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Digestibility of nutrients and energy of cultivars of forage palm for growing Nile tilapia

Digestibilidade de nutrientes e energia de variedades de palma forrageira para tilápia do Nilo em crescimento

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Abstract

The objective was to evaluate the apparent digestibility coefficients of nutrients and energy of five cultivars of forage palm (*orelha de onça, miúda, gigante, IPA 20 and comum*) for growing Nile tilapia (110.02±16.17 g). The study design was completely randomized with five treatments, three replicates of eight fish per experimental unit. The diets were composed of 300 g/kg of each cultivar of the palm and 700 g/kg of the basal diet. Masculinized fish were distributed in circular feed tanks (150 L) and kept in closed circulation of water and constant aeration. The digestibility was estimated by indirect method, using 1.0 g/kg chromic oxide as an indicator of the diet and the feces was collected the day after the last feed in digestibility aquariums. The cultivars *comum* and *onça* presented the best values for dry matter digestibility (53.5%). The lowest value for crude protein digestibility was obtained to cultivar *gigante* (60%) and all cultivars tested showed gross energy digestibility below 50%. Nile tilapia has limitation on the digestibility of dry matter, gross energy, crude protein and amino acids of the cultivars of forage palm *IPA 20*, *miúda*, *gigante*, *comum* and *orelha de onça*.
Key words: Alternative feed, aquaculture, nutritional value, *Opuntia sp.*, *Oreochromis niloticus*, performance

Resumo

Objetivou-se avaliar os coeficientes de digestibilidade aparente de nutrientes e energia de cinco variedades de farelos de palma forrageira (*orelha de onça, miúda, gigante, IPA 20 and comum*) para tilápia do Nilo em crescimento (110,02 ± 16,17 g). As tilápias, masculinizadas, foram distribuídas em tanques circulares de alimentação (150 L), mantidos em circulação fechada de água e aeração constante. Foi montado um delineamento inteiramente casualizado, composto por cinco tratamentos,

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três repetições e oito peixes por unidade experimental. As rações teste foram compostas de 30% de cada cultivar da palma e 70% da ração referência. A digestibilidade foi estimada pelo método indireto, utilizando-se óxido crômico a 0,1% da ração como indicador, efetuando-se a coleta de fezes no dia posterior a última alimentação em aquários de digestibilidade. A cultivares orelha de onça e comum apresentaram os melhores valores para a digestibilidade matéria seca (53,5%). O menor valor para digestibilidade da proteína bruta foi obtido para cultivar gigante (60%) e todas as cultivares testadas apresentaram coeficiente de digestibilidade energia bruta inferior a 50%. A tilápia-do-nilo apresenta limitação quanto à digestibilidade da matéria seca, energia bruta, proteína bruta e aminoácidos das cultivares *IPA 20*, *miúda*, *gigante*, *comum* e *orelha de onça*.
Palavras-chave: Alimento alternativo, aquicultura, *Opuntia sp.*, *Oreochromis niloticus*, *Nopallea sp.*, valor nutritivo

Introduction

The production of tilapia in Brazil in 2010 was 155.5 tons (MPA, 2012) and the global production is estimated to increase to about 8.9 million tones by the year 2020 (TACON; METIAN, 2008). This rapid rise is due in part to the increasing intensification of farming systems that take advantage of the positive characteristics of the species such as resistance to high temperatures, low concentrations of dissolved oxygen and high concentration of ammonia in water, easy to obtain larvae, beyond its organoleptic properties (MEURER et al., 2002; JUSTI et al., 2005; SILVA et al., 2006). That makes it a good choice for the semi-intensive and intensive grow-out strategies. Subsequently, the improving of a practical diet for Nile tilapia is necessary (AHMAD; ABDEL-TAWWAB, 2011)

Fish production costs in the intensive system may exceed 50% (GUIMARÃES; PEZZATO; BARROS, 2008). In this sense, agriculture by-products represent a viable alternative from the nutritional and economical points of view, and may lower total costs of fish production. One of the attempts to reduce feed costs includes the use of alternative ingredients with good availability and attractive pricing on the market. For this reason, researches have been developed for evaluating the digestibility of different by-products for Nile tilapia (SANTOS et al., 2010; BRAGA et al., 2010; SANTOS et al., 2009; CAVALHEIRO; SOUZA; BORA, 2007; KÖPRÜCÜ; ÖZDEMIR, 2005; PEZZATO, et al., 2004; RICHTER; SIDDHURAJU; BECKER, 2003).

