Apparent digestibility of fish meat and bone meal in Nile tilapia

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ADDITIONAL KEYWORDS

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SUMMARY

This paper was aimed to determine the apparent digestibility of crude protein, crude fat, gross energy, calcium and phosphorus of tilapia meat and bone meal (*Oreochromis niloticus*) (TMBM), the catfish meat and bone meal (*Ictalurus punctatus*) (CMBM), pintado cathfish meat and bone meal (*Pseudoplatystoma corruscans)* (PCMBM) and the African catfish meat and bone meal (*Clarias gariepinus*) (ACMBM) for Nile tilapia. For that, the indirect method was used, using chromium (III) oxide (Cr_2O_3), as an inert indicator incorporated in the ration of 1 g·kg^{-1}. Nile tilapia (400 fish) were distributed with 50±7.89 g (mean ± SD) in 20 conical tanks in a completely randomized experimental design, consisting of five treatments with four replications. The treatments consisted of a reference diet and four diets consisting of 800 g·kg-1 of reference diet and 200 g·kg-1 of the test ingredients. The PCMBM showed a better digestibility coefficients for crude protein, calcium and phosphorus, while TMBM obtained a higher value for digestible energy and crude fat. The highest mineral matter result was obtained from CMBM. The results of this study suggest that Nile tilapia has limited ability to digest and use the components in the evaluated ingredients. The presence of large amounts of structural collagen in these ingredients and their low digestibility may have caused reduction in the availability of calcium and phosphorus.

Digestibilidade aparente de farinha de carne e ossos de peixe para tilápia do Nilo

RESUMO

Este trabalho foi realizado com o objetivo de determinar a digestibilidade aparente da proteína bruta, extrato etéreo, energia bruta, cálcio e fósforo das farinhas de carne e ossos de tilápia do Nilo (*Oreochromis niloticus*), do catfish *(Ictalurus punctatus)*, do pintado (*Pseudoplatystoma corruscans*) e do bagre africano (*Clarias gariepinus*) para a tilápia do Nilo. Para tal, foi utilizado o método indireto, com o uso do óxido de cromo (III) (Cr_2O_3), como indicador inerte, incorporado na ração em 1 g·kg-1. Foram distribuídas 400 tilápias com 50±7,89 g (média ± DP) em 20 tanques cônicos em um delineamento experimental inteiramente ao acaso, constituído por cinco tratamentos com quatro repetições. Os tratamentos foram compostos de uma dieta referência e outras quatro dietas constituídas de 800 g·kg-1 da dieta referência e 200 g·kg-1 da farinha de carne e ossos de tilápias, catfish, pintado e bagre africano. A farinha de carne e ossos de pintado demonstrou melhor digestão para proteína bruta, cálcio e fósforo, enquanto a farinha de carne e ossos de tilápia obteve valor maior para extrato etéreo e energia digestível. Para matéria mineral, o maior resultado obtido foi para a farinha de carne e ossos de catfish. Os resultados deste estudo sugerem que a tilápia do Nilo apresenta limitada capacidade para digerir e utilizar os componentes presentes nas farinhas de ossos avaliadas. A presença de grande quantidade de colágeno estrutural nesses ingredientes e sua baixa digestibilidade pode ter causado redução na disponibilidade do cálcio e fósforo.

PALAVRAS-CHAVE ADICIONAIS

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INTRODUCTION

Aquaculture is gaining prominence in the agribusiness sector, showing high production growth when compared to other activities in the sector. The aquaculture production has increased at an annual average growth rate of 6.3%, while the extractive fishing has remained stagnant (FAO, 2014). With the high growth of aquaculture, the need for research to seek information about feed, and thus, meet the nutritional requirements of animals, then using highly quality ingredients in the diet formulation. Meeting the nutritional needs is essential for the full growth of the fish and minimal environmental impact.

Fish meal is the main animal origin protein ingredient used in the formulation of fish feed (Liu *et al*., 2012), with high levels of protein, fat and energy, low in fiber and rich in minerals (Pastore *et al*., 2013). However, fish meal is a limited and finite resource, and its excessive use is criticized by environmental organizations (Hardy, 2010). It being in low availability and high cost makes it necessary to search for alternative ingredients to lower cost without sacrificing growth performance of animals (Naylor *et al*., 2000).

