BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

FISH MEAL OBTAINED FROM THE PROCESSING OF *Rhamdia quelen*: AN ALTERNATIVE PROTEIN SOURCE

Suzete ROSSATO[1]
Daniel MASCHIO[2]
Suziane Ghedini MARTINELLI[3]
Lucas Mesquita da Costa NUNES[2]
João RADÜNZ NETO[2]
Rafael LAZZARI[4]

[1]Instituto Federal Farroupilha – IFF, Campus de São Vicente do Sul, Rua 20 de setembro, 2616, CEP 97420-000, São Vicente do Sul, RS, Brasil.

[2]Universidade Federal de Santa Maria – UFSM, Programa de Pós-graduação em Zootecnia, Avenida Roraima, 1000, CEP 97105-900, Santa Maria, RS, Brasil.

[3]Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Campus Lábrea, Rua Vinte e Dois de Outubro, 3893, Vila Falcão, CEP 69830-000, Lábrea, AM, Brasil.

[4]Universidade Federal de Santa Maria – UFSM, Campus Palmeira das Missões, Av. Independência, 3751, Vista Alegre, CEP 98300-000, Palmeira das Missões, RS, Brasil. E-mail: rlazzari@ufsm.br (corresponding author).

Received: January 28, 2018
Approved: May 10, 2018

ABSTRACT

The study of alternative protein sources is very important to lower the cost of aquafeeds. In this study, the use of waste from the processing of silver catfish (*Rhamdia quelen*) in the diet of juveniles of this species was evaluated. This feed was used in a recirculation system with 16 polypropylene tanks (280 L), each one containing 50 fish (initial weight = 5.50 ± 0.09 g). Fish were tested on four diets (37% crude protein and 3200 kcal kg^{-1} digestible energy): a control diet composed of swine meat and bone meal, one with meal made from silver catfish carcasses with viscera, a diet of meal from carcasses without viscera, and a diet of fish meal made from the whole fish. The data measured were final weight, condition factor, specific growth rate, feed conversion ratio, daily weight gain, and protein retention rate of fishes on different diets. Overall higher final weight (50.5 g), specific growth rate (3.9% day^{-1}), feed conversion (1.3:1), and deposition of body protein (6.3 g) was observed for fish fed with the diet containing carcass meal from silver catfish with viscera than on the other diets. The incorporation of waste meal from the processing of silver catfish into the diet is viable for achieving fish growth.

Key words: alternative protein sources; fish; weight gain; protein retention rate.

FARINHA DE PEIXE OBTIDA DO PROCESSAMENTO DE *Rhamdia quelen*: UMA FONTE PROTEICA ALTERNATIVA

RESUMO

O estudo de fontes de proteínas alternativas é muito importante para reduzir o custo de dietas aquícolas. Neste estudo foi avaliada a utilização de resíduos do processamento de jundiá (*Rhamdia quelen*) na dieta de juvenis desta espécie. Deste modo, foi utilizado sistema de recirculação com 16 tanques de polipropileno (280 L), cada um com 50 peixes (peso inicial = 5,5 ± 0,09 g). Foram testadas quatro dietas (37% de proteína bruta e 3.200 kcal^{-1} kg de energia digestível): dieta controle, composta por farinha de carne e ossos suína, substituída por farinha de peixe, composta por peixe inteiro (jundiá), farinha de carcaças de jundiá com vísceras e dieta com farinha de carcaças de jundiá sem vísceras. Foi avaliado, o peso final, fator de condição, taxa de crescimento específico, taxa de conversão alimentar, ganho de peso diário e taxa de retenção de proteína. Observou-se maior peso final (50,5 g), taxa de crescimento específico (3,9% dia^{-1}), conversão alimentar (1,3:1), deposição de proteína corporal (6,3 g) para os peixes alimentados com as dietas compostas por farinha de carcaça de jundiás com vísceras. A incorporação de farinha de resíduos do processamento de jundiás na dieta é viável para o crescimento dos peixes.

Palavras-chave: fontes proteicas alternativas; peixe; ganho de peso; taxa de retenção proteica.

INTRODUCTION

The proper utilization of waste from industry or fish waste with low commercial value has great importance in diet production, as well as promoting sustainable aquaculture. The sustainability of aquaculture is directly linked to the use of waste from the finfish aquaculture industry. According to SILVA *et al*. (2016), the principles of modern aquaculture encourage the development of fish feeds containing low fish meal content and several types of plant ingredients, plus nutrients, to avoid depleting global fish stocks and reduce production costs.

Research examining waste from fish processing industries has shown that these waste products can be used to feed fish (ROSSATO *et al.*, 2014). In recent years, there has been an increase in demand for cultivated silver catfish (*Rhamdia quelen*) to meet the consumption patterns and demands of the human population, as the silver catfish is being increasingly sold in the form of fillets, which uses only 30-40% of this fish. Due to this, there has been an increase in the amount of waste produced from processing this fish, and therefore measures should be taken to reduce the impact that this waste is likely to have on the environment; one of the possible solutions would be the manufacture of fish meals from this waste.

The most frequent sources of waste products for use as meals are derived from fish discarded during rating before industrial processing, particularly when fish do not reach commercial size by the time of processing. The yield of fish carcasses varies according to the kind, size, and type of fish processing. Fish waste meal can be considered a source of additional income for fishing industries, and its production contributes to decreasing the amount of waste discharged into the environment.

Fish meal is considered a standard food for use in rearing trials, and it is the preferred protein source in diets for fish because it presents a high biological value to them and an optimal balance of essential amino acids (TACON, 1996; ENKE *et al*., 2009). The best quality fish meals come from marine fisheries, such as those produced in Chile and Peru. However, with recent increases in demand, there has been a reduction in the availability of such fish meals and consequent increases in their costs (BOSCOLO *et al*., 2008).

