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AQUACULTURE

Influence of guava residue on tambaqui growth performance

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ABSTRACT. Fruit residues represent alternative ingredients that can be included in diets of tambaqui, *Colossoma macropomum*. This study evaluated the growth performance of tambaqui fed diets containing different levels of guava agroindustrial residue. The experiment was based on a completely randomised design, with 105 fish randomly distributed in 15 plastic 60 L^{-1} boxes with a water recirculation system. Feeding was carried out to apparent satiety for 45 days, using diets with 0, 50, 100, 150 and 200 g kg^{-1} inclusion of guava residue. Biometrics were performed every 15 days. Quadratic effect ($p < 0.05$) was observed for daily feed intake and apparent feed conversion, with optimum levels of 4.86 and 6.05% inclusion of guava residue, respectively. There was no significant difference ($p > 0.05$) in relation to final weight, weight gain, specific growth rate, hepato-somatic index, survival rate and protein efficiency rate by the dietary treatments. The inclusion of up to 150 g kg^{-1} of the guava agroindustrial residue in the feed did not compromise the performance of tambaqui juveniles.

Keywords: agroindustrial residues; *Psidium guajava*; fish nutrition; *Colossoma macropomum*.

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Introduction

Tambaqui, *Colossoma macropomum,* is a fish species native to the Amazon region with an omnivorous/fruity diet with potential for fish farming due to its rusticity, tolerance to low concentrations of dissolved oxygen in the water, rapid growth and ease of handling (Acuña & Rangel, 2009; Dairiki & Silva, 2011; Santos et al., 2013; Ribeiro et al., 2016). In Brazil, tambaqui is the second most cultivated species with a production of approximately 101 thousand tons in 2019, occurring mainly in the north and northeast regions of the country (Instituto Brasileiro de Geografia e Estatística [IBGE], 2020).

Fish feed can represent 70% of the production costs of fish farming, due to the use of expensive traditional ingredients of high economic value in the composition of the rations, making it necessary to search for alternative ingredients. One option is to substitute with fruit residues from agroindustry (Silva, Pereira-Filho, Cavero, & Pereira, 2007; Santos, Ludke, Barbosa, Rabello, & Ludke, 2009; Souza et al., 2013).

The fruit processing industries are of great importance in the generation of waste, especially those that work with the production of fruit juices and pulps, generating bagasse, peel and seed. The residue of fruits such as orange, apple, mango and papaya, have soluble carbohydrates (fructose, glucose and sucrose), crude fiber (cellulose), proteins and vitamins, being an alternative for animal feed (Mirabella, Castellani, & Sala, 2014). Fruits like *Ziziphus jujube* demonstrated potential useful effects of on skin mucosal immunity in carps fingerlings (Hoseinifar et al., 2019).

According to previous studies, the chemical composition of the guava residue varies between 0.17% starch, 2-11% protein, 3-7% moisture, 11-14% lipids, 1-2% ash and 63.94% crude fiber (Uchôa-Thomaz et al., 2014), which can be used with an alternative ingredient in the formulation of feed for omnivorous fish (Silva et al., 2009).

Previous studies have demonstrated the viability of using fruit residues in the formulation of diets for tambaqui, providing a satisfactory zootechnical performance. Plantains and pupunha have been shown as energy sources for this species and can replace wheat bran in a proportion of 30% (Lochmann et al., 2009). The babassu by-product contains approximately 20% crude protein, 4.6% lipid and 18% crude fiber, and can partially replace soybean meal and ground corn in the tambaqui diet (Lopes et al., 2010). The substitution of soybean meal by coconut meal did not compromise the weight gain, daily feed consumption, feed conversion and specific growth rate of this species (Lemos, Guimarães, & Miranda, 2011). Mango flour represented a source of carbohydrates, replacing up to 50% soy bran and fish meal in diets for tambaqui (Bezerra, Souza, Melo, & Campeche, 2014). Tambaquis showed satisfactory digestibility and zootechnical performance when fed diets containing 8% banana meal to replace corn bran (Silva et al., 2020). Further studies on the inclusion of fruit residues in the diet of this species are still necessary.

The objective in this study was to evaluate the performance of tambaqui fed diets containing different levels of guava agroindustrial residue from fruit pulp production.

