



Short Communication

Digestibility of agro-industrial byproducts in 200 and 300-g Nile tilapia¹

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ABSTRACT - The objective of the present study was to evaluate the apparent digestibility coefficients of dry matter (DM), crude protein (CP) and gross energy (GE) of the following agro-industrial byproducts: cassava leaf (*Manihot esculenta*), mesquite bean (*Prosopis juliflora*), cotton (*Gossypium* species), cocoa (*Theobroma cacao*), soursop (*Annona squamata*) and African oil palm cake (*Elaeis guineensis*) for Nile tilapia (*Oreochromis niloticus*). Fish from two weight classes (200±11 and 300±32 g) were stocked in tanks and fed a reference diet plus 30% of one tested byproduct with the addition of 0.1% chromic oxide. The fish were routinely moved to digestibility aquariums for feces collection, in a completely randomized design (n=3). The apparent digestibility coefficient (ADC) values between the two weight classes were similar, but differed between the byproducts for DM, CP and GE. The highest ADC_{DM}, ADC_{CP} and ADC_{GE} for 200-g and 300-g tilapias were, respectively, 0.58 and 0.53; 0.77 and 0.78; 0.66 and 0.62 for the soursop bran and 0.52 and 0.51; 0.77 and 0.80; 0.66 and 0.60 for the palm cake, respectively. The cotton and cocoa bran had the worst results of ADC of DM in two weight ranges (means of 0.34 and 0.37 g/100 g, respectively) while the mesquite bean had the lowest ADC of CP and GE, with means of 0.28 and 0.14 g/100 g for 200-g and 300-g tilapias, respectively. The byproducts analyzed may be used in formulating diets for Nile tilapia adults, observing their contributions to the digestibility of nutrients and energy for the species.

Key Words: alternative food, apparent digestibility, byproduct, nutritive value, *Oreochromis niloticus*

Introduction

Feeding accounts for 50% to 70% of the production costs in intensive fish farming systems (Pezzato et al., 2000), triggering the search for cheaper, alternative, locally available feedstuff (Silva et al., 2002). Several studies have demonstrated the importance of the use of these ingredients at levels that could guarantee adequate growth rates and consequent fish production (Oliveira et al., 1998; Boscolo et al., 2002; Meurer et al., 2003).

Digestibility is the ability of the animal to digest a given food or feed and absorb the nutrients and energy contained therein (Pezzato et al., 2002a). Tilapias are omnivorous fish that readily accept many types of processed feed (Boscolo et al., 2001). Because of the importance of tilapias for the world aquaculture, continuous efforts have been made to fine tune many aspects of their nutrition (Degani & Revach, 1991).

The coefficient of apparent digestibility (ADC) can be calculated by two methods. The indirect method involves the collection of indigestible excreta and using it as an indicator. The direct method measures the total amount of feed ingested and all excreta (Shiau et al., 1988; NRC, 1993; Meurer et al., 2003). However, measurements of all the consumed feed and all the feces are difficult to be achieved in the water, so the indirect method is commonly used (Morales et al., 1999). The objective of the present study was to determine the coefficients of digestibility of dry matter, gross protein and gross energy of six readily available agro-industrial byproducts by juvenile Nile tilapia (*Oreochromis niloticus*) in two weight classes (200 g and 300 g).

Material and Methods

A male-reversed population of Nile tilapia, Thai line, was divided into two weight classes (200 g and 300 g) and

distributed in a completely randomized design with 12 treatments, in a 6 × 2 factorial arrangement (feed × weight) and three replications.

The fish were housed in circular tanks (310 L) with a water recirculation system and a biological filter and constant aeration through linked porous stone with a 1 HP air compressor (Dancor®, RJ, Brazil). Water quality was measured daily before the first feeding using digital equipments (YSI Incorporated, OH, USA). All the water parameters were in the optimum range (temperature 26.8±0.6 °C, pH 6.3±0.7, dissolved oxygen 5.2±0.7 g mL⁻¹). An experimental unit consisted of a tank containing ten fish with a mean weight of 200.1±11.1 g and seven with a mean weight of 300.0±32.0 g.

The fish remained in the tanks throughout the adaptation period for experimental diet (three days) and the period during the day when they were fed. Residues were siphoned off during this period every day.

Six agro-industrial byproducts, which were bran obtained from the aerial parts of cassava (*Manihot esculenta* Crantz), mesquite bean (*Prosopis juliflora* (Sw.) DC), cotton (*Gossypium* species), cocoa (*Theobroma cacao* L.), soursop (*Annona squamata* L.) and African oil palm cake (*Elaeis guineensis* Jack.) (hereafter called palm cake) were selected and analyzed for their chemical composition: dry matter (DM), mineral matter (MM), crude protein (CP), gross energy (GE), acid detergent fiber (ADF) and neutral detergent fiber (NDF), according to methodology of the AOAC (1995) (Table 1).

Test diets consisted of 70% of the reference diet and 30% of the tested byproduct. Ingredients were milled in a 1-mm sieve (Hayashi et al., 1999) and mixed according to a formulation based on the NRC (1993), and the values of apparent digestibility coefficients for the Nile tilapia were reported by Boscolo et al. (2002), Pezzato et al. (2002a) and Furuya et al. (2010) (Table 2).

Table 1 - Composition of the byproducts offered in the experimental diets tested in the digestibility trial for 200 and 300-g Nile tilapia (*Oreochromis niloticus*)

Ingredient (bran)	DM (g kg ⁻¹)	CP (g kg ⁻¹)	MM (g kg ⁻¹)	GE (MJ kg ⁻¹)	CF (g kg ⁻¹)	ADF (g kg ⁻¹)	NDF (g kg ⁻¹)
Aerial part of cassava (<i>Manihot esculenta</i> Crantz)	927	219	65	19.5	245	253	384
Mesquite bean (<i>Prosopis juliflora</i> (Sw.) DC)	903	138	63	17.3	40	69	153
Cotton (<i>Gossypium</i> species)	921	276	35	18.3	332	280	531
Cocoa (<i>Theobroma cacao</i> L.)	918	130	61	16.0	260	340	411
Soursop (<i>Annona squamata</i> L.)	853	63	7.1	15.0	220	207	265
Palm cake (<i>Elaeis guineensis</i> Jack.)	931	158	12	18.4	569	301	743

DM - dry matter; CP - crude protein; MM - mineral matter; GE - gross energy; CF - crude fiber; ADF - acid detergent fiber; NDF - neutral detergent fiber.

Table 2 - Approximate composition of the reference diet used in the digestibility trial for 200 and 300-g Nile tilapia (*Oreochromis niloticus*)

Ingredient	(g kg ⁻¹)
Fish meal	300
Soybean meal	236
Wheat flour	129
Corn starch	114
Corn	100
Cotton meal	80
Soybean oil	31
Vitamin and mineral premix ¹	10
Antioxidant BHT	0.2
Chromium oxide III	1.0
Ingredient test	0.0
Calculated value	(g kg ⁻¹)
Digestible protein	280
Digestible energy (MJ kg ⁻¹)	13
Crude fiber	50
Fat	62

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.

BHT - butylated hydroxytoluene.

The ingredients mix was moistened with water at 35 °C and pressure-pelletized. Pellets were dried under forced ventilation (55 °C) for 24 hours, crushed, size-graded and stored.

After adaptation period, fish were fed with the test diets at five daily meals. For feces collection, the fish were transferred to the digestibility aquaria 20 minutes after the last meal, where they remained overnight. Seven 200-L digestibility aquaria, conical-bottomed tanks, equipped with a valve and glass collector (100 mL) dip in a polystyrene box with ice were used.

Feces were collected the following morning (7:00 a.m.). One sample of feces from each aquarium was composed of a set of five collections series performed individually. At an interval of eight days, feces were collected for a repetition of each test diet. The supernatant in the glass collectors was removed and the moist feces were transferred to aluminum bottles and dried under forced ventilation at 55 °C for 36 hours. Scales in the excreta were removed using a sieve with a 1 mm mesh and forceps. Dried feces were stored

in plastic recipients under refrigeration (4 °C) until analyses (AOAC, 1995). Chromic oxide concentrations were determined by atomic absorption (Williams et al., 1962).

