Average Daily Gain, Specific Growth Rate, Final Total Length and Final Standard Length., No significant difference was found between the type of oil used and between the levels of substitution of fish meal with fish residue meal (Table 5 and 6).

Table 3. Average (± standard deviation) of water quality parameters during the experiment.

Parameters	Means ± Standard Deviation
Temperature (°C)	29.35 ± 0.73
pH	6.03 ± 0.25
Dissolved oxygen (mg L^{-1})	6.18 ± 0.85
Ammonia (mg L^{-1})	0.35 ± 0.13

Table 4. Survival rate of pacamã fry fed diets containing different levels of substitution of fish meal for fish residue meal with fish oil or fish residue oil.

Replacement levels	Survival (%)	
	fish oil	waste oil
0%	100.00	87.50
10%	100.00	100.00
20%	100.00	75.00
30%	100.00	91.67
CV(%)	11.90	

Table 5. Weight gain, relative weight gain and average daily gain of pacamã fry fed diets containing different levels of substitution of fish meal with fish residue meal with fish oil or fish residue oil.

Replacement levels	Weight gain (g)		Relative weight gain (%)		Average daily gain (g)	
	fish oil	waste oil	fish oil	waste oil	fish oil	waste oil
0%	18.21±9.93	15.78±3.81	151.93±82.79	131.51±31.72	0.30±0.17	0.25±0.07
10%	19.88±2.03	19.37±2.56	165.63±16.93	161.39±21.32	0.33±0.03	0.32±0.04
20%	14.70±2.20	24.09±7.24	122.50±18.30	200.76±60.31	0.25±0.04	0.40±0.12
30%	19.24±1.39	17.36±1.52	160.31±11.57	144.70±12.63	0.30±0.03	0.29±0.03
CV(%)	25.91		25.90		26.69	

After weighing the viscera, it was possible to obtain the carcass yield of fry heads in the different treatments, with no significant difference found between the diets with fish oil and fish residue oil at the level of 5% probability ($P > 0.05$). There was also no significant difference in the interaction between the type of oil used and the levels of substitution of fish meal with fillet residue flour. For the Substitution Levels factor, polynomial regression was applied, and no significant difference was found. The same occurred with the hepatosomatic index and the viscerosomatic index, which did not differ in any treatment, nor was there any significant interaction between the factors (Table 6 and 7).

The percentages of protein and fat in weight gain in the fry carcasses did not differ between treatments, either between the types of oils, levels of substitution, or the interaction between factors. the average values are described in Table 8 and 10.

The values observed for Fat and Protein Deposition Rate are expressed in Table 9. No significant difference was found between treatments for the Protein Deposition Rate variable between the types of oils used, substitution levels and the interaction between factors (P > 0.05).

As for the Fat Deposition Rate, no significant difference was observed between treatments for the types of oils used or between the levels of substitution. However, there was an interaction between the two factors that resulted in a cubic regression equation.

Table 6. Total length, standard length and specific growth rate of pacamã fry fed diets containing different levels of fish meal substitution with fish waste flour with fish oil or fish waste oil.

Replacement levels	Total Length (cm)		Standard Length (cm)		Specific growth rate (%)	
	fish oil	waste oil	fish oil	waste oil	fish oil	waste oil
0%	11.20±1.41	10.54±0.49	13.27±1.55	12.69±0.75	1.48	1.07
10%	11.13±0.66	11.35±0.54	13.28±0.60	13.54±0.52	1.57	1.60
20%	10.50±0.49	11.72±1.56	12.58±0.59	14.17±1.16	1.33	1.81
30%	11.40±0.63	11.09±0.47	13.46±0.64	13.36±0.78	1.55	1.49
CV(%)	6.69		7.97		17.28	

Table 7. Carcass yield with head, Hepatosomatic Index and Viscerosomatic Index of pacamã fry fed with diets containing different levels of fish meal substitution with fish oil meal with fish oil or fish residue oil.

Replacement levels	Carcass yield with head (%)		Hepatosomatic Index (%)		Viscerosomatic Index (%)	
	fish oil	waste oil	fish oil	waste oil	fish oil	waste oil
0%	93.48±1.61	93.52±0.46	1.30±0.32	1.42±0.19	6.52±1.61	6.48±0.46
10%	92.73±0.74	93.47±0.28	1.52±0.28	1.40±0.12	7.27±0.74	6.53±0.28
20%	93.34±1.34	92.92±0.90	1.44±0.43	1.61±0.69	6.57±1.34	7.08±2.12
30%	91.91±0.63	93.47±0.90	1.76±0.29	1.35±0.37	8.09±0.63	6.53±0.90
CV(%)	1.25		24.54		18.43	

Table 8. Crude Protein in Weight Gain and Fat in Weight Gain of pacamã fry fed diets containing different levels of substitution of fish meal for fish meal flour with fish oil or fish residue oil.