One of the feedstuff with potential use in aquaculture is the palm bran, which belongs to the Cactaceae family and the genus *Opuntia* and *Nopallea*. The palm bran stands out for its use in animal feed, especially in arid and semi-arid environments due to their characteristics such as resistance to the rigors of climate and prolonged droughts, and its nutritional characteristics. However there is limited information about the nutritional value of palm bran to farmed fish.

Confined fish need food in sufficient quantity and quality for appropriate reproductive and productive performance, without damage to the environment (FURUYA et al., 2010; BOMFIM et al., 2008). Thus it is important to know the nutrients digestibility in formulating feeds (FURUYA et al., 2001). Also, according to Kleemann, Barros and Pezzato (2009), crude protein digestibility coefficients do not reflect most amino acids digestibility coefficients. Thus, for a more precise and economic formulation of feeds, digestible amino acids values must be used.

In this context, the aim of this study was to assess the digestibility of dry matter, crude protein, gross energy and amino acids of five cultivars of forage palm (*orelha de onça*, *miúda, gigante*, *comum* and IPA 20) for growing Nile tilapia.

Material and Methods

The experiment was carried out at the Laboratory of Fish Nutrition and Feeding (Aquanut), of Universidade Estadual de Santa Cruz-UESC

(14°47′50″S, 39°2′8″W), from January through February, 2011. The study design was completely randomized with five treatments and three replicates to evaluate the digestibility of the following cultivars of forage palm: *orelha de onça*, *miúda*, *gigante*, *IPA 20* and *comum.* Samples of palm cultivars after harvest, were cut to pieces of 5 cm and dried under forced ventilation (55 °C) for 72 hours. After, the samples were ground in mills knife using a 1 mm sieve mesh.

A group of 48 masculinized specimens of Nile tilapia (*Oreochromis niloticus)* with mean weight of 110.02±16.17 g, was provided by Aguavale Farm, Ituberá, Bahia, Brazil. The physical structure was made up of cages (60 L) installed in feeding tanks (150 L), supplied in continuous flow (0.084 m^3/h) of water in a closed circulation system with biological filtration, through constant aeration (aerator Mod. CV-101R, VENTBRAS Ind. Eletrometalúrgica Ltda, SP, BR) and controlled photoperiod (12 h of light). The fish remained in the 150 L feeding tanks during the adaptation period for each experimental diet (four days) and were fed three times a day. Residues were siphoned off during this period every day. The 200-L digestibility aquariums, conical-bottomed tanks, equipped with a valve and glass collector (100 mL) dip in a polystyrene box with ice were used as proposed by Portz and Cyrino (2004), to collect fish faeces.

The physic-chemical variables of water – pH (7.0±0.1), temperature (26.8±0.43ºC) and dissolved oxygen (7.2±1.43 mg/L) – were monitored daily during the whole experimental period by means of multi-parameter digital equipment (YSY model63-10FT and YSY model55-12FT, YSI Corporation, Owings Mills, MA, USA).

The feeds were prepared by the computer program SUPER CRAC® (Viçosa, MG, BR), from the apparent digestibility coefficient values of ingredients used obtained for Nile tilapia, according to Furuya et al. (2010), beyond to cultivars of forage palm evaluated. Indirect method with partial collection of fish feces was used, and test feeds were prepared with the bran made from each palm cultivar, added to the reference feed in the proportion of 300 g/kg (Table 3). To determine the apparent digestibility coefficients, 1.0 g/kg of chromium oxide (Cr_2O_3) indicator was added to reference and test feeds, according to Nose (1966).

For the manufacture of animal feed, the ingredients were ground with knife grinder with 0.5 mm sieve, being later homogenized in accordance with the wording of each feed. Following to that soybean oil and water at 40ºC were added to moisten the mixture. The feeds were then granulated in pellet mill with frequency inverter (3 mm matrix) and dried in an oven with forced air (55ºC) for 24 h.