Thus, the fish processing waste has shown to be an interesting alternative as a fish meal substitute. In fish slaughterhouses, the industrialization process produces large quantities of waste, which can be as high as 70% of the production, becoming necessary to make use of these by-products to avoid environmental impact and provide a new raw material for the nutrition industry. Studies have shown that the waste from fish slaughterhouses can be used to fed fish in form of meals and silage (Boscolo *et al*, 2001; Meurer *et al*, 2003; Santa Rosa, 2009). Residues from aquaculture are rich in valuable oils, minerals, enzymes, pigments, among others (Aguiar *et al*., 2014).

A waste with great potential is the mechanically separated meal (MSM), which can be used in a multitude of products, increasing the profit of processing plants (Vidal *et al*., 2011). However, the MSM production also generates waste (bone), which has the potential to be used in the production of meal, which can be used as a source of calcium and phosphorus in fish feed, as well as being a reducing factor of the cost of feed formulation.

According to Cho (1987), knowing the digestibility of raw materials, is the first step when it is intended to assess their potential for inclusion in fish diets, because the digestibility reveals data about the bioavailability of nutrients and energy of these ingredients that will be used in fish feed (Fracalossi and Cyrino, 2013).

The Nile tilapia (*Oreochromis niloticus*) is among the most farmed fish in the world and has shown highly desirable characteristics for good production performance, such as rusticity (Santiago, 1987), acceptance of artificial feed from the earliest stages of production (Zimmermann and Fitzsimmons , 2004), they adapt well to production in cages, dug ponds, *raceways*, or circular tanks (Meurer *et al*., 2002), excellent meat quality with good acceptance in the consumer market and is suitable for filleting industry (Boscolo *et al*., 2001).

Table I. Centesimal composition of experimental feeds (Composição centesimal das dietas experimentais).

Ingredients (g·kg^{-1})	Experimental diets				
	Reference feed	Tilapia meat and bone meal	African catfish meat and bone meal	Catfish meat and bone meal	Pintado catfish meat and bone meal
Soybean meal	332.5	264.9	264.9	264.9	264.9
Corn	312.6	248.0	248.0	248.0	248.0
Broken rice	100.0	80.0	80.0	80.0	80.0
Fish meal 55%	100.0	80.0	80.0	80.0	80.0
Wheat bran	72.6	57.1	57.1	57.1	57.1
Poultry by-product meal	61.6	49.3	49.3	49.3	49.3
Di-calcium phosphate	4.5	4.5	4.5	4.5	4.5
Salt	3.0	3.0	3.0	3.0	3.0
Anti-fungal	2.0	2.0	2.0	2.0	2.0
Chromium oxide	1.0	1.0	1.0	1.0	1.0
Antioxidant	0.2	0.2	0.2	0.2	0.2
Tilapia meat and bone meal	-	200.0	-	-	-
African catfish meat and bone meal	-	-	200.0	-	-
Catfish meat and bone meal	-	-	-	200.0	-
Pintado catfish meat and bone meal	-	-	-	-	200.0
Min. and vit. supplement[1]	10.0	10.0	10.0	10.0	10.0
Total	1000.0	1000.0	1000.0	1000.0	1000.0
Nutrients (g·kg^{-1})					
Dry matter	975.7	959.8	977.8	976.6	973.3
Crude protein[2]	342.2	340.3	341.6	341.1	342.4
Crude fat[2]	55.5	86.4	69.2	69.5	69.3
Mineral matter[2]	76.2	148.3	143.1	141.1	142.3
Calcium[2]	24.1	51.4	60.4	61.3	60.5
Phosphorus[2]	10.6	23.8	23.1	23.4	23.6
Gross energy (MJ·kg^{-1})*	17.32	17.53	17.19	17.23	17.22

Guarantee levels per kilogram: vit. A: 1200000 UI; vit. D_3: 200000 UI; vit. E: 12000 mg; vit. K_3: 2400 mg; vit. B_1: 4800 mg; vit. B_2: 4800 mg; vit. B_6:48000 mg; vit. B_{12}: 4800 mg; Folic acid: 1200 mg; Pantotenic acid: 12000 mg; vit. C: 48 mg; Biotin: 48 mg; Colin: 65 mg; Niacin: 24000 mg; Fe: 10000 mg; Cu: 600 mg; Mn: 4000 mg; Zn: 6000 mg; I: 20 mg; Co: 2 mg e Se: 20 mg.
[2]Based on dry matter.

Thus, this study was conducted in order to determine the apparent digestibility values of energy, protein, crude fat, calcium and phosphorus from Nile tilapia, catfish (*Ictalurus punctatus*), Pintado catfish (*Pseudoplatystoma corrunscans*) and African catfish (*Clarias gariepinus*) meat and bone meal as well for Nile tilapia.

MATERIALS AND METHODS

Fish meat and bones meals obtainment

The materials tested were fish meat and bone meal (FMBM), which were obtained from waste generated from mechanically separated meat (MSM) of Nile tilapia, African catfish, catfish and pintado catfish. The material used in the MBM preparation were obtained after MSM extraction from carcasses obtained from a local fish farm. The extraction of MSM was done in mechanical de-pulping machine, model HI-Tech 250. After extraction of the MSM, the meat and bone were placed in plastic bags and stored in a freezer at -18°C for further processing.

The preparation of the MBM was done at the Fish Technology Laboratory of Universidade Estadual do Oeste do Paraná. To create the FMBM, a process of drying the material in an forced ventilation oven for 72 hours at 55°C. After drying, all material was individually processed in a hammer-mill with 0.5 mm mesh sieve and immediately placed in plastic bags, identified, and samples taken for chemical analysis of dry matter, crude fat, crude protein , Mineral matter, calcium and phosphorus.

Experimental design

The digestibility trials were conducted at the Aquaculture and fish Nutrition Laboratory for Fish Management Study Group on Aquaculture (GEMAq), Universidade Estadual do Oeste do Paraná (UNIOESTE), *campus* of Toledo-PR. Were used 20 cylindrical tanks with 180 L each, the initial weight of the tilapias was 50±7.89 g (mean ± SD) in a density of 20 fish per tank. The fishes were distributed randomly, following a completely randomized design (CRD), consisting of five treatments (control; tilapia meat and bone meal (TMBM); African catfish meat and bone meal (ACMBM); catfish meat and bone meal (CMBM), and pintado catfish meat and bone meal (PCMBM) with four replications each, totaling 20 experimental units. The experiment was conducted until obtain an amount of 20 g of feces, taking 20 days to reach it. The feces collection method used was of Guelph modified (Pezzato *et al*., 2002).

Experimental diets

The diets were prepared using a practical extruded ration as a reference and a test extruded ration, which was composed of 800.00 g·kg^{-1} of the reference diet and 200.00 g·kg^{-1} of the ingredient to be tested, procedure adapted from (NRC, 2011) indication and added 1.00 g·kg^{-1} chromium oxide, used as inert marker. The energy levels and digestible nutrients were estimated based on the values observed by; Boscolo *et al*. (2008) and was prepared to contain at least 340.00 g·kg^{-1} crude protein and 16.74 MJ kg^{-1} of digestible energy **(table I)**.

For the preparation of the experimental diets, the ingredients were milled individually in a hammermill with 0.5 mm mesh sieve, weighed, homogenized, moistened with 220.00 g·kg^{-1} of water and extruded through a 3.0 mm die. Subsequently, the feed was dried in a forced ventilation oven (55°C) for 12 hours, cooled to room temperature, packed in plastic bags and stored at -18°C.

The fish were subjected to an adaptive period in the facilities, handling and feeding for seven days before the start of the experiment. The subjects were fed five times a day (8, 11, 14, 17 and 19:00 hours) until apparent satiation and submitted to the methodology of feces collection done daily at seven in the morning, 12 hours after the last feeding. The feces were frozen at -18°C until the beginning of analysis.

Fecal material was dried in a forced ventilation oven 55 °C for 72 hours, pre-ground, sieved to remove scales, and subsequently milled to perform the analysis of nutrients and chromium oxide.