Material and methods

Processing of guava residue

The study was approved by the Ethics Committee of the Universidade Federal Sergipe - UFS (CEUA/CEPAP-UFS 02/2017). The experiment was based on a completely randomised design, consisting of 5 treatments and 3 replicates. The treatments comprised one control diet and four experimental diets, containing 0, 50, 100, 150 and 200 g kg^{-1} inclusion of guava agroindustrial residue.

The guava residue from pulp production, basically consisting of seeds and pulp, was donated by an industry (Pomar do Brasil) located in the city of Aracaju, Brazil. The residue was sent to the LANCOA- DEPAQ, UFS, Brazil. The residue was frozen at -18°C, dehydrated in a forced air circulation oven at 55°C for 48h and minced in a willey-type knife mill to obtain the meal with 1-mm granulometry. A sample of the meal was collected for determination of the proximate composition (Table 1).

Table 1. Proximate composition: crude energy (CE), dry matter (DM), neutral detergent fibers (NDF), total carbohydrate (TCHO), ethereal extract (EE), crude protein (CP) and ashes (ASH) of the guava residue (% dry matter).

CE (kcal kg^{-1})⁋	4652.90
DM (%)	91.70
NDF (%)	73.31
TCHO (%)§	70.96
EE (%)	15.49
CP (%)	10.51
ASH (%)	3.04

⁋ CE = {[(CP x 4.0 kcal g^{-1}) + (EE x 9.0 kcal g^{-1}) + (TCHO x 4.0 kcal g^{-1})] x 10}. § TCHO = 100% - (CP + EE + ASH).

Formulation of diets

The diets were formulated to meet the nutritional requirements of tambaqui according to Oliveira, Miranda, and Correa (2012). The guava residue meal was included in the feed at 0, 50, 100, 150 and 200 g kg^{-1} The guave residue was homogenised with the other ingredients with the addition of water at 65°C. The homogeneous material was processed in an electric grinder to form pellets and dried in a forced circulation air oven at 55°C for 24h to produce the experimental diets. Five isoproteic (310 g kg^{-1} crude protein) and isoenergetic rations (3700 kcal kg^{-1} crude energy) were formulated according to the fish feed formulation sheet, described in Table 2.

Nutritional analysis

Analyses of proximate composition of guava residue, experimental rations and fish were carried out at the LANA-DZO, UFS, Brazil. The levels of different components were determined as follows: dry matter (DM) by greenhouse dehydration; ash (ASH) by muffle incineration; crude protein (CP) by Kjeldahl and ethereal extract (EE) by Weende. Neutral detergent fibre content (NDF) was determined in guava residue (Silva & Queiroz, 2005).

Total carbohydrate content (TCHO) was obtained by difference, decreasing by 100% the sum of ASH, CP and EE. Crude energy (CE) was calculated from the approximate centesimal conversion fator of Atwater (Núcleo de Estudos e pesquisas em Alimentação [Nepa], 2011).

Table 2. Formulation and proximate composition of the experimental diets containing 0, 50, 100, 150 and 200 g kg^{-1} inclusion of guava agroindustrial residue.

Ingredient	Diets				
	0	50	100	150	200
Guava residue	0.00	5.00	10.00	15.00	20.00
Soybean meal	32.00	31.50	30.50	30.00	31.00
Corn gluten	7.95	7.80	7.60	7.60	5.00
Fish meal	22.00	22.50	23.00	22.85	22.95
Corn meal	15.00	12.00	11.00	6.00	5.00
Wheat bran	10.45	8.40	7.00	7.85	5.00
L-Lysine	0.50	0.50	0.50	0.50	0.50
DL-Methionine	0.50	0.50	0.50	0.50	0.50
Soy oil	5.50	5.22	4.20	4.02	3.73
Dicalcium phosphate	5.00	5.00	5.00	5.00	5.00
Vitamin C†	0.50	0.50	0.50	0.50	0.50
Common salt	0.10	0.10	0.10	0.10	0.10
Premix min,vit,aa⸸	1.00	1.00	1.00	1.00	1.00
BHT	0.02	0.02	0.02	0.02	0.02
Proximate composition					
Crude energy (kcal kg^1)⁋	3727.4	3705.2	3778.6	3728.7	3722.3
Dry matter (%)	93.96	96.07	95.44	96.44	95.54
Neutral detergent fibers (%)	37.46	44.60	50.33	49.27	50.43
Total carbohydrate (%)§	43.06	43.90	44.08	44.41	44.29
Crude protein (%)	32.17	31.80	31.42	31.73	31.33
Ashes (%)	16.79	16.62	16.48	16.27	16.63
Ethereal extract (%)	7.98	7.68	8.02	7.59	7.75