The most important components of animal tissues are proteins that, when digested, are hydrolyzed into amino acids that will form new proteins, which will then be used for growth, reproduction, and body maintenance (BOSCOLO *et al*., 2004). Fish feed must therefore contain a high percentage of protein for it to support proper fish growth. From the proteins in their food, fish need to get the necessary amino acids to build their muscle tissues and produce other important proteins for the functioning of their body (GUILHERME *et al*., 2007). The objective of this study was to evaluate the use of waste from the processing of cultivated silver catfish in the diet of juveniles of this species.

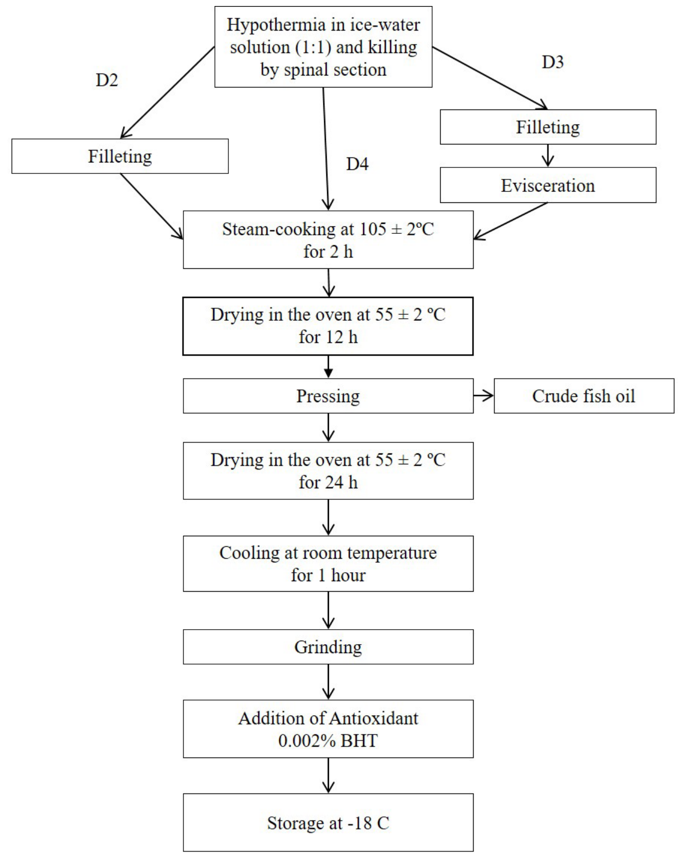

Figure 1. Flowchart of production of silver catfish waste meal. Feedstock: D2: Carcass meal from silver catfish with viscera; D3: Carcass meal from silver catfish without viscera; D4: Silver catfish meal made from the whole fish.

METHODS

Obtaining fish meal

Fish used in production of fish meals were cultured for a period of two years. They were initially taken from the nursery and debugged to remove any ectoparasites, and then were selected by weight. Animals weighing more than 300 g were filleted. Animals weighing less than 300 g were used whole. A total of 80 kg of fish was used to make fish meal, and this was done in the fish farming laboratory at UFSM. The fish meals were prepared as shown in Figure 1, using the methodology adapted by VIDOTTI and GONÇALVES (2006), in which animals are processed through periods of purification, filleting, and steam-cooking wrapped in aluminum foil.

Place and time of study

This study was conducted at Santa Maria, RS, Brazil (altitude 95 m, lat 29°43'S, lon 53°42'W), from December 2010 to February 2011. The experiment lasted 56 days. The fish were placed in an indoor recirculation system with two biological filters, composed of 16 polypropylene tanks (280 L) with individual systems of water supply and drainage.

Analysis of percent composition of silver catfish waste meal

Initially, the waste catfish meals used for the formulation of diets were analyzed using the following methods, as described and recommended by the AOAC (1995). Fat was extracted and quantified using the method of BLIGH and DYER (1959) (Table 1).

Experimental diets

The dry ingredients were ground, weighed, and mixed in an electric mixer to achieve homogenization. The addition of oil, when used, occurred at this stage. Then, water was added (40%).

Table 1. Bromatological percent (%) compositions of flour and amino acid residues in silver catfish meal.

Ingredients	fish meal with viscera	Fish meal without viscera	Whole fish meal
Dry matter (%)	92.05	94.07	90.78
Crude protein (%)	57.05	57.04	62.43
Fat (%)	5.56	5.28	5.12
Ashes (%)	2.77	2.67	2.55
Amino acids			
Lysine	6.4	5.98	4.7
Methionine	1.08	1.15	1.64
Cystine	0.12	0.13	0.77
Threonine	2.16	1.94	2.7
Tryptophan	-	-	0.64
Valine	3.02	3.46	3.17
Isoleucine	2.12	2.62	2.63
Leucine	4.17	4.39	4.83
Phenylalanine	2.35	2.31	2.29
Histidine	1.52	1.42	1.7
Arginine	2.59	2.33	4.23

The wet mixture was formed into pellets in a meat grinder and dried in an oven with forced air circulation at 50 °C for 24 h. After they were dried, the fish feeds were stored in a freezer (-18 °C) until their delivery to animals

Four different diets were tested (Table 2), with four replications of each diet. A control diet composed of swine meat and bone meal as its source animal ingredients (D1) was used. In the other diets tested, the source animal ingredients were instead meal from silver catfish carcasses (carcass meal) with viscera (D2), carcass meal from silver catfish without viscera (D3), or fish meal made from the whole fish (D4).