Replacement levels	Crude Protein in Gain of weight (%)		Gain Fat of weight (%)	
	fish oil	waste oil	fish oil	waste oil
0%	56.03±5.56	60.87±0.54	28.92±1.97	27.31±1.49
10%	59.54±5.27	61.58±8.54	29.99±1.26	28.10±1.15
20%	62.51±0.62	60.92±2.26	29.27±4.04	25.11±1.77
30%	61.25±6.68	64.48±4.22	27.04±0.52	28.04±2.90
CV(%)	8.20		7.70	

Table 9. Fat deposition rate and protein deposition rate of pacamã fingerlings fed diets containing different levels of fish meal substitution with fish waste flour with fish oil or fish waste oil.

Replacement levels	Fat Deposition Rate (mg day^{-1})		Protein Deposition Rate (mg day^{-1})	
	fish oil	waste oil	fish oil	waste oil
0%	79.45±62.57	56.36±20.07	165.47±92.53	146.77±42.17
10%	85.08±24.72	83.57±14.54	193.40±33.99	190.38±13.94
20%	55.42±7.92	118.32±8.89	149.26±21.05	235.98±73.56
30%	78.34±10.41	75.74±17.68	183.55±36.70	179.17±19.40
CV(%)	33.78		27.19	

Table 10. Chemical composition of carcasses of pacamã fry (averages + standard deviation) fed diets containing different levels of fish meal replacement with fish meal flour with fish oil or fish residue oil.

Variables	Initial population	Levels of substitution of fish meal by fish residue meal with inclusion of fish oil				Levels of substitution of fish meal for fish waste meal with the inclusion of fish waste oil			
		0%	10%	20%	30%	0%	10%	20%	30%
Moisture	75.87	72.84	73.88	74.01	73.62	73.77	74.01	73.53	73.06
Crude protein	16.53	16.07	15.90	16.33	16.36	16.78	16.60	16.77	17.76
Ether extract	5.66	7.22	7.15	6.85	6.72	6.68	6.79	6.48	7.00
Mineral	2.49	3.13	3.14	3.12	3.02	2.63	2.87	3.56	2.78
Som	100.55	99.25	100.06	100.31	99.72	99.87	100.27	100.34	100.60

Values expressed as a percentage of the total dry matter of the feed. [2]Calculated from the average values for protein (5.64 kcalg-1) and lipids (9.44 kcalg-1) described in the NRC (2011).

Table 11. Apparent digestibility coefficients of experimental diets.

Replacement levels	Dry matter		Proteína Bruta	
	fish oil	waste oil	fish oil	waste oil
0%	29.74±0.38	27.75±2.79	67.91±0.17	67.51±1.64
10%	35.38±1.82	33.89±0.64	69.23±0.87	73.61±0.22
20%	42.27±1.20	41.76±0.10	70.58±0.70	71.06±0.05
30%	47.21±3.99	45.29±1.59	74.19±1.95	70.79±0.72
CV(%)	5.24		1.45	

Digestibility

There was no statistical difference (P > 0.05) between the averages of the results of the apparent digestibility coefficient of dry matter and crude protein between the types of oils used in the diets. However, a linear effect was observed in the levels of substitution of fish meal by fish residue meal represented by the equation expressed (Table 11).

Discussion

Performance

The measured water quality parameters remained adequate for the creation of pacamã throughout the experimental period with average values close to the optimum (Navarro et al., 2017). The mortality observed in fish fed with diets composed of waste oil was disassociated from the other parameters of performance and water quality, so it cannot be inferred that there was an influence of the different diets.

In the present experiment, the performance was statistically similar between the groups of animals fed with the evaluated diets, thus indicating that there was no influence of the type of oil or flour used in the diets. The result can be explained by the similar characteristics that fish meal and fish residue have in relation to the levels of PB, EE, amino acids, as well as in the energy content and fatty acid profile that both oils have, as described in works by Boscolo, Hayashi, Feiden, Meurer, and Signor (2008) and Galan et al. (2013).

The average specific growth rate found of 1.48% was similar to that observed by Souza et al. (2014) in diets for pacamã fry with different levels of protein, where all diets contained 20% fish meal. The values are also similar to those found by Canton et al. (2007) in jundiá juveniles. A similar result was also found by Terrazas, Pereira-Filho, and Oliveira-Pereira (2002) in Tambaqui fed diets with different proportions of fish residue. Numerically, the highest rate was observed with the diet consisting of 20% substitution of fish meal for waste meal with the addition of waste oil, which provided greater weight gain for this treatment at the end of the experiment.

The carcass yield had averages higher than those found by Souza et al. (2013), Meurer et al. (2003).

The hepatosomatic index found is in accordance with the values found by Souza et al. (2013), who, evaluating the crude protein requirement for pacamã juveniles, found values between 0.53 to 1.70. The hepatosomatic index represents the percentage of liver mass in relation to body mass and is a way of quantifying the energy supply (glycogen) in the liver (Cyrino, Portz, & Martino, 2000). The results found were expected since the fish were at an adequate temperature, with the same handling, without being subjected to stress and with isoenergetic diets.

The rate of protein deposition observed can be considered adequate when compared to other results found. Melo et al. (2001) when evaluating different sources and levels of lipids for feeding jundiá fry found an average protein deposition rate of 101.3 mg day^{-1}, lower than that found in the present experiment. As for the tambacu hybrid, the protein deposition rate found by Pereira et al. (2011) was much lower with average levels of 55.7 mg day^{-1}.

The treatment consisting of the level of 20% substitution of fish waste flour with fish residue oil provided a body fat deposition rate that was statistically higher than the other treatments, and also numerically higher for the protein deposition rate. This result can be explained by the greater weight gain and specific growth rate found for this diet. However, there was no difference in carcass composition and in the percentage of fat and protein in weight gain between treatments.

The analyzed carcasses showed a similar proportion of nutrients to those found for piaupara hybrids (Leporinus macrocephalus) x Leporinus elongatus) in an experiment conducted by Finkler et al. (2010), who assessed levels of substitution of fish meal for poultry offal meal.

However, the composition of the carcasses based on dry matter, which presented 63.07 crude protein, 25.61 ether extract and 11.31% mineral matter, differed from that found by Souza et al. (2013) in pacamã fry fed with different levels of protein in the diet, which obtained 73.09 CP and 9.4% EE. The greater accumulation of lipids in the carcasses can be explained by the fact that the diets used in the present experiment have an energy density higher than those used by those authors. According to Signor et al. (2007), the chemical composition of the carcass is directly related to the nutrients provided through the diet, that is, a diet with a different balance in nutrients can result in different values of nutrients (proteins, lipids and others) in the fish carcass.

The performance results found in the present study are corroborated by Kotzamanis, Alexis, Andriopoulou, Castritsi-Cathariou, and Fotis (2001), who used flour from trout processing to feed the gilthead bream, a marine species, and were successful in replacing approximately 20% of fish meal with fish residue. When evaluating the effect of using fish waste flour and chicken waste flour in tambaqui diets, Terrazas et al. (2002) also found no differences in the performance of fish fed with different proportions of these flours in experimental diets. Boscolo et al. (2005) when using increasing levels of fish residue in the feeding of Nile tilapia larvae, up to the proportion of 20% of the total DM, there was no difference in performance and mortality, also showing its use to be satisfactory up to that level.

Digestibility

The measured water quality parameters remained adequate for the creation of pacamã during the entire experimental period.

Fish residues in general have higher levels of minerals and less digestible proteins since the raw material is largely made up of skins, heads and fins. However, there was a linear increase in the apparent digestibility of dry matter with the increase in the proportion of waste flour in the present experiment. Since the proportion of nutrients did not differ between diets and neither performance was affected by the substitution of fish meal for fish residues, it is inferred that the used meal flour had high nutritional quality.

Fish meal flour has a very varied composition depending on the species used, the type of waste and the processing method, and may present a high variation in its composition, in terms of protein, fat, ash and amino acids, and may also vary in terms of digestibility of these nutrients, which can damage fish performance (Aksnes, Izquierdo, Robaiana, Vergara, & Montero, 1997). This fact can be proven through discrepant results such as those presented by Signor et al. (2013) who found an average of 89.94% digestibility of protein from fish meal flour supplied to juveniles of piavuçu and those presented by Boscolo et al. (2005) who found CP digestibility values of 70.67 for corvina waste flour and 67.09% for tilapia waste flour.

Fishmeal is also a highly digestible ingredient. Tonini et al. (2012) evaluated the digestibility of fish meal for Trichogaster leeri and found values of 68.63 and 89.25% for MS and PB respectively. Likewise, Melo et al. (2001) evaluating several ingredients in the pacamã diet found apparent digestibility values of DM and CP of 85.2 and 82.4% for fish meal. However, Pezzato et al. (2002) found lower values of fish meal digestibility of 57.46 and 78.55% for DM and PB.

In the same way, fishmeal has a highly variable digestibility in the literature. Kaushik, Covès, Dutto, and Blanc (2004) evaluating the substitution of fish meal for vegetable ingredients for Dicentrarchus labrax found no differences between the apparent digestibility of the diets with dry matter and crude protein digestibility values of 80.28 and 95.36% respectively. Similarly, Carter and Hauler (2000), evaluating the substitution of fish meal for flours of vegetable origin in diets for Atlantic Salmon found apparent digestibility values between 76.52 and 85.5% for DM and between 92.71 and 95.9% for PB. A similar result was observed by Allan et al. (2000) who found digestibility values of DM ranging from 76.8 to 93.9% and BP ranging from 89 to 94.2% in Bidyanus bidyanus fed with three types of fish meal.

In the present experiment the contents of apparent digestibility of dry matter were low compared to the aforementioned literature, which may have occurred due to the characteristics of the flours used and the interaction with the other ingredients.

Conclusion

Fish meal flour can be used as a substitute for fish meal by up to 30% in diets for pacamã fry without prejudice to fish performance and without changing the composition of the carcasses. Fish waste oil can be used to replace fish oil in diets for pacamã fry.

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