⁋ CE = {[(CP x 4.0 kcal g^{-1}) + (EE x 9.0 kcal g^{-1}) + (TCHO x 4.0 kcal g^{-1})] x 10}. † Ascorbic acid polyphosphate = 350.000 g kg^{-1}. ⸸ Premix min,vit e aa - Composition per pound of product: Vit. A = 2,000,000 UI kg^{-1}; Vit. D3 = 800,000 UI kg^{-1}; Vit. E = 20,000 UI kg^{-1}; Vit. K3 = 1,000 mg kg^{-1}; Vit. B1 = 5,000 mg kg^{-1}; Vit. B2 = 5,000 mg kg^{-1}; Vit. B6 = 5,000 mg kg^{-1}; Vit. B12 = 6,000 mg kg^{-1}; Ac. folic = 1,000 mg kg^{-1}; Ac. Pantothenic = 10 g kg^{-1}; Ac. ascorbic = 75 g kg^{-1}; Biotine = 160 mg kg^{-1}; Choline = 200 g kg^{-1}; Co = 40 mg kg^{-1}; Cu = 2,800 mg kg^{-1}; Fe = 20 g kg^{-1}; Mn = 5,200 mg kg^{-1}; I = 120 mg kg^{-1}; K = 28 g kg^{-1}; Niacine = 20 g kg^{-1} e Methionine = 2,600 mg kg^{-1}.

Growth performance experiment

Juvenile tambaqui, *C. Macropomum,* were acquired from CODEVASF 5th Fisheries Station and were subjected to 9 days of acclimatisation and 13 days of treatment with enrofloxacin, malachite green and common salt. The fish were kept in two polyethylene tanks with a capacity of 500 L and fed commercial diets containing 320 g kg^{-1} crude protein, 60 g kg^{-1} ethereal extract, 120 g kg-1 mineral matter and 4447 kcal kg^{-1} crude energy.

During the acclimation period, the fish were subjected to initial biometry with 7 individuals per experimental unit. Mean weight and standard deviation was 6.09 ± 0.39 g and mean length was 7.22 ± 0.20 cm. The experimental units consisted of 15 rectangular plastic boxes (60-L capacity) which were individually aerated, with filtration through a water recirculation system fitted with a biofilter, and thermostatically heat-controlled.

The concentrations of dissolved oxygen (mg L^{-1}), temperature (°C) and pH were measured daily using a multiparameter (Hanna, HI 9829, Portugal). Concentrations of total ammonia (ppm) and nitrite (ppm) were determined twice a week by colorimetry (Alfakit, Camboriú, Brazil). The following values were obtained: dissolved oxygen 4.77 ± 0.15 mg L^{-1}; pH 5.41 ± 0.11; temperature 29.90 ± 0.27°C; total ammonia 0.25 ± 0.13 ppm and nitrite 0.75 ± 0.54 ppm.

Feed was offered at 9:00 am and 3:00 pm until the apparent satiety; the weight of the consumed ration was recorded. Biometrics were performed every 15 days using an ichthyometer and digital scales. The experiment was completed after a period of 45 days. Fish were subjected to euthanasia by immersdion in an ice bath, followed by section of the spinal cord. Fish were dissected and the livers collected for weighing.

Growth performance parameters were determined in the fish by Fracalossi, Rodrigues, Silva, and Cyrino (2012) for weight gain (WG), apparent feed convertion (FC), specific growth rate (SGR), hepatic-somatic index (HSI), survival rate (SR), protein efficiency rate (PER) and Costa-Bomfim, Silva, Bezerra, Druzian, and Cavalli (2017) for daily feed intake (DFI). The equations (1, 2, 3, 4, 5, 6, and 7) can be seen as follows:

$$\text{Weight gain (WG)} = \text{final weight} - \text{initial weight} \quad (1)$$

$$\text{Apparent feed conversion (FC)} = \text{total apparent feed intake weight gain}^{-1} \quad (2)$$

Specific growth rate (SGR) = [ln (final weight) - ln (initial weight) / feeding period (days)] × 100 (3)

Hepatic-somatic index (HSI) = liver weight × 100 / live weight (4)

Survival rate (SR) = (final number of fish × 100) / initial number of fish (5)

Protein efficiency rate (PER) = (weight gain / protein intake) (6)

Daily feed intake (DFI) = (feed intake) / [(final weight + initial weight) / 2] / days of trial × 100 (7)

Statistical analysis

The effects of the experimental diets on growth performance parameters in tambaqui were subjected to analysis of variance, Tukey test and, when significant, a regression test at 5% of significance was performed. Statistical analyses were performed using the statistical programme, Sisvar 5.6 (Ferreira, 2011).