Animals

For the experiment, 800 juvenile silver catfish produced from induced reproduction at the Fish Farming Lab of the University of Passo Fundo were used, with an initial average weight ± standard deviation (SD) of 5.5 ± 0.09 g, initial average length of 8.8 ± 0.3 cm, and approximate age of 60 days. At the beginning of the experiment, fish were weighed and measured. These animals were placed in 16 tanks, distributed in batches of 50 fish per experimental unit, at an initial stocking density of 0.98 g fish L^{-1}. The animals were fed three times a day (at 8 am, 1 pm, and 5 pm) with initially restricted food levels representing 4.5% of body weight. Initially, fish were given a period of 10 days to acclimate to experimental conditions, during which they were fed with the control diet (D1 = meat and bone meal); these procedures were adapted from those of LAZZARI *et al*. (2008). The experimental procedures were approved by the Internal Committee of Ethics in Animal Use of UFSM (n. 86/2010).

Water quality

The water in each tank was individually oxygenated with the aid of aerators, plus the central reservoir also had aeration. The flow of water through the experimental units during the period was 2.4 L min^{-1}. Water quality was monitored daily by measuring temperature (°C) and dissolved oxygen (mg L^{-1}), plus a digital oximeter brand YSI 550 was used to take more precise measurements every seven days. Other water parameters, such as pH, alkalinity (mg L^{-1} $CaCO_3$), hardness (mg L^{-1} $CaCO_3$), and ammonia content (mg L^{-1}) were measured daily with the aid of colorimetric kits. The water used for these analyses was collected at the entrance of the first biological filter, always in the morning and before daily cleanings. The water quality parameters remained within appropriate limits for the studied species. The average temperature was 24 ± 1.7 °C, dissolved oxygen 6.2 ± 0.5 mg L^{-1}, pH 7.43 ± 0.3, alkalinity 36 ± 3.2 mg L^{-1} $CaCO_3$, hardness 43 ± 5.4 mg L^{-1} $CaCO_3$, and ammonia was 0.15 ± 0.05 mg L^{-1}. The water used for the experiment came from an artesian well.

Data collection

Every 14 days, a biomass estimate was performed in which all animals in an experimental unit were weighed together, adjusting for the given diet, but still taken every 14 days. Initially, animals were weighed and measured individually for growth monitoring. The animals were sedated with eugenol (0.2 mL L^{-1}), and were then weighed and measured in order to obtain the following data: weight: W = weight of whole fish (g); total length (cm) (TL); survival (%) (S); condition factor: CF = (Weight × 100) /(total length^3); specific growth rate (% day^{-1}): SGR = (ln (final weight) - ln (initial weight))/experimental days)x100; apparent feed conversion ratio: AFCR = total dry feed offered (g)/wet weight gain (g);

Table 2. Composition of diets utilized in the experiment for feeding juvenile silver catfish.

Diet formulation[1] (%)				
Ingredients	D1	D2	D3	D4
Swine meat and bone meal	30.00	0.00	0.00	0.00
Silver catfish meal (whole fish)	0.00	0.00	0.00	**30.00**
Carcass meal from silver catfish with viscera	0.00	**30.00**	0.00	0.00
Carcass meal from silver catfish without viscera	0.00	0.00	**30.00**	0.00
Soybean meal	40.60	35.35	40.00	35.80
Wheat bran	9.49	12.50	10.00	10.49
Ground corn (grain)	15.60	17.84	15.49	19.20
Soybean oil	0.80	0.80	1.00	1.00
Vitamins[2]	1.00	1.00	1.00	1.00
Minerals[2]	1.00	1.00	1.00	1.00
Calcitic limestone	1.00	1.00	1.00	1.00
Common salt	0.50	0.50	0.50	0.50
Antioxidant (BHT)	0.01	0.01	0.01	0.01
Diet Composition (%)				
Dry matter[4]	95.19	94.84	94.83	94.33
Crude Protein[4]	36.68	36.46	37.50	37.09
Lysine[3]	2.11	3.03	3.02	2.53
Methionine[3]	0.55	0.60	0.64	0.76
Methionine + Cystine[3]	0.49	0.34	0.37	0.54
Threonine[3]	1.32	1.38	1.38	1.54
Tryptophan[3]	0.42	0.28	0.31	0.47
Valine[3]	1.74	1.86	2.08	1.91
Isoleucine[3]	1.45	1.52	1.76	1.68
Leucine[3]	2.66	2.81	2.99	3.02
Phenylalanine[3]	1.59	1.68	1.76	1.67
Histidine[3]	0.85	0.95	0.97	1.01
Arginine[3]	2.65	2.17	2.21	2.66
Lipid[4]	7.17	6.44	6.61	5.83
Neutral detergent fiber[4]	12.13	14.97	14.84	13.96
Nitrogen free extract[4]	34.08	31.69	29.95	34.24
Mineral matter[4]	9.94	10.44	11.10	8.88
Relationship DE/CP (kcalg^{-1})[6]	8.98	9.05	8.72	8.89
Calcium[3]	1.57	1.72	1.76	1.71
Phosphorus[3]	0.95	1.72	1.63	1.45
Relationship Ca/P	1.65	1.00	1.08	1.18
Estimated digestible energy (kcal kg^{-1})[5]	3295	3298	3270	3299