Proximate and mineral analysis

The chemical and energy assessments in the feed, experimental diets and feces were carried out in the Food Quality Control Laboratory - LQA, UNIOESTE,

Table II. Centesimal analysis on dry matter of tilapia meat bone meal (TMBM), african catfish meat bone meal (ACMBM), catfish meat bone meal (CMBM) and pintado catfish meat bone meal (PCMBM) (Composição centesimal na matéria-seca da farinha de carne e ossos de tilápia (TMBM), bagre africano (ACMBM), catfish (CMBM) e pintado (PCMBM)).

Variables	Tilapia meat and bone meal	African catfish meat and bone meal	Catfish meat and bone meal	Pintado catfish meat and bone meal
Dry matter	973.8^{NS}	972.5^{NS}	975.4^{NS}	974.7^{NS}
Crude protein	358.8 ± 5.5^{c}	372.1 ± 9.8^{b}	390.3 ± 6.2^{a}	380.3 ± 12.9^{ab}
Crude fat	229.6 ± 3.6^{a}	15.5 ± 0.4^{b}	14.2 ± 0.2^{c}	15.6 ± 0.2^{b}
Mineral matter	369.5 ± 3.5^{d}	404.8 ± 4.7^{a}	389.6 ± 1.4^{b}	381.5 ± 4.7^{c}
Calcium	135.9 ± 0.8^{b}	161.2 ± 4.9^{a}	136.1 ± 4.3^{b}	138.3 ± 2.5^{b}
Phosphorus	61.8 ± 1.3^{c}	73.4 ± 1.8^{a}	67.8 ± 1.2^{b}	66.7 ± 1.3^{b}
Ca/P	2.2^{NS}	2.2^{NS}	2.0^{NS}	2.1^{NS}
Gross energy (MJ·kg^{-1})	16.3^{NS}	15.4^{NS}	15.5^{NS}	15.6^{NS}

^{a,b}Values followed with different letters in same line are different by Tukey test (p<0.05); NS= not significant.

Toledo-Paraná, Brazil, in accordance to protocols approved by AOAC (2005). The dry matter content was calculated by using an oven at 105°C until constant weight (Tecnal, model TE-394/2), the Mineral matter by sample calcination at 550°C (TRADELAB, model 200D TLA), while the lipid content was obtained by the specific solvent (petroleum ether) (Tecnal TE-044-5/50 model). The crude protein content was determined by the Kjeldahl method, using digestion system (Tecnal, TE-018 model) and distillation system (Tecnal, TE-0363 model). Gross Energy was determined using calorimeter pump (IKA, C Básic 2000), calcium was determined by Flame Atomic Absorption Spectrometry (F AAS) following the procedures recommended in the equipment manual (Cookbook Shimadzu, 2002). Phosphorous was determined by Molecular Absorption Spectrometry (MAS) using vandate-molybdate method and chromic oxide by methodology developed by Bremer Neto *et al*. (2005) using spectrophotometer (FEMTO, model 600 plus).

Digestibility analysis

The apparent digestibility coefficient, ADc, of energy and nutrients were determined using formulas described by Nose (1960):

$$ADc = 100 - \left(100 \cdot \frac{\%Cr_2O_{3d}}{\%Cr_2O_{3f}} \cdot \frac{N_f}{N_d}\right)$$

Where: $Cr_2O_{3\ d}$ = % chromium oxide in the diet; $Cr_2O_{3\ f}$ = % chromium oxide in the feces; N_d = diets nutrients; N_f = nutrients in feces.

The ADc_{ing} of energy and nutrients of the ingredients were calculated using the equation described by Cho and Slinger (1979):

$$ADc_{ing} = \frac{(100 \cdot AD_{td} - b \cdot AD_{bd})}{a}$$

Where: AD_{td} = apparent digestibility coefficient of diet with tested ingredient; AD_{bd} = apparent digestibility coefficient of basal diet; b = basal diet inclusion percentage; a = tested ingredient inclusion percentage.

Water quality parameters

The tank water was maintained at an average temperature of 25.0 ± 1.50°C; pH 6.27 - 6.73; dissolved oxygen 4.20 ± 0.50 $mg \cdot L^{-1}$, ammonia 0.04 ± 0.01 $mg \cdot L^{-1}$ and water conductivity 13.68 ± 0.12 $\mu S \cdot cm^{-1}$ respectively (YSI Plus professional multi parameter water quality meter device), calcium 3.87 ± 0.032 $mg \cdot L^{-1}$ and phosphorus 0.0062 ± 0.00012 $mg \cdot L^{-1}$, these factors within the comfort range for the species according to Boyd (1990).

Statistical analysis

At the end of the experiment the data was submitted to analysis of variance at 5% probability and in case of differences, applied Tukey test as a means of comparison, through statistical software SAEG (2007).

RESULTS AND DISCUSSION

Fish bone meal centesimal composition

In aquaculture production, there are many wastes product from fish processing, which are potential environmental polluters, but also potential ingredients that can be used to animals nutrition. Thus, it is worth highlight that fish processing, as in the slaughter and fish filleting operations, produce large amounts of waste, consisting of in treals, heads, skin and bones (Falch *et al*., 2006).

The bones from fish processing can be used as ingredients in fish feed in the form of bone meal. The centesimal composition of meat and bone meals (TMBM, ACMBM, CMBM and PCMBM) evaluated are presented in **table II**.

The meat and bone meal of catfish and pintado catfish showed higher crude protein values in its composition (390.30 and 380.30 $g \cdot kg^{-1}$, respectively), being classified as second quality meal, since they have less than 600 $g \cdot kg^{-1}$ of crude protein values in their chemical composition (Boscolo *et al*., 2008), but it may present an important biological value because they are derived from waste from filleting industries. The TMBM showed higher crude fat content and it may be related to the large amount of fat present in the by-product of tilapia, as the material used was not centrifuged prior

Table III. Apparent digestibility coefficient of ingredient on dry matter (Digestibilidade aparente dos ingredientes na matéria-seca).

Apparent digestibility coefficient (ADc) (%)	Ingredient			
	Tilapia meat and bone meal	African catfish meat bone meal	Catfish meat and bone meal	Pintado Catfish meat and bone meal
Dry matter	50.85 ± 1.92^{a}	50.16 ± 1.90^{a}	53.49 ± 2.02^{a}	55.27 ± 2.09^{a}
Crude protein	67.47 ± 1.24^{ab}	65.31±1.20^{b}	69.08 ± 1.27^{a}	69.09 ± 1.27^{a}
Crude fat	97.65 ± 2.41^{a}	96.18 ± 2.38^{ab}	89.82 ± 2.22^{c}	91.14 ± 2.25^{bc}
Mineral matter	50.18 ± 3.29^{a}	51.46 ± 3.38^{a}	53.85 ± 3.53^{a}	53.11 ± 3.48^{a}
Calcium	33.28 ± 4.19^{b}	25.29 ± 3.18^{b}	32.47 ± 4.09^{b}	45.64 ± 5.75^{a}
Phosphorus	37.44 ± 2.09^{c}	47.62 ± 2.66^{ab}	44.07 ± 2.46^{b}	52.21 ± 2.91^{a}
Energy	84.10± 1.23^{a}	82.58±1.55^{a}	77.90 ± 2.33^{b}	82.18 ± 2.21^{a}

[a,b]Values followed with different letters in same line are different by Tukey test (p<0.05). NS= not significant.

to making the bone meal. According to Martins *et al*. (2009), the higher fat content in the TMBM may be related to the low amount of crude protein in the same.

As for mineral matter content, ACMBM showed the highest value (404.80 $g \cdot kg^{-1}$) and therefore higher values for calcium and phosphorous (161.20 $g \cdot kg^{-1}$ and 73.40 $g \cdot kg^{-1}$, respectively). The Ca:P ratio of all FMBM are in accordance with the recommendations and the standardization of Sindirações (2013), establishing a maximum permitted ratio of 2.20:1.00. This board also provides that the feed should have phosphorus values higher than 38.00 $g \cdot kg^{-1}$, which is independent to the protein content of the product. As literature containing information for FMBM is scarce, and the BM had at least 40.00 $g \cdot kg^{-1}$ of P and Ca:P ratio not exceeding 2.20, it can considered as meat and bone meal (MBM) (AAFCO, 2014).

Apparent digestibility coefficient

Chemical analysis is the first step to determine the nutritional value of a food or feed ingredient (Maynard and Loosly, 1966). However, after ingestion, the use of the nutrients depends on the physiological aptitude of each species (Pezzato *et al*., 2004).