Results and discussion

Composition of the guava agroindustrial residue was as follows: 4652.90 kcal kg^{-1} in CE, 917.0 g kg^{-1} in DM, 733.1 g kg^{-1} in NDF, 709.6 g kg^{-1} in TCHO, 154.9 g kg^{-1} in EE, 105.1 g kg^{-1} in CP and 30.4 g kg^{-1} in ASH. The guava residue can be considered an energetic ingredient due to the low protein concentration and high energy content.

Table 3 shows the mean values and standard deviation of IW, FW, WG, DFI, FC, SGR, HSI, SR and PER in tambaqui given diets containing 0, 50, 100, 150 and 200 g kg^{-1} guava residue. The analysis of variance showed that there was no significant difference ($p > 0.05$) between treatments in relation to FW, WG, SGR, HSI, SR and PER. Regarding the DFI and FC, a significant difference was observed.

Table 3. Mean values (±SD) of initial weight (IW), final weight (FW), weight gain (WG), daily feed intake (DFI), apparent feed conversion (FC), specific growth rate (SGR), hepato-somatic index (HSI), survival rate (SR) and protein efficiency rate (PER) of tambaqui, *Colossoma macropomum*, fed rations containing 0, 50, 100, 150 and 200 g kg^{-1} inclusion of guava residue.

	0	50	100	150	200	P*
IW (g)	6.20 ± 0.4	5.96 ± 0.6	6.38 ± 0.0	6.02 ± 0.4	5.94 ± 0.2	0.701
FW (g)	54.97 ± 7.3	55.09 ± 3.6	72.47 ± 9.9	55.18 ± 4.2	60.32 ± 6.3	0.038
WG (g)	48.77 ± 7.0	49.13 ± 4.2	66.09 ± 9.9	49.16 ± 4.7	54.38 ± 6.2	0.044
DFI (% $fish^{-1}$ day^{-1})	3.47 ± 0.0a	3.44 ± 0.1a	3.63 ± 0.2a	3.63 ± 0.0a	4.36 ± 0.5b	0.001
FC (g g^{-1})	0.98 ± 0.0a	0.96 ± 0.0a	0.97 ± 0.0a	1.01 ± 0.0a	1.19 ± 0.1b	0.003
SGR (%)	4.84 ± 0.2	4.95 ± 0.3	5.38 ± 0.3	4.92 ± 0.3	5.15 ± 0.1	0.255
HSI (%)	1.07 ± 0.1	1.12 ± 0.0	0.92 ± 0.0	0.94 ± 0.1	0.92 ± 0.0	0.093
SR (%)	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	0.000
PER (%)	1.51 ± 0.2	1.54 ± 0.1	2.10 ± 0.3	1.55 ± 0.1	1.74 ± 0.1	0.033

*Different letters between lines represent a significant difference at 5% ($p < 0.05$).

The regression analysis indicated a quadratic effect in relation to the DFI and FC. For DFI, the optimum level was 4.86% inclusion of the guava residue, expressed bythe equation $Y = 3.504 - 0.037x + 0.003x^2$ (R^2 = 90.95%). In FC, the ideal level was 6.05% inclusion of guava residue, expressed by the equation: $Y = 0.992 - 0.014x + 0.001x^2$ (R^2 = 96.46%).

The effect of feed containing inclusion levels of guava agroindustrial residue on daily feed intake and apparent feed conversion in tambaqui is represented by means of scatter plots and quadratic regression equations that are represented in Figure 1 and 2.

The tambaqui showed satisfactory weight gain reaching approximately 9× (900%) their initial weight at day 45 of the experiment. The apparent feed conversion was also satisfactory, since fish needed to consume around 1 g of feed to gain the same value in body weight. As for the centesimal composition of the fish (Table 4), a significant difference ($p < 0.05$) was observed only for the ethereal extract (EE) content among the tambaqui fed the diet without guava residue inclusion and those receiving the diets containing 150 and 200 g kg^{-1} residue.