[1]Diet adjusted from LAZZARI *et al*. (2008). [2]Composition of mineral and vitamin mixture (1% Mig Fish inclusion / Mig Plus ®): Ac. Folic: 299.88 mg, BC. Pantothenic: 3000 mg, Cobalt: 60 mg, Copper: 1000 mg, Choline: 103.500 mg, Iron: 6.416 mg, Biotin: 0.06 mg, Iodine: 45.36 mg, Manganese: 8000.40 mg Magnesium: 5.10%, Selenium: 60.30 mg, Vit.A: 1.000.000UI, Vit. B1: 1500.38 mg Vit. B2: 1500 mg, Vit. B6: 1500.38 mg Vit. C: 15.000 mg, Vit. D: 240.000 IU Vit. E: 10.000 mg, Vit. K: 400 mg Zinc: 14000mg, Inositol 10 000 mg Niacin 9000 mg, 0.01% sulfur, 2.30% chloro. [3]Calculated from the analyzes of the ingredients. Analyzed at the Laboratory of Fish Farming - DZ/UFSM. [4]Based on centesimal analysis. [5]Digestible Energy (DE) values estimated from the physiological standards, i.e. 4 kcal g^{-1} for protein and digestible carbohydrate, 9 kcal g^{-1} for lipids (LEE and PUTNAM, 1973; SHYONG *et al*., 1998). [6]DE/CP: Digestible Energy/Crude Protein. D1: Diet composed of swine meat and bone meal; D2: Diet composed of carcass meal from silver catfish with viscera; D3: Diet composed of carcass meal from silver catfish without viscera; D4: Diet composed of silver catfish meal made from the whole fish.

daily weight gain (g): DWG = (final weight-initial weight) /days; and total biomass (g).

For implementation of biometric measurements, animals were fasted for 12 h so that there would be no influence of food still in the gastrointestinal tract on measures taken. They were then anesthetized by hypothermia in ice-water solution (1:1) and killed by spinal section. In order to alleviate the stress caused by handling while recording biometrics and to facilitate the handling of animals, eugenol anesthetic (20 µL L^{-1}) was used. Tanks were cleaned twice a day (10 am and 4 pm) by siphonage to remove residues of food and animal feces.

At the beginning and at the end of the 56-day experiment, two fish/tank (8 fish/treatment) were collected, slaughtered, and eviscerated in order to obtain data on carcass weight, weight of the digestive tract, digestive tract length, visceral fat weight, and liver weight. From these results, the following parameters were calculated: digestive somatic index (%): DSI = ((digestive tract weight /whole weight) * 100); hepatosomatic index (%): HSI = (liver weight / whole weight) * 100; intraperitoneal fat index (%): IFI= (intraperitoneal fat weight / whole weight) * 100; intestinal quotient: IQ = (digestive tract length / total length); and protein efficiency ratio (PER) = weight gain / amount from dietary protein offered.

Analyses

The analysis of the chemical composition of fishes on different diets were performed by initially collecting of a sample of 50 fish every 14 days with five fish (10% of biomass) per experimental unit. From these samples, data for dry weight, protein, lipid, and ash were obtained. These analyzes were performed following the methods recommended by the AOAC (1995), and lipid was extracted and quantified by the BLIGH and DYER (1959) method. From these results, the rates of deposition of body protein and lipid were calculated. These values were used in the following equations: deposition of body protein (g): DBP = ((final weight * final body protein) / 100) - ((initial weight * initial body protein) / 100); and body lipid deposition (g): BLD = ((final weight * final body lipid) / 100) - ((initial weight* initial body lipid) / 100).

Statistical design

For statistical analyses, a completely randomized block design was used, wherein four treatments (diets) and four replicates were tested with analysis of variance (ANOVA). The data were tested for normality of residuals and homogeneity of variances before performing ANOVA. If there were overall significant differences among diets, then means of different diets were compared using Tukey's test (significant difference: $P < 0.05$). Values are expressed as means ± standard error of the mean.

RESULTS

At the end of the experimental period, the highest overall final weights (50.52 g) were registered in fish fed with the D2 diet (Table 3). Total length differed among diet treatments. The highest average daily weight gain (0.81 g day^{-1}) (Figure 2) and specific growth rate (3.99% day^{-1}) were also observed in fish fed with the D2 diet (Table 2).

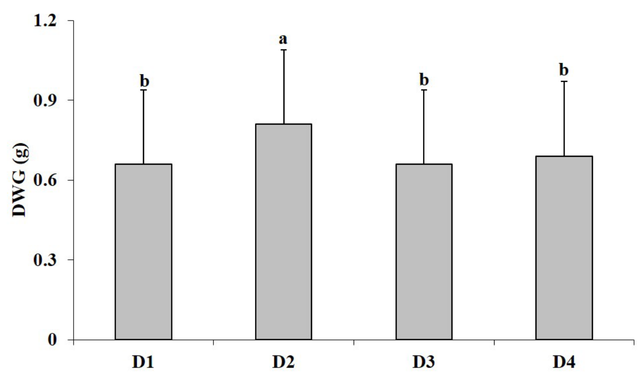

Figure 2. Daily weight gain (g day^{-1}) of silver catfish fed with different waste meal diets. Values are expressed as means ± standard error of the mean. Means with different letters differed significantly based on Tukey's test ($P < 0.05$). Treatments: D1: Diet composed of swine meat and bone meal; D2: Diet composed of carcass meal from silver catfish with viscera; D3: Diet composed of carcass meal from silver catfish without viscera; D4: Diet composed of silver catfish meal made from the whole fish.

Table 3. Performance parameters of juvenile silver catfish fed diets composed of silver processing catfish waste as a replacement for meat and bone meal.