Aquaculture, as well as other agricultural activities, can cause pollution and environmental degradation, through degradation of the quality of receiving water bodies. In the farming of aquatic organisms, the potential polluting substances are coming from excrements and food scraps, which are converted to organic materials, carbon dioxide, ammoniacal nitrogen, phosphates and other compounds (Montoya *et al*., 2000). Thus, study of apparent digestibility of feed is important not only to achieve balanced diets that offer total support for growth and performance of cultured organisms, but as a way to reduce the emission of effluents in the farming environments, reducing the environmental impact of the same.

There was not observed significant differences between apparent digestibility of gross energy among the treatments evaluated. However, the apparent digestibility of the gross energy value of TMBM was the highest observed, this can be explained by the high fat content found in TMBM in our work. According to Furuya *et al*. (2001), a high presence of crude fat in the by-products and the oxidation of this fats results in greater energy production by metabolism way.

The knowledge of the nutritional composition of feeds used in animal nutrition and the availability of these nutrients allow a better nutritional balance of diets, with consequent improvement in health status and fish resistance created in environmental adversities of cropping system (Signor *et al*., 2010). Thus, the results of apparent digestibility of TMBM, ACMBM, CMBM and PCMBM for Nile tilapia, are described in **table III**.

The apparent digestibility coefficients of FMBM showed that there was a significant loss in nitrogen, Ca and P, through the feces, to the aquatic environment. Sugiura *et al*. (1998) emphasize that the low availability of Ca, unlike other minerals, may be due to the strict regulation of absorption, or even by the Ca precipitation in the intestinal lumen in the form of calcium phosphate and prevent its absorption. On the other hand, the animals used efficiently fat and gross energy contained in the evaluated diets.

The ADc of dry matter and Mineral matter of FMBM had showed no significant differences ($p>0.05$). While the apparent digestibility of crude protein, crude fat, Ca, P and gross energy, had shown significant differences ($p<0.05$), the MBM of catfish and pintado catfish had presented highest ADc of crude protein, lowest ADc values of this nutrient was to ACBM. Differences in the use of protein from different ingredients evaluated, even though all from the fish processing, may be explained, because the ingredients are not identical in their nutritional and biological value, with distinct amino acids rate, altering its digestibility (Wilson, 1985).

The CMBM had showed the worst ADc for gross energy and crude fat among evaluated feeds. The highest ADc values of Ca and P were observed for the PCMBM. The apparent digestibility of phosphorus is important, as is an essential macro-mineral for the full

Table IV. Comparison of the apparent digestibility coefficient (ADc) (%) of dry matter, energy, crude protein, crude fat, mineral matter and phosphorus of meat bone meal (MBM) for Nile tilapia presented in the literature (Comparação dos ADc (%) da matéria seca, energia, proteína bruta, extrato etéreo, matéria mineral e fósforo).

Ingredient	Dry matter	Energy	Crude protein	Crude fat	Mineral matter	Phosphorous	References
MBM 34%	93.64	32.18	33.69	8.9	42.64	-	
MBM 37%	94.15	34.49	37.4	10.6	39.62	-	
MBM 40%	94.86	36.64	40.17	11.57	36.77	-	(Xavier *et al*., 2014)
MBM 43%	95.25	39.67	43.48	13.16	33.83	-	
MBM 46%	95.64	41.86	46.38	14.46	30.91	-	
MBM	95.8	95.8	86.3	-	-	-	(Torres *et al*.,2010)
MBM	-	-	78.4	-	-	-	(Guimarães *et al*., 2008)
MBM	47	77.5	73.2	-	-	-	(Pezzato *et al*.,2002)
MBM	71.9	83.9	63.9	91.7	-	58	(Zhou *et al*., 2012)
MBM	66.49	77.37	78.84	-	-	-	(Engin *et al*., 2008)
MBM	69.9	78.4	82.6	-	-	-	(Wang *et al*., 2011)

growth and reproduction of fishes, being an important structural constituent of skeletal tissue (Roy and Lall, 2003), its deficiency impairs bone mineralization causing deformities in different areas of the body of the fishes, fed with diets deficient in this mineral. Besides being one of the most important nutrients in the eutrophication of farm environments, it is essential to reducing its excretion to the environment (Furuya *et al.*, 2001).