The content of ash (3.04%), ethereal extract (15.49%), neutral detergent fibres (73.31%) and crude energy (4652.90 kcal kg^{-1}) in the guava agroindustrial residue used in this study were higher than those reported by Silva et al. (2009), where values were 1.25%, 11.71%, 64.06% and 4290 kcal kg^{-1}, respectively. Santos et al. (2009) reported crude energy values of 5389 kcal kg^{-1} in guava residue, higher than the value obtained in this experiment. The content of dry matter (91.70%) and crude protein (10.51%) was similar to that found by Silva et al. (2009), 90.81% and 10.09% respectively. The different values of centesimal composition for this residue are related to the different conditions for cultivation and processing of the fruit.

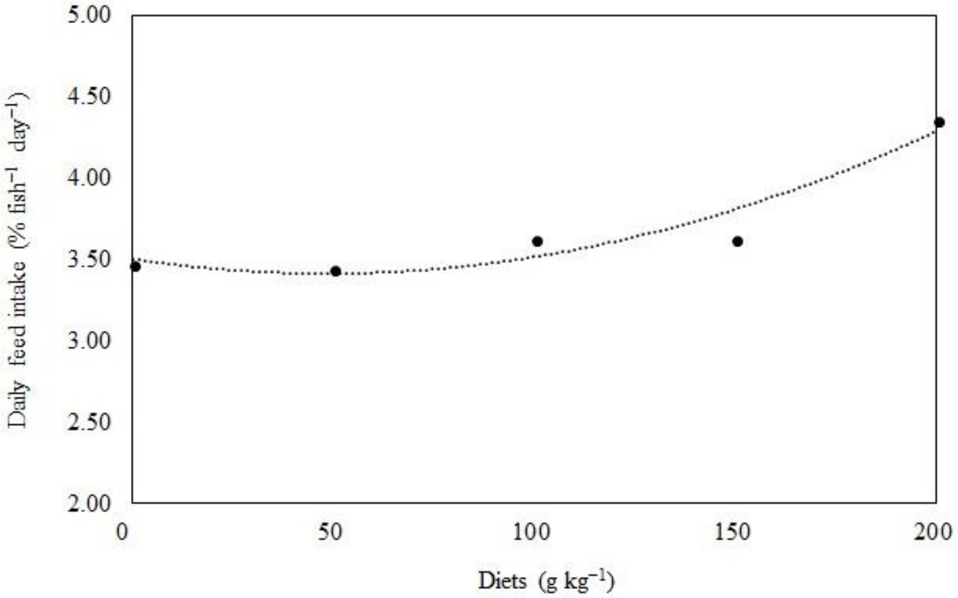

Figure 1. Scatter plot of the means and quadratic regression equation showing the effect of rations containing 0, 50, 100, 150 and 200 g kg^{-1} of guava agroindustrial residue on the daily feed intake of tambaqui, *Colossoma macropomum*.

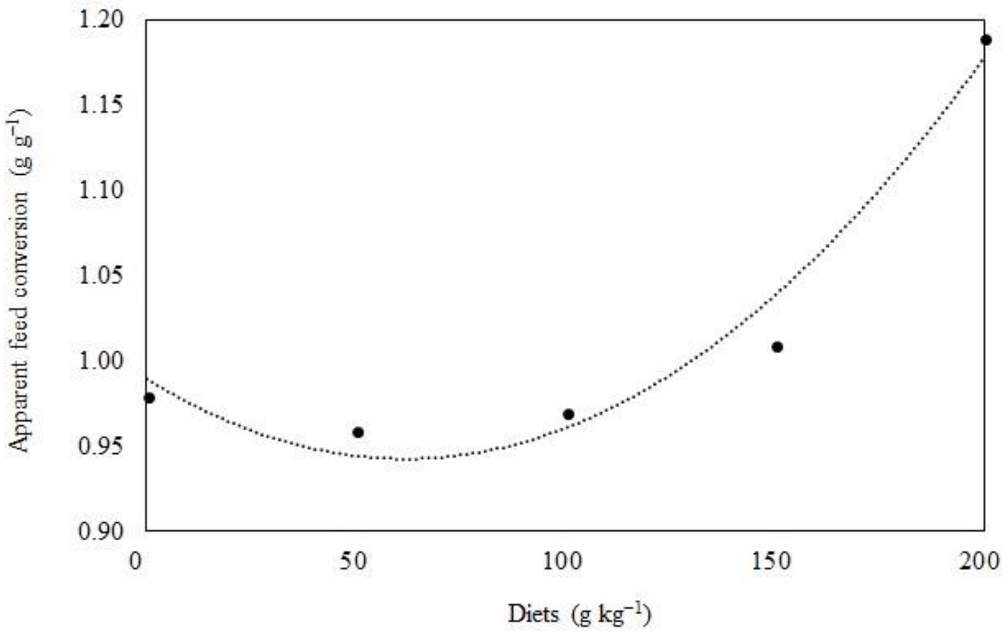

Figure 2. Scatter plot of the means and quadratic regression equation showing the effect of rations containing 0, 50, 100, 150 and 200 g kg^{-1} of guava agroindustrial residue on the apparent feed conversion of tambaqui, *Colossoma macropomum*.

Table 4. Proximate composition: dry matter (CM), crude protein (CP), ethereal extrfact (EE) and asches (ASH) of tambaqui, *Collossoma macropomum* fed diets containing 0, 50, 100, 150 and 200 g kg^{-1} inclusion of grava residue (neam ± SD, % dry matter).

	0	50	100	150	200	P*
DM (%)	95.79 ± 0.7	95.05 ± 0.8	95.38 ± 0.4	95.01 ± 0.6	95.13 ± 0.3	0.612
CP (%)	61.21 ± 3.7	59.79 ± 1.5	59.66 ± 1.3	61.63 ± 0.7	63.13 ± 0.9	0.389
EE (%)	23.91 ± 1.9b	21.03 ± 1.1ab	20.75 ± 1.1ab	19.42 ± 0.8a	19.12 ± 1.5a	0.023
ASH (%)	15.14 ± 0.6	15.17 ± 0.0	15.12 ± 0.4	15.75 ± 0.7	15.69 ± 0.5	0.457

* Different letters between lines represent a significant difference at 5% ($p < 0.05$).

In a study with Nile tilapia, *O. niloticus*, was estimated the digestibility the guava residue, obtaining 6.89% of digestible protein and 3601.13 kcal kg^{-1} of digestible energy (Santos et al., 2009). The inclusion to 15% of the agroindustrial residue of pineapple in diets for Nile tilápia did not compromise the weight gain and survival of the fish (Lima et al., 2012). The results demonstrate that residues of pineapple and guava can be included in diets of omnivorous fish.

Tambaqui that were fed diets containing until 20% of guava residue demonstrated satisfactory weight gain, reaching approximately 9× (900%) their initial weight at day 45 of the experiment. This shows that the fish used in this study had a good productive development, since it is suggested that studies of growth performance in large fish are completed when a weight gain of 2 to 3× (200% to 300%) the initial weight has been reached, or after 8 to 12 weeks of feeding (Jobling, 2012).

Development of the fish is mainly influenced by concentrations of energy and protein in the diet; imbalance of this relationship can compromise use of the protein fraction, adversely affecting animal growth (Ribeiro et al., 2016). Energy is not a nutrient, but it is of paramount importance in biochemical and physiological processes related to growth, maintenance and reproduction (Boscolo, Signor, Freitas, Bittencourt, & Feiden, 2011). Protein is the main organic constituent of fish tissues, accounting for 65 and 75% of total body dry matter, which makes it key to structural conformation (muscle, collagen and keratin), regulation of metabolism (enzymes and hormones), transport (haemoglobin) and immune defense (antibodies) (Kaushik & Seiliez, 2010).

Thus, we can explain the satisfactory weight gain of the tambaqui in this experiment, since the guava residue has a high energy level of 4652.90 kcal kg^{-1}, may have a protein-sparing effect that was destined for fish growth (Ribeiro et al., 2016). This same effect was observed when mango residue was added to the diet of tambaqui juveniles (Bezerra et al., 2014). The diet containing 20% guava residue produced a weight gain in tambaqui of 54.38 ± 6.2 g higher than that 18.92 g reported by Lopes et al. (2010), using feed with inclusion of 12% babaçu residue.

With regard to the daily feed intake, the ideal level of guava residue inclusion was estimated at 4.86%, at this level the tambaqui increased their intake to maintain their weight gain, influencing the apparent feed conversion that presented level with 6.05% inclusion. Less satisfactory results were obtained for these parameters with 20% inclusion, suggesting that the high NDF content (73.31%) of the guava residue interfered with the utilisation of the rations. This is because the tambaqui, as with other fish species, do not produce the enzyme cellulase, reducing their capacity to digest structural carbohydrates (Boscolo et al., 2011).

The same effect was observed by Souza et al. (2013), in a study where maize was replaced with mango residue in proportions of 0, 33, 66 and 100% in feed of Nile tilapia, and results showed an increase in feed conversion values as the replacement level increased. In general, the use of up to 9.0% crude fiber in the feed of omnivorous species such as tambaqui and tilapia is reported (Boscolo et al., 2011).

Specific growth rates of 4.84, 4.95, 5.38, 4.92 and 5.15% were achieved with 0, 50, 100, 150 and 200 g kg^{-1} of guava residue, respectively, and were considered to be satisfactory. Tambaqui presented similar results with a 4% growth rate when fed with diets containing 50% of mango residue (Bezerra et al., 2014). This parameter has been used to evaluate experimental diets and ingredients with regard to the relationship between weight gain and feeding period, and is an important indicator of fish growth (Fracalossi et al., 2012).

Leporinus obtusidens juveniles fed with diets containing 7% of guava residue for 45 days, had a SGR of 0.73 ± 0.03% (Lazzari et al., 2015), lower than the tambaqui in this study (5.15 ± 0.1%) which received a diet containing 200 g kg^{-1} guava residue. This result shows that tambaqui demonstrate better body development than the piava, although these species have similar gastrointestinal tracts, with the presence of trypsin and chymotrypsin enzymes in the intestine (Rodrigues, 2014; Lazzari et al., 2015), and were fed with rations containing the same test ingredient.

The HSI represents the energy storage capacity of fish and indicates the effect of antinutritional factors present in food. Decrease in the hepato-somatic index shows that energy reserves present in the liver were used to compensate for energy losses, or, is a response to the action of antinutritional factors present in a certain ingredient (Lopes et al., 2010).

In this study there was no effect of the experimental diets on the HSI, varying between 0.92 and 1.12% and demonstrating that the guava residue did not alter the hepatic metabolism of the tambaqui. These results differ to those reported by Lemos et al. (2011), 1.23 ± 0.25%, and Bezerra et al. (2014), 1.80 ± 0.44%, with rations containing 100% coconut meal and 50% mango residue, respectively. When the coconut concentration increased, there was a reduction in the hepato-somatic index, while the mango had a positive polynomial effect as the level of inclusion increased.

The survival rate of the tambaqui was 100% and was unaffected by the different inclusion levels of the guava residue in the diet. These results corroborate those of Souza et al. (2013), where maize was replaced with mango residue at proportions of 0, 33, 66 and 100% in rations of Nile tilapia and no significant difference was observed in this parameter.

The efficacy of fish in converting protein to body weight can be determined using the protein efficiency rate (Fracalossi et al., 2012). The tambaqui did not show a significant difference for this variable as observed by Lemos et al. (2011), replacing soybean meal with coconut meal.

Fruit residues may improve or impair the nutritional composition of cultured fish, according to the levels of inclusion in the diet, dietary habits and physiological adaptations of each species (Lazzari et al., 2015). In the proximate composition of fish, a significant difference was observed only for ethereal extract, showing the lowest content with 200 g kg^{-1} inclusion of the guava residue. This result demonstrates that the use of this ingredient reduced the lipid composition of the tambaqui, corroborating the results obtained by Souza et al. (2013).

In the natural environment, the tambaqui diet is mainly composed of fruits, seeds and zooplankton, resulting in its classification as omnivorous/fructiferous, making possible its commercial creation associated to fruit cultivation (Bezerra et al., 2014). There are several morphological characteristics that enable this species to feed on fruits, such as: presence of molar teeth, strong mandibles (Dairiki & Silva, 2011), short esophagus, bag-shaped stomach with large capacity to swell, about 43 to 75 pyloric cecum. The pyloric cecum are diverticula with a blind bottom that increase the intestinal absorption surface of tambaquis, also present in carnivorous species (Borges, Sanches, Oliveira, & