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Agroindustrial byproducts in diets for Nile tilapia juveniles[1]

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ABSTRACT - This study was conducted to evaluate performance and body composition of tilapia (*Oreochromis niloticus*) fed diets containing byproducts aerial parts of cassava meal (*Manihot esculenta*), mesquite pod meal (*Prosopis juliflora*), cocoa meal (*Theobroma cacao*) and palm kernel cake (*Elaeis guineensis*) and to analyze the economic viability of the feed. A total of 1,350 juvenile males (100 g) were distributed in 15 cages (1 m^3) in completely randomized design with five treatments (basal diet and four test diets) and three replicates. The following aspects were evaluated: final weight, total feed intake, total weight gain, feed conversion, specific growth rate, protein efficiency ratio and survival rate, dry matter, crude protein, fat and ash body, the average cost of feed per kilogram of weight gain and economic efficiency rate. No differences were observed for total consumption of food or survival rate. For other variables, the inclusion of cocoa and cassava meal impaired fish performance. No differences were observed for dry matter, crude protein and body ash. The lower body fat accumulation was recorded for the tilapia fed palm kernel cake. The best economic indicators were found to diets containing palm kernel cake. The byproducts evaluated can be used up to 150 g/kg in feed formulation, providing good performance and economic rate for Nile tilapia.

Key Words: economic evaluation, feed alternative, *Oreochromis niloticus*, productive performance

Introduction

Nile tilapia (*Oreochromis niloticus*) is one of the most commonly used species in intensive farms in Brazil, considered the most promising for fish farming due to the rapid growth in captivity and for having good quality meat (Furuya et al., 2008). It is omnivorous and takes diets with great ease, from the post-larva to the finishing phase (Boscolo et al., 2001).

The increase in productivity requires the use of complete diets, since the natural feed is not able to meet the requirements of fish, especially when raised in tanks and "raceways", where high biomass per unit area and nutrient deficiencies or imbalance can lead to productivity losses and consequently lower economic profit (Furuya et al., 2001). In intensive fish farming, the feeding factor can reach up to 70% of the total production cost (Guimarães et al., 2008), a fact that has stimulated studies on feeding of fish with the use of alternative foods that meet the nutritional requirements of animals, without, however, altering the quality of diet.

There is a wide variety of foods with potential for use in feeding of tropical fish. Thus, studies involving the use of agroindustrial byproducts as components of fish diet have become increasingly common (Mbahinzireki et al. 2001; Omoregie, 2001; Cheng & Hardy, 2002; Santos et al., 2009; Lopes et al., 2010).

In this context, the objective of this research was to assess performance and body composition of tilapias (*Oreochromis niloticus*) fed diets containing the byproducts: aerial parts of cassava meal (*Manihot esculenta*), mesquite pods meal (*Prosopis juliflora*), cocoa meal (*Theobroma cacao*) and palm kernel cake (*Elaeis guineensis*).

Material and Methods

The experiment was conducted at Vale do Juliana Farm (Aquavale), in the city of Ituberá, Bahia, Brazil, located at geographic coordinates Latitude 13°53' 45" and Longitude 39°17' 10", for 60 days between January and March 2010.

A total of 1350 juvenile Nile tilapia (*Oreochromis niloticus*), Thai strain, sexually reverted to male and with an initial weight of 100.0±3.5 g were used. A completely randomized design with five treatments and three replicates was used; each tank was considered an experimental unit.

The fish were distributed in 15 tanks (1.0 × 1.0 × 1.2 m, working volume of 1 m^3), with a mesh of 17 mm between

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knots, with stocking density of 90 fish per m^3. The average depth (4.0±1.3 m) was determined by bathymetry (Sonar). The tanks were arranged in a row (30 m) with 2 m of spacing between tanks.

Treatments consisted of a control diet, free from byproduct, and four test diets, each one including a byproduct (cassava leaf meal, mesquite pod meal, cocoa meal and palm kernel cake), in proportion of 150 g/kg, considering the pre-tests performed regarding their palatability to the tilapia. In these studies, it was observed that values above 150 g/kg of inclusion of the respective byproducts resulted in reduced consumption of the diets.

All diets were formulated according to the NRC recommendations (1993) and based on values of apparent digestibility coefficients of the byproducts (Braga et al., 2010) and other ingredients (Boscolo et al. 2002) for the Nile tilapia (Table 1).

To prepare the control diet and test diets (Table 2), all ingredients and byproducts were ground separately and sieved using a 0.7-mm mesh sieve. Later, they were weighed according to each treatment, mixed, and again crushed using a 0.3-mm sieve. Then, vitamin and mineral supplement, lysine, BHT and soybean oil were added, and the resulting mixture was taken to the extruder. Diets were processed using 4-mm diameter array, dried in a condenser, stored and identified according to the treatments. All manufacturing steps of diets were performed in the Food Plant of UNESP - FCAV, Jaboticabal campus.

The fish were fed four times a day (8:00 a.m., 11:00 am, 2:00 pm and 4:00 pm), with supply of diet until their apparent satiation. Biweekly, samples were collected from fish for performance monitoring by means of samples from nine fish in each tank.

The physico-chemical variables of water, pH (6.8±0.1) and dissolved oxygen (4.8±0.8 mg/L) were monitored weekly

Table 1 - Chemical composition of byproducts used in experimental diets

Variable	Cassava leaf meal	Mesquite pod meal	Cocoa meal	Palm kernel cake
Dry matter (g/kg)	927.4	903.4	918.3	930.8
Mineral matter (g/kg)	65.0	62.5	61.3	11.5
Crude fiber (g/kg)	245.0	40.0	260.0	569.0
Digestible protein (g/kg)[1]	80.4	145.3	37.3	120.8
Digestible energy (kcal/kg)[1]	1.246	5.81	9.26	2.731

[1] Based on the values of apparent digestibility coefficients obtained by Braga et al., 2010.

Table 2 - Composition of experimental diets in g/kg of natural material

Food (g/kg)	Treatment				
	Control	Cocoa	Mesquite	Palm	Cassava
Fish meal	280.0	290.0	280.0	270.0	267.8
Soybean meal	171.8	225.0	200.0	208.5	235.0
Wheat meal	120.0	120.0	120.0	107.4	120.0
Corn meal	198.4	135.5	96.8	140.0	145.0
Cottonseed meal	200.0	41.8	95.1	101.3	48.0
Soybean oil	18.4	27.4	47.8	10.4	23.9
Mineral and vitamin supplement[1]	10.0	10.0	10.0	10.0	10.0
BHT antioxidant	0.2	0.2	0.2	0.2	0.2
L-lysine HCl	1.1	-	-	2.1	-
Cocoa meal	-	150.0	-	-	-
Mesquite pod meal	-	-	150.0	-	-
Palm kernel cake	-	-	-	150.0	-
Cassava leaf meal	-	-	-	-	150.0
Total	1000.0	1000.0	1000.0	1000.0	1000.0
Parameter			Calculated value		
Digestible protein[2] (g/kg)	270.0	260.0	267.4	270.0	260.0
Digestible energy[2] (kcal/kg)	2900	2800	2800	2900	2800
Crude fiber (g/kg)	78.6	80.0	63.1	80.0	80.0
Fat (g/kg)	54.7	76.7	80.0	53.1	62.6
Lysine (g/kg)	20.0	18.9	18.8	20.0	20.0