After adaptation period, fish were fed with the test diets at five daily meals. Fish were transferred to the digestibility aquaria (200 L) 20 minutes after the last meal, where they remained overnight. Feces were collected the following morning (7:00 a.m.). One sample of feces from each aquarium was composed of a set of four collections series performed individually. The excess water in the collectors was eliminated and the remaining material was dried under forced ventilation (55 °C) for 36 hours. The removal of the scales with the aid of tweezers and a 0.5 mm sieve was performed and the material was stored at a freezer (-10ºC), until the chemical analyses were performed.

Crude protein, gross energy and dry matter analyses of experimental feeds and fish excreta were conducted at Laboratory of Animal Nutrition and Aquanut of UESC, according to AOAC (2000) (Table 1). Analyses of forage palm bran amino acids (Table 2), experimental feeds and fish excreta was carried out at the laboratory of Ajinomoto do Brasil Indústria e Comércio de Alimentos Ltda, using HPLC – High Performance Liquid Chromatography.

Table 3. Formulation and chemical composition of reference diet (in the natural matter).

Ingredient	(g/kg)
Soybean meal	290.0
Fish meal	215.8
Wheat meal	210.0
Corn starch	138.1
Corn	127.4
Vitamin and mineral premix[1]	10.0
Soybean oil	8.5
BHT[2]	0.2
Chromium oxide III	1.0
Ingredient test	0.0
Calculated value	(g/kg)
Crude protein	290.7
Digestible protein	260.0
Digestible energy (Kcal/Kg)	3004
Fat	40.4
Crude fiber	40.0

[1] Vitamin and mineral premix. Guarantee level per kg of product: vit. A = 6,000,000 UI; vit. D3 = 2,250,000 UI; vit. E = 75,000 mg; vit. K3 = 3,000 mg; vit. thiamin = 5,000 mg; riboflavin = 10,000 mg; vit. pyrodoxin = 8.000 mg; biotin = 2,000 mg; vit. C = 192,500 mg; niacin = 30,000 mg; folic acid = 3,000 mg; Fe = 100,000 mg; Cu = 600 mg; Mn = 60,000 mg; Zn = 150,000 mg; I = 4,500 mg; Co = 2,000 mg; Se = 400 mg

[2]BHT = Butylated hydroxytoluene

Source: Elaboration of the authors.

Table 1. Composition of the cultivars of forage palm bran offered (in the natural matter).

Cultivar	Dry matter (%)	Gross energy (kcal/kg)	Crude protein (%)	NDF[1] (%)	ADF[2] (%)
Orelha de onça	88.33	2,84	6.99	39.78	19.26
Miúda	89.22	3,03	12.71	30.61	11.03
Gigante	88.82	3,36	6.07	39.01	18.75
IPA 20	88.33	3,28	10.05	41.77	19.63
Comum	88.77	3,42	7.09	42.96	22.13

[1] Neutral detergent fiber

[2] Acid detergent fiber

Source: Elaboration of the authors.

Table 2. Amino acid compositions (g/100g) of the cultivars of forage palm bran (in the natural matter).

Amino acid	Cultivar of forage palm				
	Orelha de onça	Miúda	Gigante	IPA 20	Comum
Alanine	0.329	0.962	0.288	0.401	0.316
Arginine	0.238	1.167	0.239	0.410	0.114
Asparagine	0.568	1.647	0.485	0.715	0.548
Cystine	0.100	0.298	0.082	0.139	0.100
Glutamine	0.765	2.494	0.665	0.913	0.775
Glycine	0.304	1.225	0.261	0.354	0.260
Histidine	0.095	0.397	0.093	0.190	0.099
Isoleucine	0.253	0.684	0.220	0.344	0.240
Leucine	0.450	1.294	0.401	0.617	0.436
Lysine	0.301	0.921	0.254	0.427	0.285
Methionine	0.088	0.352	0.145	0.139	0.076
Phenylalanine	0.296	0.816	0.264	0.447	0.272
Serine	0.296	0.968	0.250	0.404	0.292
Threonine	0.268	0.712	0.226	0.365	0.267
Tyrosine	0.177	0.516	0.155	0.282	0.154
Valine	0.331	0.847	0.281	0.395	0.313

Source: Elaboration of the authors.

Chromium oxide content in feeds and excreta were determined by atomic absorption at Laboratory of Animal Nutrition of EMBRAPA, Dourados, Mato Grosso do Sul, Brazil. The apparent digestibility coefficients (ADC) were calculated according to Köprücü and Özdemir (2005):

$$ADC = 100 \times [1 - (F/D) \times (Di/Fi)]$$

$$ADC_I = [ADC_T - (0.7 \times ADC_R)]/0.3$$

where: D = % nutrient or diet energy; F = % nutrient or feces energy; Di = % marker (Cr_2O_3) in the diet; Fi = % marker (Cr_2O_3) in feces, ADC_T = % apparent digestibility coefficient of nutrient or energy in the test diet; ADC_R = apparent digestibility coefficient of nutrient or energy in the reference diet; I = test ingredient under investigation.

The data obtained were subjected to ANOVA at 5% of significance level. In case of differences, it was applied the Tukey test by using the PROC MIXED do SAS (*Statistical Analysis System*, version9.0).

Results and Discussion

Apparent digestibility coefficients (ADC) of dry matter, crude protein, gross energy and amino acids presented statistical differences ($P<0.05$) between the cultivars of forage palm bran studied (Table 4). Cultivars *orelha de onça* and *comum* presented similar dry matter ADC and were higher ($P<0.05$) than *gigante*, IPA 20 and *miúda*. The cultivar *gigante*, in turn, was higher ($P<0.05$) than cultivars *IPA 20* and *miúda*.

Dry matter ADC of some cultivars of palm bran studied (*orelha de onça* and *comum*) were higher than those obtained for traditional ingredients used in Nile tilapia feeds, such as corn (52.3%) and corn starch (48.7%) (PEZZATO et al., 2002) and wheat bran (45.0%) (GUIMARÃES; PEZZATO; BARROS, 2008). It was observed that the results observed in this study, when compared to dry matter ADC obtained with alternative products for Nile tilapia, for all palm cultivars studied, were higher than cocoa bran (43.9%) (BRAGA et al., 2010) and lower than triticale (70.9%) (TACHIBANA et al., 2010).

Table 4. Apparent digestibility coefficients (%) of the cultivars of forage palm bran for Nile tilapia.

Parameter	Cultivar of forage palm					CV(%)
	Orelha de onça	Miúda	Gigante	IPA 20	Comum	
Dry matter	54.04[a]	47.92[c]	50.02[b]	48.29[c]	53.08[a]	0.92
Crude protein	66.63[ab]	73.34[ab]	60.04[b]	75.43[a]	78.21[a]	7.21
Gross energy	49.65[a]	45.46[ab]	46.48[ab]	43.02[b]	47.55[ab]	4.96

Means within lines followed by different letters statically differ by Tukey test at 5% of probability.
Source: Elaboration of the authors.

The variations between dry matter ADC presented between palm cultivars may be due to the presence of tannin. In a study conducted by Cardador-Martínez, Jiménez-Martínez and Sandoval (2011) with cactus pear (*Opuntia* spp.) wastes was observed that tannins were the major phenolics in cactus pear seeds accounting for almost 50% for all cultivars. According to Pinto et al. (2000), tannin concentration equal to or higher than 4.6 g/kg in feed significantly decreases dry matter ADC in Nile tilapia.

As regards crude protein ADC, cultivars *IPA 20* and *comum* were, on average, 27.9% higher (P<0.05) in relation to *gigante*, but did not differ (P>0.05) from cultivars *orelha de onça* and *miúda*. When compared to the traditional feeds used in the manufacturing of tilapia feed, crude protein ADC for all cultivars found in this study were lower to those evaluated by Pezzato et al. (2002), for energetic sources like a corn (91.6%) and corn starch (91.9%) for Nile tilapia. However, when compared to the agro-industrial by-products tested by Braga et al. (2010) for the same species, we verified superiority in relation to the ADC of mesquite pod bran protein (51.6%), manioc leaves bran (49.8%) and cocoa bran (38.5%). The lower values of crude protein ADC, when compared to traditional ingredients, are possibly due to the presence of tannin that has an inhibiting action on digestive enzymes (PINTO et al., 2000).

As to gross energy ADC, the cultivar *orelha de onça* was 15.2% higher (P<0.05) than *IPA 20* and similar (P>0.05) to the other cultivars, which were similar (P>0.05) to *IPA 20*. A possibility to explain the variation between the results is the non-fiber carbohydrate present in cultivars. According to Shiau (1997) the intestinal absorption of carbohydrate is low when diets contain fiber, regardless of source. Meal frequency affects carbohydrate utilization in fish. Some carbohydrate metabolic enzymes are altered due to changes in meal frequency. The use of cultivars evaluated as possible substitutes for energy sources in feed formulation for tilapia must be done with discretion due to the limited ability to digest and absorb the energy fraction.

When compared to the ingredients commonly used for the manufacture of feeds, the gross energy values are lower than those obtained for wheat bran (91.3%), corn meal (83.9%), and corn starch (77.7%) by Pezzato et al. (2002) for Nile tilapia. On the other hand, as regards alternative ingredients, values were higher than cotton bran (39.6%), mesquite pod bran (30.5%), manioc leaves bran (29.3%) and cocoa bran (23.1%), obtained by Braga et al. (2010) for Nile tilapia, similar to those found by Biudes, Pezzato and Camargo (2009) using water lilies (42.3%) and lower than those found by Lima et al. (2011), who evaluated mango waste bran (76.9%), both for Nile tilapia.

In general, differences found in the ADC can be attributed to the high amount of minerals and fiber, such as lignin, cellulose, hemicellulose and pectin, and the tannin present in palm bran. Hilton, Atkinson and Slinger (1983) claimed that the high concentration of fiber in feed can result in lower feed ingestion and reduce digestibility of all nutrients present in the feed. Values lower than 50 g/kg do not influence crude protein and dry matter ADC (LANNA et al., 2004).

Cultivars that presented the higher (P<0.05) results of essential and nonessential amino acids ADC were *comum*, *IPA 20* and *orelha de onça*, in contrast to the cultivar *gigante*, that presented the worst (P<0.05) amino acids ADC. Essential and nonessential amino acids ADC were similar (P>0.05) for the cultivars *orelha de onça*, *IPA 20* and *comum*, with exception for phenylalanine and tyrosine (Table 5).

Table 5. Apparent digestibility coefficients of amino acids (%) of the cultivars of forage palm bran for Nile tilapia.

Amino acid	Cultivar of forage palm					CV(%)
	Orelha de onça	Miúda	Gigante	IPA 20	Comum	
Alanine	78.72[a]	73.04[b]	59.60[c]	78.54[a]	81.04[a]	1.52
Arginine	85.18[a]	86.53[a]	65.13[b]	87.82[a]	87.79[a]	1.95
Asparagine	84.11[a]	78.69[a]	62.50[b]	84.27[a]	84.34[a]	2.98
Cysteine	77.45[a]	75.54[a]	59.12[b]	76.23[a]	78.03[a]	3.02
Glutamine	86.14[a]	82.48[b]	64.71[c]	85.70[ab]	87.24[a]	1.53
Glycine	82.58[a]	77.44[b]	62.17[c]	79.94[ab]	83.11[a]	1.66
Histidine	79.91[a]	80.02[a]	61.10[b]	82.54[a]	81.39[a]	1.89
Isoleucine	78.03[a]	73.77[b]	59.73[c]	81.03[a]	81.03[a]	2.06
Leucine	76.54[ab]	73.74[b]	60.25[c]	79.26[a]	79.88[a]	1.85
Lysine	79.69[a]	75.73[b]	61.08[c]	80.41[a]	81.71[a]	1.42
Methionine	79.04[a]	78.27[a]	60.55[b]	83.60[a]	82.80[a]	3.13
Phenylalanine	74.52[b]	74.55[b]	59.88[c]	79.06[a]	79.73[a]	1.66
Serine	84.19[a]	79.61[b]	62.82[c]	82.74[ab]	84.19[a]	1.81
Threonine	78.14[a]	71.90[b]	59.34[c]	77.18[a]	78.46[a]	2.39
Tyrosine	71.53[c]	73.50[bc]	60.69[d]	78.33[ab]	80.40[a]	2.65
Valine	77.18[ab]	4.44[b]	59.30[c]	79.10[a]	79.86[a]	1.46

Means within lines followed by different letters statically differ by Tukey test at 5% of probability.
Source: Elaboration of the authors.