The apparent digestibility values of dry matter, crude protein and crude fat for all FMBM tested in this study were higher than those found by Xavier (2014), to evaluate the digestibility of commercial meat and bone meal (37% crude protein) for Nile tilapia. In the study of Zhou and Yue (2012), evaluating the digestibility of meat and bone meal for tilapia, they found nutritional balances of dry matter and higher P and crude protein values, crude fat and gross energy lower than those found in this work for the BMs. For carnivorous species feeding habits, there is the preference for the use of animal protein, were found in the literature higher values of ADc for crude protein compared to tilapia (74.60%) for *Sciaenops ocellatus* (McGoogan *et al.*, 1996), 81.8% for *Lepomis macrochirus* (Masagounder *et al.*, 2009), 90% for rockfish *Sebastes schlegeli* (Lee, 2002) and 87.36% for *Pseudoplatystoma reticulatum* (Silva *et al.*, 2013).

The difference between the apparent digestibility coefficients of nutrients from fish with different eating habits and different weight classes can be explained because the digestibility of foods may increase with the size of fish (mostly omnivores and herbivores), due to the relative length of the intestine, thereby prolonging the time of digestion and assimilation of nutrients (Ferraris *et al.*, 1986).

Compared to the ADc of tilapia for food presented in this paper, **table IV** presents values found in the literature ADc for tilapia of MBM.

The results of this study corroborate, in general, with those described in different investigations with tilapia for similar foods. Among the values published in literature it is observed variations in the values of the ADc, which according to the researchers may be caused by differences in methodologies for the determination of the digestibility coefficients, among others, the processing of the diet, differences in the levels of inclusion of tested ingredient , feed grade used (Anderson *et al.*, 1995;. Boscolo *et al.*, 2008;. Furuya *et al.*, 2001; Guimarães *et al.*, 2008; Masagounder *et al.*, 2009), form of feces collection (Meurer *et al.*, 2003), fish size, the equation used to calculate the coefficients (Foster, 1999) and the process of preparation of experimental diets (Allan *et al.*, 2000).

The ADc of the dry matter allows an estimate digestibility of ingredients evaluated and low values may indicate a large amount of low digestible components present in the ingredient (Li *et al.*, 2013), indicating the amount of solid waste that will be thrown into water bodies, making it possible to evaluate the environmental impact of aquaculture activity. Solid waste undergoes anaerobic degradation and this means that there is a deterioration in the quality of the soil, causing changes in the local benthic ecosystem (Sugiura *et al.*, 2000).

The protein in MBM tested had presented low value of ADc, because the presence of collagen in the bones, in addition to the large amount of mineral matter (Bureau *et al.*, 1999; Boscolo *et al.*, 2004; Eyng *et al.*, 2011).

The availability of Mineral matter varies widely because it is dependent on the species and feed employed (NRC, 2011). According to Rodehutscord *et al.* (2000), the digestibility of P is dependent on the concentration of the Mineral matter and the P concentration in the ingredient, being higher in ingredient with smaller Mineral matter and P content, due to the fact each species has a great amount of use of this mineral, the excess being eliminated. Differences in the use of minerals can be related to the amount of collagen present in each FMBM.

Thus, digestibility studies have great importance for the feed processing for use in aquaculture (Jones and De Silva, 1997) and it is one of the primary factors to evaluate the ability of a specie to utilize nutrients in the feed in question (Hanley, 1987), and may be a potential indicator of energy and nutrients available for growth, maintenance and reproduction of the animal, besides level of indigestible nutrients for the assessment of waste released by aquaculture (Cho, 1993). In addition, studies on the digestibility of protein and energy of the main products and by-products produced in Brazil used in the feed formations are of fundamental importance in the nutritional and economic aspects, resulting in greater precision in balanced diets for aquatic organisms and making viable the use of by-products from agribusiness (Abimorad and Carneiro, 2004).

The determination of apparent digestibility of ingredients and complete feeds is a prerequisite for further study as the inclusion levels for the various stages of development of the studied species (Boscolo *et al.*, 2002).

The results of this study suggest that Nile tilapia has limited ability to digest and utilize the components present in the evaluated FMBM. Large amounts of collagen and its low digestibility may have caused reduction in the availability of Ca and P.

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