Parameters	Initial	D1	D2	D3	D4
W (g)	5.53±0.09	42.69±1.63^{b}	50.52±3.99^{a}	42.40±2.59^{b}	44.02±2.82^{b}
TL (cm)	8.88±0.31	15.99±0.18^{b}	16.83±0.26^{a}	15.97±0.19^{b}	16.18±0.49^{ab}
CF	0.79±0.07	1.04±0.01	1.06±0.04	1.03±0.02	1.03±0.03
SGR (% day^{-1})		3.64±0.07^{b}	3.99±0.13^{a}	3.62±0.08^{b}	3.68±0.10^{b}
AFCR		1.44±0.03^{a}	1.28±0.05^{b}	1.31±0.06^{b}	1.24±0.04^{b}

Values are expressed as means ± standard error. Means with different letters beside them differed significantly based on Tukey's test ($P < 0.05$). Treatments: D1: Diet composed of swine meat and bone meal; D2: Diet composed of carcass meal from silver catfish with viscera; D3: Diet composed of carcass meal from silver catfish without viscera; D4: Diet composed of silver catfish meal made from the whole fish. W= Weight (g); TL: Total length (cm); CF: Condition factor; SGR= Specific growth rate; AFCR: Apparent feed conversion ratio.

Table 4. Indices of lipid and protein deposition in the carcass, digestive somatic index, intestinal quotient, hepatosomatic index, intraperitoneal fat index, and survival of juvenile silver catfish fed diets composed of silver catfish processing waste as a replacement of meat and bone meal.

Parameters	D1	D2	D3	D4	P
BPD (g)	5.43±0.41[ab]	6.31±0.44[a]	5.33±0.54[b]	5.61±0.33[ab]	0.03
BLD (g)	1.65±0.59	1.57±0.15	1.52±0.12	1.57±0.20	0.95
PER	2.37±0.19	2.84±0.32	2.38±0.23	2.48±0.29	0.09
DSI (%)	4.07±0.09	3.65±0.19	3.91±0.51	3.64±0.60	0.40
IQ	1.57±0.13	1.57±0.07	1.62±0.19	1.47±0.04	0.45
HSI (%)	1.33±0.14	1.30±0.19	1.22±0.10	1.26±0.27	0.83
IFI (%)	1.19 ±0.20	0.89±0.50	0.79±0.30	0.70±0.32	0.36
S (%)	98.0±2.83	96.0±2.83	97.5±1.91	95.5±2.51	0.48

Values are expressed as means ± standard error. Means with different letters beside them differed significantly based on Tukey's test (P < 0.05). Treatments: D1: Swine meat and bone meal; D2: Carcass meal from silver catfish with viscera; D3: Carcass meal from silver catfish without viscera; D4: Silver catfish meal made from the whole fish. Parameters: BPD: body protein deposition; BLD: body lipid deposition; PER: protein efficiency rate; DSI: digestive somatic index; IQ: intestinal quotient; HSI: hepatosomatic index; IFI: intraperitoneal fat index; S: survival.

The apparent feed conversion ratio (AFCR) was best for diets with waste meal of silver catfish (Table 3), which makes sense considering that the fish meal is composed of a larger amount and availability of amino acids compared to diets made from swine meat and bone meal.

The initial mean biomass in all treatments was 276.59 ± 4.95 g, and, in the end, a higher biomass of 1829.7 ± 91.05 g was observed for the animals that received the D2 diet than for those on all other diets. The somatic digestive index, intestinal quotient, hepatosomatic index, visceral fat index, and survival were not significantly influenced (P > 0.05) by dietary treatment (Table 4).

The rate of protein deposition was higher for animals which were fed with the D2 diet than for those fed all other diets (Table 4), but did not differ between the D1 and D4 diets, and was lowest for animals fed the diet D3. In terms of the deposition of lipid, no differences were found among the treatments. (Table 4)

DISCUSSION

The use of fish waste is essential for the maintenance of the quality of the continental waters, and is also very important and essential for the maintenance of commercial fish farming (KUMAR *et al*., 2017). However, when we compare the quality of fish produced with diets of meat-and-bone meal or those fed fish meal against those produced from commercial fisheries (which would be the same as those offered on the market), we find similar results. However, when we compare the use of fish silage (ENKE *et al*., 2009) among these industries we find superior parameters (weight, total length, daily weight gain, and specific growth rate) among fish that are raised on fish meals.

The results obtained in this study are related to the amino acid balance of the D2 diet, which has more lysine than the others. Lysine is an amino acid that is present in high proportions in muscle tissue, and thus the lysine that forms the diet is used primarily for the deposition of muscle tissue (FURUYA *et al*., 2006; CHILDRESS *et al.,* 2015); this leads to fish on higher-lysine diets producing more tissues.

In the diets tested, a low percentage of soybean oil (Figure 2) was used, in addition to the amount of oil already contained in animal meal. Soybean oil has high levels of 18: 2n–6 fatty acids, so inclusion of adequate amounts of soybean oil can improve the growth of fish, but also leads to high percentage increases in lipid deposition (LI *et al.*, 2016).

The highest amount of oil present in the diet was derived from the animal meal, which in the diets of fish meal consisted of approximately 5% fish oil. The oil of freshwater fish is characterized by high proportions of n-6 PUFAs, especially linoleic acid and arachidonic acid (SOUZA *et al*., 2007), which are essential for the proper development of fish. This amount of fish oil combined with soybean oil in the diet provided a good, balanced diet with essential fatty acids for the proper development of animals, while also providing greater growth in the animals that were fed with the D2 diet.

Consumption of D2 food offered in the diet was faster than that of other food types, which may have reduced nutrient losses (HAWKYARD *et al.*, 2015) and contributed to the excellent performance of the animals in this diet treatment group. The fish fed with the D2 diet showed higher specific growth rate, and this diet showed a better ratio of lysine/methionine. The growth of tilapia was positively influenced when 16% of waste meal from tilapia was included in their feed by BOSCOLO *et al*. (2010), which they attributed to the greater amount of methionine included in this diet; they thus concluded that waste meal is a good source of amino acids and phosphorus. When a fish diet has an amino acid profile with adequate levels of lysine and methionine, these probably result in rapid growth of the animals (ENYIDI *et al*., 2017).

In terms of the deposition of lipid, no differences were found between treatments, which was likely because the diets had the same lipid content and all relative energy / protein ratios were suitable for this species. The catfish metabolism may be protein-sparing when there is enough lipid for its energy utilization (ENYIDI *et al*., 2017). The energy / protein ratio considered optimal for silver catfish, according SALHI *et al*. (2004), is 8.8 kcal g^{-1} for diets with 37% crude protein. The records for most studied species range from 84-105 g digestible protein Mcal $^{-1}$ of digestible energy (NRC, 2011). A proper balance of protein and energy improves growth rates and feed and protein efficiency, minimizes excessive accumulation of lipids and glycogen in the liver and somatic tissues, and minimizes the undesirable production of nitrogenous wastes (ALMEIDA BICUDO *et al*., 2009).

Higher values for specific growth rate and apparent feed conversion were found by ABDUL KADER *et al*. (2011) using a diet consisting of 24.5% of a diet equivalent to D1 in the present study. The main factor driving feed intake responses and metabolic use of the diets is the total availability of energy, amino acids, and protein, and not the specific quality of one of the ingredients (ENYIDI *et al*., 2017). In a study of fish meal type produced from fish processing waste, OLIVEIRA FILHO and FRACALOSSI (2006) mentioned that this meal is most easily obtained in Brazil, and to the silver catfish the digestibility of such meals were 77.7% CP, 74.8% of GE, and 58.6% of DM. Based on animal performance, it can be inferred that waste meal of silver catfish has superior digestibility for this species than the waste meal available on the market today. ALLAN *et al*. (2000) observed that when fish meal is made with whole fish, it has high digestibility values (above 80%) for both omnivores and carnivores, as fish meal provides high levels of essential amino acids and fatty acids, low carbohydrate levels, and few anti-nutritional factors.

The digestibility of meat and bone meal was studied by SIGNOR *et al*. (2010) for tilapia, and they concluded that the digestibilities of protein and energy were 57.42% and 59.24%, respectively. This may be an indication that the better results for the use of fish waste meals in relation to meat and bones in the present study was due to increased digestibility of the nutrients in their composition. According to BOSCOLO *et al*. (2010), the correct use of waste fish and its inclusion as a meal in animal nutrition are among the best options for economic development of diets that meet their requirements and could contribute to the development of organic production of fish within the framework of sustainable aquaculture.

The intraperitoneal fat index obtained indicate good, balanced diet, in that all of the protein consumed was converted into muscle, with no leftovers used for visceral fat accumulation. Other authors found higher fat indices (above 1.9%) when using pelletized or extruded diets for channel catfish feeds, differing in their feeding rates from our study (XU *et al*., 2017). Carcass yield was higher in this study than that found by PEDRON *et al*. (2008), and similar to that found by CORREIA *et al.* (2009) and LOSEKANN *et al*. (2008).

The use of up to 15% of waste meal in tilapia in the feed of Piavuçu (*Leporinus macrocephalus*) was tested by BOSCOLO *et al*. (2005), and led to their conclusion that the inclusion of tilapia meal in the diet did not impair growth performance of Piavuçu because it increased the level body protein and provided better nutritional quality. LAZZARI *et al*. (2006) tested protein sources for silver catfish, noting that diets with 30% fish meal plus yeast promoted a lower protein efficiency ratio (1.6) to that obtained with the use of D2 silver catfish waste (2.84).

CONCLUSIONS

The use of fish meal from the processing of silver catfish with viscera, with 30% inclusion in the diet, is a good choice for the feed of juveniles of this species. The use of waste from local native species contributes to the certainty of quality and origin of the material used, and moreover the reuse of this raw material contributes to the sustainability of aquaculture.

ACKNOWLEDGEMENTS

The authors give thanks to Capes for a Master's scholarship awarded to the first author (S.R.) and to CNPq for the scholarship of research productivity awarded to Prof. João Radünz Neto.

REFERENCES

ABDUL KADER, M.; BULBUL, M.; YOKOYAMA, S.; ISHIKAWA, M.; KOSHIO, S.; SAKHAWAT HOSSAIN, M.; AHMED, G.U.; ARSHAD HOSSAIN, M. 2011 Evaluation of meat and bone meal as replacement for protein concentrate in the practical diet for sutchi catfish, *Pangasius hypophthalmus* (SAUVAGE 1878), Reared under Pond Condition. *Journal of the World Aquaculture Society*, *42*(3): 287-296. **http://dx.doi.org/10.1111/j.1749-7345.2011.00466.x**.

ALLAN, G.L.; PARKINSON, S.; BOOTH, M.A.; STONE, D.A.J.; ROWLAND, S.J.; FRANCES, J.; WARNER-SMITH, R. 2000 Replacement of fish meal in diets for Australian silver perch, *Bidyanus bidyanus*: I Digestibility of alternative ingredients. *Aquaculture (Amsterdam, Netherlands)*, *186*(3-4): 293-310. **http://dx.doi.org/10.1016/S0044-8486(99)00380-4**.

ALMEIDA BICUDO, Á.J.; SADO, R.Y.; CYRINO, J.E.P. 2009 Growth and haematology of pacu, *Piaractus mesopotamicus*, fed diets with varying protein to energy ratio. *Aquaculture Research*, *40*(4): 486-495. **http://dx.doi.org/10.1111/j.1365-2109.2008.02120.x**.

AOAC – Association of Official Analytical Chemists. 1995 *Official methods of analysis*. 16th ed., Washington: AOAC. 1094p.

BOSCOLO, W.R.; HAYASHI, C.; FEIDEN, A.; MEURER, F.; SIGNOR, A.A. 2008 Apparent energy digestibility and meal nutrients from tilapia filleting industrial waste for the Nile, tilapia (*Oreochromis niloticus* L.). *Ciência Rural*, *38*(9): 2579-2586. **http://dx.doi.org/10.1590/S0103-84782008000900027**.

BOSCOLO, W.R.; HAYASHI, C.; MEURER, F. 2004 Apparent Digestibility of the Energy and Nutrients of Conventional and Alternatives Foods for Nile Tilapia (*Oreochromis niloticus*). *Revista Brasileira de Zootecnia*, *31*(2): 539-545. **http://dx.doi.org/10.1590/S1516-35982002000300001**.

BOSCOLO, W.R.; SIGNOR, A.; FEIDEN, A.; SIGNOR, A.A.; SCHAEFER, L.A.; REIDEL, A. 2005 Effects of Feeding Tilapia By-products Flour for Piauçu (*Leporinus macrocephalus)* fingerlings. *Revista Brasileira de Zootecnia*, *34*(6): 1819-1827. **http://dx.doi.org/10.1590/S1516-35982005000600004**.

BOSCOLO, W.R.; SIGNOR, A.A.; COLDEBELLA, A.; BUENO, G.W.; FEIDEN, A. 2010 Organic diet supplemented with fish residuum flour for Nile tilapia juveniles. *Revista Ciência Agronômica*, *41*(4): 686-692. **http://dx.doi.org/10.1590/S1806-66902010000400024**.

BLIGH, E.G.; DYER, W.J. 1959 A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*(8): 911-917. **http://dx.doi.org/10.1139/o59-099**. PMid:13671378.

CHILDRESS, C.J.; FULLER, S.A.; RAWLES, S.D.; BECK, B.H.; GAYLORD, T.G.; BARROWS, F.T.; MCENTIRE, M.E. 2015 Lysine supplementation of commercial fishmeal-free diet in hybrid striped bass *Morone chrysops x M. saxatilis* affects expression of growth-related genes. *Aquaclture Nutrition*, 22(4):738-744.

CORREIA, V.; RADÜNZ NETO, J.; LAZZARI, R.; VEIVERBERG, C.A.; BERGAMIN, G.T.; PEDRON, F.A.; FERREIRA, C.C.; EMANUELLI, T.; RIBEIRO, C.P. 2009 Crescimento de jundiá e carpa húngara criados em sistema de recirculação de água. *Ciência Rural*, 39(5): 1533-1539. **http://dx.doi.org/10.1590/S0103-84782009005000070.**

ENKE, D.B.S.; LOPES, P.S.; KICH, H.A.; BRITTO, A.P.; SOQUETTA, M.; POUEY, J.L.O.F. 2009 Use of fish silage flour in diets for the jundiá in the juvenile phase. *Ciência Rural*, *39*(3): 871-877. **http://dx.doi.org/10.1590/S0103-84782009005000006**.

ENYIDI, U.D.; PIRHONEN, J.; KETTUNEN, J.; VIELMA, J. 2017 Effect of Feed Protein: Lipid Ratio on Growth Parameters of African Catfish *Clarias gariepinus* after Fish Meal Substitution in the Diet with Bambaranut (*Voandzeia subterranea*) Meal and Soybean (*Glycine max*) Meal. *Fishes*, *2*(1): 1-12. **http://dx.doi.org/10.3390/fishes2010001**.

FURUYA, W.M.; SANTOS, V.G.; SILVA, L.C.R.; FURUYA, V.R.B.; SAKAGUTI, E.S. 2006 Digestible lysine requirements of Nile tilapia juveniles. *Revista Brasileira de Zootecnia*, *35*(3): 937-942. **http://dx.doi.org/10.1590/S1516-35982006000400001**.

GUILHERME, R.F.; CAVALHEIRO, J.M.O.; SOUZA, P.A.S. 2007 Chemical characterization and profile of the amino acids of the flour of shrimp head. *Ciência e Agrotecnologia*, *31*(3): 793-797. **http://dx.doi.org/10.1590/S1413-70542007000300028**.

HAWKYARD, M.; LAUREL, B.; BARR, Y.; HAMRE, K.; LANGDON, C. 2015 Evaluation of liposomes for the enrichment of rotifers (*Brachionus* sp.) with taurine and their subsequent effects on the growth and development of northern rock sole (*Lepidopsetta polyxystra*) larvae. *Aquaculture*, 441: 11-125. **http://dx.doi.org/10.1016/j.aquaculture.2015.02.012**.

KUMAR, S.; SÁNDOR ZS, J.; NAGY, Z.; FAZEKAS, G.; HAVASI, M.; SINHA, A.K.; DE BOECK, G.; GÁL, D. 2017 Potential of processed animal protein versus soybean meal to replace fish meal in practical diets for European catfish *(Silurus glanis*): growth response and liver gene expression. *Aquaculture Nutrition*, *23*(5): 1179-1189. **http://dx.doi.org/10.1111/anu.12487**.

LAZZARI, R.; RADÜNZ NETO, J.; EMANUELLI, T.; PEDRON, F.A.; COSTA, M.L.; LOSEKANN, M.E.; CORREIA, V.; BOCHI, V.C. 2006 Different protein sources for jundiá (*Rhamdia quelen*) feeding. *Ciência Rural*, *36*(1): 240-246. **http://dx.doi.org/10.1590/S0103-84782006000100037**.

LAZZARI, R.; RADÜNZ NETO, J.; PEDRON, F.A.; VEIVERBERG, C.A.; BERGAMIN, G.T.; LIMA, R.L.; EMANUELLI, T.; STEFFENS, C. 2008 Performance and fillet composition of jundiá (*Rhamdia quelen*) submitted to different diets in the rearing. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *60*(2): 477-484. **http://dx.doi.org/10.1590/S0102-09352008000200030**.

LEE, D.J.; PUTNAM, G.B. 1973 The response of rainbow trout to varying protein/energy ratios in a test diet. *The Journal of Nutrition*, *103*(6): 916-922. **http://dx.doi.org/10.1093/jn/103.6.916**. PMid:4705278.

LI, Y.; LIANG, X.; ZHANG, Y.; GAO, J. 2016 Effects of different dietary soybean oil levels on growth, lipid deposition, tissues fatty acid composition and hepatic lipid metabolism related gene expressions in blunt snout bream (Megalobrama amblycephala) juvenile. *Aquaculture*, 451: 16-23. **http://dx.doi.org/10.1016/j.aquaculture.2015.08.028.**

LOSEKANN, M.E.; RADÜNZ NETO, J.; EMANUELLI, T.; PEDRON, F.A.; LAZZARI, R.; BERGAMIN, G.T.; CORRÊIA, V.; SIMÕES, R.S. 2008 Feeding of jundiá with diets containing rice, canola or soybean oils. *Ciência Rural*, *38*(1): 225-230. **http://dx.doi.org/10.1590/S0103-84782008000100036**.

NRC – National Research Council 2011 *Nutrient requirements of fish and shrimp*. Washington: NRC. 392p.

OLIVEIRA FILHO, P.R.C.; FRACALOSSI, D.M. 2006 Apparent digestibility coefficients of feed ingredients for jundiá juveniles. *Revista Brasileira de Zootecnia*, *35*(4): 1581-1587. **http://dx.doi.org/10.1590/S1516-35982006000600002**.

PEDRON, F.A.; RADÜNZ NETO, J.; EMANUELLI, T.; SILVA, L.P.; LAZZARI, R.; CORRÊIA, V.; BERGAMIN, G.T.; VEIVERBERG, C.A. 2008 Rearing of jundiá fed with diets containing soy or cotton hull. *Pesquisa Agropecuária Brasileira*, *43*(1): 93-98. **http://dx.doi.org/10.1590/S0100-204X2008000100012**.

ROSSATO, S.; LAZZARI, R.; LIBERALESSO DE FREITAS, I.; MASCHIO, D.; CORRÊIA, V.; RADÜNZ NETO, J. 2014 Diferentes níveis de incorporação de farinha de resíduos de jundiás (Rhamdia quelen) cultivados na dieta. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 66(3): 894-902. **http://dx.doi.org/10.1590/1678-41625678**.

SALHI, M.; BESSONART, M.; CHEDIAK, G.; BELLAGAMBA, M.; CARNEVIA, D. 2004 Growth, feed utilization and body composition of black catfish, *Rhamdia quelen*, fry fed diets containing different protein and energy levels. *Aquaculture (Amsterdam, Netherlands)*, *231*(1-4): 435-444. **http://dx.doi.org/10.1016/j.aquaculture.2003.08.006**.

SHYONG, W.J.; HUANG, C.H.; CHEN, H.C. 1998 Effects of dietary protein concentration on growth and muscle composition of juvenile *Zacco barbata. Aquaculture (Amsterdam, Netherlands)*, *167*(1-2): 35-42. **http://dx.doi.org/10.1016/S0044-8486(98)00313-5**.

SIGNOR, A.A.; SIGNOR, A.; BOSCOLO, W.R.; FEIDEN, A. 2010 Meat and bone meal to feed Nile tilapia larvae. *Ciência Rural*, *40*(4): 970-975. **http://dx.doi.org/10.1590/S0103-84782010005000059**.

SILVA, R.F.; KITAGAWA, A.; SÁNCHEZ VÁZQUEZ, F.J. 2016 Dietary self-selection in fish: a new approach to studying fish nutrition and feeding behavior. *Reviews in Fish Biology and Fisheries*, *26*(1): 39-51. **http://dx.doi.org/10.1007/s11160-015-9410-1**.

SOUZA, S.M.G.; ANIDO, R.J.V.; TOGNON, F.C. 2007 Fatty acids Omega-3 and Omega-6 in fish nutrition – sources and relations. *Revista de Ciências Agroveterinárias*, *6*(1): 63-71.

TACON, A.G.J. 1996 Trends in aquaculture production, with particular reference to low-income food-deficit countries 1984-1993. *Food Aquaculture Newsletter*, *12*(1): 6-9.

VIDOTTI, R.M.; GONÇALVES, G.S. 2006 *Production and characterization of silage, meal and oil tilapia and its use in animal feeding*. São Paulo: Instituto de Pesca. Available from: <http://www.pesca.sp.gov.br./index.php/publicacoes/outros-textos-para-consulta>. Accessed on: 11 aug. 2017.

XU, H.; LI, X.; SUN, W.; CHEN, J.; GAO, Q.; SHUAI, K.; LENG, X. 2017 Effects of different feeding rates of extruded and pelleted feeds on growth and nutrient retention in channel catfish (*Ictalurus punctatus*). *Aquaculture International*, *25*(3): 1361-1372. **http://dx.doi.org/10.1007/s10499-017-0119-0**.