[1] Composition/kg: Mg – 2,600 mg; Zn – 14,000 mg; Fe – 10,000 mg; Cu – 1.400 mg; Co – 20 mg; I – 60 mg; Se – 60 mg; vit. A – 1,000,000 UI; vit. D3 – 400,00 UI; vit. E – 10,000 mg; vit. K3 – 500 mg; vit. B1 – 2,500 mg; vit. B2 – 2,500 mg; vit. B6 – 2,500 mg; vit. B12 – 3,000 mcg; vit. C – 35,000 mg; folic acid – 500 mg; pantothenic acid – 5,000 mg; niacin – 10,000 mg; biotin – 80,000 mcg; coline – 200,000 mg; methionine – 130 g; inositol – 5,000 mg; ethoxyquin – 15,000 mg.
[2] Based on the values proposed by Boscolo et al. (2002) and Braga et al. (2010).

and temperature (25.6±1.1 ° C) was monitored daily by morning and afternoon, using a multiparameter meter. The values remained within the recommended range for the farming of this species (Ross, 2000).

Chemical analyses of dry matter, mineral matter, crude protein, gross energy and crude fiber of byproducts were performed at the Laboratory of Animal Nutrition, Universidade Estadual de Santa Cruz (UESC), Ilhéus, BA, according to the techniques described by AOAC (2000).

At 60 days of experiment, the final biometrics of the fish was performed, resulting in the total weight in each experimental unit. Two copies of each treatment were randomly removed using dip nets; fish were sacrificed with an overdose of anesthetic benzocaine (120 mg/L), and then packed in plastic bags identified and kept in a freezer (-10 º C) for further body composition analysis. The same procedure was carried out at the beginning of the experiment with ten fishes, sampled at random.

For analysis of initial and final body composition of tilapias, they were crushed in an industrial blender and pre-dried in a forced ventilation oven (65 °C) for 72 hours. Initially, quantitative analysis of fat content was performed to enable the grinding and mixing of samples. After this procedure, degreased samples were crushed in a knife mill (1-mm sieve) for posterior determination of dry matter, crude protein, ash and energy.

For the analysis of animal performance, final weight, total weight gain, total diet consumption, apparent feed conversion, protein efficiency rate, specific growth rate and survival rate were assessed.

To analyze the economic viability of diets containing byproducts, data were collected regarding the amount and price of inputs used in the suppliers of ingredients. The cost of diets used in this experiment was calculated based on retail prices; however, these values were converted into dollars.

The cost of diet per kg of weight gain was calculated according to Bellaver et al. (1985). After obtaining this value, the economic efficiency index was calculated according to Barbosa et al. (1992).

Data on animal performance and body composition of fish obtained at the end of the experiment were subjected to variance analysis as per totally randomized design ($\alpha = 0.05$). In case of differences between treatments, the Tukey test was applied. All procedures were performed using the PROC GLM of SAS (Statistical Analysis System, version 9.0).

Results and Discussion

There was no mortality case in any of the treatments, confirming that diets containing up to 150 g/kg of byproducts can be used without any harm to fish. It is also noteworthy that the environmental conditions and animal management were adequate during the experimental period.

No significant differences for the variables total diet intake and survival rate were observed for the different byproducts tested in diets for Nile tilapia. For other variables, including the different byproducts, it significantly altered the fish performance (Table 3).

Tilapias showed different animal performance for the variable final weight and total weight gain, as well as for specific growth rate. Fishes ingesting diets with cocoa meal and cassava foliage meal had, respectively, final weight 13.2% and 8.5% lower than for those in the control diet. These results directly reflected on the total weight gain, and this parameter for control diet is 17.8 and 11.4% higher than that found in diets with cocoa and cassava foliage, respectively. The specific growth rate followed the same trend, confirming itself through the worst results in tilapias that consumed the same byproducts.

The apparent food conversion and protein efficiency rate of fishes ingesting diets containing cocoa meal worsened in 16.7 and 15.5%, respectively, when compared with fishes ingesting the control diet. However, they showed similar values to those of other treatments.

Table 3 - Performance of tilapia fed with basal diet and diets with byproducts

Variable	Treatment					P Value	CV (%)
	Control	Cocoa	Palm	Mesquite	Cassava		
Initial weight (g)	100±3.5	100±3.5	100±3.5	100±3.5	100±3.5	-	-
Final weight (g)	390.29a	338.78b	365.91ab	365.96ab	357.16b	0.003	3.0
Total diet intake (kg)	29.79	28.66	28.26	30.87	29.84	0.067	3.5
Total weight gain (kg)	26.13a	21.49b	23.93ab	23.93ab	23.14b	0.003	4.2
Apparent food conversion	1.14b	1.33a	1.18ab	1.29ab	1.29ab	0.023	5.3
Specific growth rate (%/day)	2.27a	2.03b	2.16ab	2.16ab	2.12b	0.003	2.4
Protein efficiency rate (%)	3.25a	2.78b	3.14ab	2.87ab	2.87ab	0.002	5.4
Survival rate (%)	100.00	100.00	100.00	100.00	100.00	-	-

Means in rows, followed by different letters, differ statistically by Tukey test (P<0.05); CV - coefficient of variation.

Oliveira et al. (1997) found no differences in values of weight gain of Nile tilapia when under diets containing up to 350 g/kg of palm kernel cake. In an experiment with cocoa husk meal for Nile tilapia, Falaye & Jauncey (1999) had values up to 74% higher than those found in this experiment for weight gain, which can be explained by the different stages of development of fish and the different amounts of protein used in the experiments. However, the results obtained for weight gain for all byproducts used in this experiment are similar to those obtained by Boscolo et al. (2001) using commercial diet (280 g/kg crude protein) for Nile tilapia, Thai strain, mean initial weight of 60.73 g.

The lowest values for weight gain obtained by fishes fed cocoa meal may be due to the presence of antinutritional factors, such as theobromine (Bonvehí & Coll, 2000). It should also be noted that the difference of 10 g/kg of digestible protein and 100 kcal/kg of digestible energy in diets with cocoa meal and cassava foliage, when compared with the diet containing palm oil, may have affected the tilapia growth.

Regarding the specific growth rate (%/day) for fish ingesting diets containing palm kernel cake, values similar to those obtained in this experiment were obtained by Oliveira et al. (1997) in a research with Nile tilapia, when they found specific growth rate ranging from 1.98 to 2.02. Dealing with cocoa meal to Nile tilapia, Falaye & Jauncey (1999) obtained values for specific growth rate ranging from 3.3 to 3.5 according to the level of inclusion of the byproduct, higher than those obtained in this experiment, which may be due to the size of fishes (0.97±0.02 g) used by these authors.

Falaye & Jauncey (1999) investigated the effects of addition of cocoa meal to Nile tilapia and had the worst food conversion values obtained in the present experiment, ranging from 4.3 to 4.9. Similarly, Oliveira et al. (1997), in a research of palm kernel cake for the same species, observed values of apparent feed conversion ranging from 2.01 to 2.18, according to the level of inclusion of the byproduct. Even though fish raised in tanks have restricted access to natural feed (Ono & Kubitza, 2003), its availability may have been responsible for the differences obtained, since these experiments were conducted in laboratories, in enclosed systems with recirculating water. It should be emphasized that extruded diets (used in this experiment) tend to have higher digestibility than pelleted diets, which may be responsible for better apparent feed conversion. The results for this variable for all byproducts assessed are within the commonly observed range for the intensive farming of tilapias (Kubitza, 2000).

Oliveira et al. (1997) and Falaye & Jauncey (1999) found lower values than those obtained in this experiment for protein efficiency ratio in Nile tilapia. Working with palm kernel cake, the first authors found values ranging from 1.54 to 1.67%, according to the level of inclusion of byproduct. In the second study, using cocoa meal, the authors found values of protein efficiency ratio of 0.67 and 0.74%, respectively, for the inclusion levels of 100 and 200 g/kg of byproduct. The various processing of diets may have influenced protein digestibility. In addition, the diets used in this experiment were based on digestible protein rather than crude protein, which may have been responsible for the better utilization of this nutrient, as observed by other authors (Pezzato et al., 2009; Boscolo et al., 2010).