The ADC of the tested byproducts was determined by the NRC (1993) procedure of the indirect method using 0.1% III chromic oxide (Cr₂O₃) added to the reference diet and test diets as indicator, calculated by the formulae utilized by Köprücü & 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 (Cr₂O₃) in the diet; Fi = % marker (Cr₂O₃) 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 submitted to analysis of variance and the differences between the means were determined by the Tukey test ($\alpha=0.05$). SPSS 12.0 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analyses.

Results and Discussion

Differences ($P<0.05$) between the ADC of the byproducts were observed for dry matter, crude protein and gross energy for both weight classes. However, ADC values for fish weight classes did not differ ($P>0.05$) (Table 3).

The highest ADC_{DM} registered for 200-g tilapia were represented by soursop bran and palm cake bran; soursop bran differed from cotton bran and cocoa bran. The highest ADC_{DM} for 300-g tilapia were also registered for soursop bran and palm cake, while the lowest values were registered for cassava, mesquite bean and cotton.

The ADC values for crude protein varied significantly for the different treatments. The highest ADC_{CP} values were for soursop bran, cotton bran and palm cake. These values did not differ significantly from each other, but in comparison to cocoa, mesquite bean and cassava for 200-g tilapias.

For 300-g tilapias, the highest ADC_{CP} were registered for palm cake, soursop and cotton bran, and did not differ statistically ($P>0.05$). The lowest ADC_{CP} were recorded for cassava and mesquite bean and differed from the other byproducts ($P<0.05$).

The GE digestibility was affected ($P<0.05$) in both weight classes. For 200-g tilapias, the soursop bran and palm cake presented a similar value. The smallest ADC_{GE} were recorded for mesquite bean. Cocoa, cassava and cotton presented intermediary values. The ADC_{GE} of soursop bran and palm cake were the highest values for 300 g-tilapias, and differed ($P<0.05$) from mesquite bean, cotton, cassava and cocoa, which registered the lowest ADC_{GE}.

Determination of digestibility of an ingredient is the first priority when evaluating its inclusion in a feed (Pezzato et al., 2002a). Although it presented the best ADC_{DM}, the soursop bran was less attractive as shown by visual observation of the apparent consumption of the diet containing this byproduct. The low attraction of the soursop bran can be explained by the presence of the alkaloids anonin and muricin, which are toxic to some animals (Cysne et al., 2006).

Oliveira et al. (1998) conducted an experiment with young Nile tilapia (15.32 g) and obtained an ADC_{DM} of 0.703 for palm cake, and the results were 0.185 and 0.197 greater than the findings of the present experiment, for tilapias with medium weight of 200 and 300 g, respectively. Oliveira et al. (1997) conducted an experiment with 180-g pacu (*Piaractus mesopotamicus*), another omnivorous species (Tesser & Portela, 2006) and found an ADC_{DM} of 0.548, a value similar to that obtained in the present study.

For cotton bran, the ADC_{DM} was less than that reported by Souza & Hayashi (2003) and Pezzato et al. (1988; 2002a), who worked with Nile tilapia (0.35, 0.75 and 100 g, respectively) and obtained coefficients of 0.702, 0.844 and 0.889, respectively. Falaye & Jauncey (1999), working with cocoa bran in the feeding of Nile tilapias (0.97 g), found an ADC_{DM} of 0.398, similar to that found in the present study.

The low digestibility of the cotton and cocoa bran might have been due the presence of high concentration of

Table 3 - Coefficients of apparent digestibility (g/100 g) of the dry matter (ADC_{DM}), crude protein (ADC_{CP}) and gross energy (ADC_{GE}) of the agro-industrial byproducts for Nile tilapia (*Oreochromis niloticus*) weighing 200 g and 300 g

Ingredient (bran)	Tilapia - 200 g			Tilapia - 300 g		
	ADC _{DM}	ADC _{CP}	ADC _{GE}	ADC _{DM}	ADC _{CP}	ADC _{GE}
Aerial part of cassava (<i>Manihot esculenta</i> Crantz)	0.444ab	0.368b	0.269b	0.260b	0.179c	0.223b
Mesquite bean (<i>Prosopis juliflora</i> (Sw.) DC)	0.431ab	0.332b	0.141c	0.303b	0.228c	0.143b
Cotton (<i>Gossypium</i> species)	0.353b	0.767a	0.292b	0.319b	0.772a	0.211b
Cocoa (<i>Theobroma cacao</i> L.)	0.361b	0.288b	0.243b	0.381b	0.367b	0.271b
Soursop (<i>Annona squamata</i> L.)	0.576a	0.769a	0.658a	0.531a	0.776a	0.621a
Palm cake (<i>Elaeis guineensis</i> Jack.)	0.518ab	0.767a	0.621a	0.505ab	0.801a	0.603a

Means followed by different letters in the columns differ ($P<0.05$) by the Tukey at 5% probability.

fiber and antinutritional factors in these byproducts. Younger fish probably showed decrease in digestibility as well, due to the presence of antinutritional factors and high levels of crude fiber in the feed.

Free gossypol, when present in large quantities in the diet, has shown to be toxic to monogastric animals, including fish (Barros et al., 2002). Gossypol in cotton bran can inhibit the activity of several enzymes (Beaudoin, 1985). Robinson et al. (1984) reported that the maximum concentration of free gossypol, which is 180 mg kg^{-1} , does not affect the growth of *Tilapia aurea*. Juvenile hybrid tilapia (*Oreochromis niloticus* × *O. aureus*) maintained adequate growth when fed with diets containing up to 337.6 g kg^{-1} (28.05 mg kg^{-1} of free gossypol) replacement of soybean meal by cottonseed meal (Yue & Zhou, 2008).

Cocoa bran contains antinutritional substances such as the alkaloids theobromine, theophylline and caffeine, and the inhibitor trypsin (Sotelo & Alvarez, 1991). The addition of cocoa bran in quantities exceeding 100 affects the production performance of tilapia (Falaye & Jauncey, 1999).

Also for 200-g tilapias, the low digestibility of cassava bran might be a result of the presence of antinutritional substances. Apparently fiber levels above 10% reduce the digestibility of the material (Shiau et al., 1988). In addition to the high proportion of fiber, one of the main limitations to the use of cassava bran is the presence of the cyanogenic glycosides, linamarin and lotaustralin (Borin et al., 2006).

Cassava bran was one of the least attractive byproducts and its digestibility was slightly lower than that of soursop bran. The smaller attraction might be due to the presence of tannins, which are astringent and reduce intake of the diet containing this byproduct (Fasuyi, 2005).

Oliveira et al. (1998) with Nile tilapia (15.3 g) and Oliveira et al. (1997) with *Piaractus mesopotamicus* (180 g) obtained a ADC_{CP} for palm cake of 0.915 and 0.752, respectively, and the latter were similar in value to the value obtained in the present study. Pezzato et al. (2002b) found ADC_{CP} for 100 g Nile tilapia, which varied from 0.817 to 0.857, in function of the size of the particle.

Pezzato et al. (2002a), in an experiment with juvenile tilapia (100 g), found an ADC_{CP} for cotton bran of 0.749, which was 1.8% and 2.3% lower than the values obtained in the present experiment with 200 and 300-g tilapias, respectively. Souza & Hayashi (2003), working with two omnivorous species (167 g-Nile tilapia) and 168-g piavuçu (*Leporinus macrocephalus*), obtained ADC_{CP} of 0.887 and 0.780, respectively. Variation in the cotton bran composition due to different processing and suppliers might also have influenced the comparison of the coefficients of the different studies.

Regarding the ADC_{CP} for 200 and 300 g-tilapias, the lowest values were found with cocoa, mesquite bean and cassava. The low digestibility of these byproducts might be a result of the high fiber percentage in the diet and the presence of antinutritional factors.

Soursop bran and palm cake presented the best ADC_{GE} values for 200 and 300 g-tilapias. For both weight classes, the lowest ADC_{GE} were for brans of mesquite bean, cocoa, cassava and cotton. The low digestibility obtained for mesquite bean bran can be explained by the presence of tannin (Mukhopadhyay, 1997). An additional reason for using byproducts is the reduced environmental impact of feed residues (Sugiura et al., 1998) and feces and metabolic residues of fishes (Silva et al., 2007).

Conclusions

Among the byproducts examined, soursop bran and palm cake presented the best coefficients of apparent digestibility for dry matter, crude protein and gross energy, for 200 g and 300 g tilapias. The byproducts analyzed may be used in formulating diets for Nile tilapia adult, observing their contributions on the digestibility of nutrients and energy for the species.

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