Among the essential amino acids, arginine presented higher ADC, corroborating the results obtained for Nile tilapia by Santos et al. (2010), who studied forage radish bran; Freire, Barros and Pezzato (2005) using low tannin sorghum and Ribeiro et al. (2011) for soybean bran, corn gluten and fishmeal. Cultivars *orelha de onça*, *miúda*, *IPA 20* and *comum* presented higher (P<0.05) arginine ADC in relation to the cultivar *gigante*.

The lower (P<0.05) ADCs for histidine, methionine was observed for the *gigante* cultivar, being in average 32.9% lower when compared to the other cultivars. ADC values of methionine of cultivars with higher values (*orelha de onça*, *miúda*, *IPA 20* and *comum*) were higher than the ADC obtained for corn (76.3%) (GUIMARÃES; PEZZATO; BARROS, 2008) and wheat (74.2%) (FURUYA et al., 2001) and lower than wheat bran ADC (86.7%) (GONÇALVES et al., 2007) for Nile tilapia. Despite the low methionine content presented by the palm cultivars studied, this amino acid presented high ADC, with exception for the cultivar *gigante*. According to Guimarães, Pezzato and Barros (2008) this is an indication that amino acids excess or imbalance not always reduces its bioavailability.

Digestibility values of amino acids lysine, threonine and isoleucine were, on average, 31.7% higher for cultivars *orelha de onça*, *IPA 20* and *comum*, in comparison with cultivar *gigante*. The cultivar *miúda* presented intermediary values. Values found for lysine ADC in this study were lower than those found by Furuya et al. (2001), Gonçalves et al. (2007) and Guimarães, Pezzato and Barros (2008) who evaluated soybean bran, gluten bran and cotton bran, respectively. When compared to energetic feeds, lysine ADCs for the cultivars with the higher values (*orelha de onça*, *miúda*, *IPA 20* and *comum*) were higher than those found by Guimarães, Pezzato and Barros (2008) for corn meal, wheat bran, rice bran and sorghum.

Cultivars *orelha de onça*, *miúda*, *IPA 20* and *comum* presented the highest ADCs ($P<0.05$) for leucine and valine, being, on average, 30.2% higher than the value observed for *gigante*. Values obtained for valine ADC were higher than those obtained for wheat bran (69.9%) and lower than soybean bran (89.4%) by Furuya et al. (2001).

Among nonessential amino acids, cysteine and asparagine presented higher ADC ($P<0.05$) for the cultivars *orelha de onça*, *miúda*, *IPA 20* and *comum* compared to the cultivar *gigante*. Amino acids glutamine, alanine, glycine and serine, found in the bran of palm cultivars, were more digestible in *orelha de onça*, *comum* and *IPA 20*, and less digestible in *gigante* and *miúda*. Tyrosine amino acid ADC was similar to cultivars *IPA 20* and *comum*, followed by *miúda* and *orelha de onça*; cultivar *gigante* presented the worst tyrosine digestibility.

The differences between the ADCs obtained for essential and nonessential amino acids in this study may be related to the tannin level present in the palm bran cultivars assessed. According to Mueller-Harvey and Mcallan (1992), tannin can exert a sequestering action on amino acids. This action can be observed in a study by Freire, Barros and Pezzato (2005), who evaluated low sorghum high tannin amino acids ADC do for Nile tilapia, obtaining higher ADC values for cultivars with lower tannin level.

Although Kleemann, Barros and Pezzato (2009) claim that crude protein ADC does not reflect most amino acids ADC, this study observed the same trend, as the cultivar *gigante* that presented the lowest protein ADC also presented the lowest amino acids ADC values.

Conclusion

Nile tilapia has limitation on the digestibility of dry matter, gross energy, crude protein and amino acids of the cultivars of forage palm *IPA 20*, *miúda*, *gigante*, *comum* and *orelha de onça*.

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