For the variables dry matter, crude protein and body mineral matter of tilapias fed different experimental diets, no significant differences were seen (Table 4).

In relation to body fat, fishes fed palm kernel cake and cassava foliage meal had the lowest rates, differing significantly from fishes fed cocoa meal and similar to those under control diet and diets containing mesquite pod meal. Oliveira et al. (1997) found mean values of 980.2, 543.6 and 128.1 g/kg, respectively, for dry matter, crude protein and body mineral matter of Nile tilapia subjected to diets with different levels of inclusion of palm kernel cake.

According to Veiverberg et al. (2010), variable results on body composition of fishes are obtained as the effect of inclusion of plant ingredients, with the main response observed in the body fat and/or fillet contents. In addition to the energy/protein, a diet with an imbalanced amino acid profile can result in greater fat deposition (Botaro et al., 2007), which may explain the variation in this experiment of

Table 4 - Body composition of Nile tilapia fed with basal diet and diets with byproducts

Variable	Treatment					P Value	CV (%)
	Control	Cocoa	Palm	Mesquite	Cassava		
Dry matter (g/kg)	254.6	255.9	243.5	259.2	254.1	0.314	3.5
Crude protein[1] (g/kg)	738.4	754.1	757.1	737.4	757.6	0.331	1.2
Fat[1] (g/kg)	573.6ab	606.1a	536.1b	571.6ab	537.8b	0.004	3.9
Mineral matter (g/kg)	144.8	142.6	183.5	148.3	136.7	0.082	3.1

Means in rows, followed by different letters, differ statistically by Tukey test (P<0.05); CV - coefficient of variation.
[1]Values expressed in g/kg of dry matter.

fat values in the carcass. In this sense, the high biological value of palm oil protein had already been pointed out by Jauncey & Ross (1982).

The mean measurement of body crude protein was 749 g/kg, with low coefficient of variation, showing the stability of this variable in body composition. This confirms the observations made by Cho et al. (1976) that there is a direct relationship between body composition and composition of the diet that the animals are ingesting.

There was a variation of U$ 0.06 (cents) between the diets of higher (mesquite) and lower cost (palm) (Table 5).

Regarding the cost of diet per kg of weight gain, we can see that the diet consisting of palm kernel cake, plus the control diet, tended to provide better rates when compared with diets containing cocoa meal, mesquite pod and cassava foliage, which can be explained by the small difference in cost per kg of diet, which made the economic analysis dependent on animal performance indexes. The diet with the highest index of economic efficiency was that including palm kernel cake.

A common difficulty observed when alternative feed sources are used in fish feed is acceptability, which is related to palatability (Rodriguez et al., 1996). In this research, there was wide acceptance to all diets, showed by the lack of significance for the variable total feed intake, demonstrating that the level of inclusion (150 g/kg) of byproducts and the addition of high palatability of ingredients, such as fish flour, were effective.

Table 5 - Average cost per kg of diet, cost of diet per kg of weight gain, and economic efficiency index of cultivation of Nile tilapia fed with experimental diets[1]

Variable	Treatment				
	Control	Cocoa	Palm	Mesquite	Cassava
U$/kg	0.63	0.62	0.60	0.66	0.65
U$/weight gain	0.73	0.83	0.71	0.85	0.83
Index of economic efficiency (%)	97.82	85.98	100.00	83.34	84.99

[1] Exchange rate of the dollar at the time: R$ 1.72.

Conclusions

The mesquite meal and palm kernel cake promote better growth of Nile tilapia when compared with cocoa meal and cassava leaf meal. The best economic efficiency index is achieved with the use of palm kernel cake.

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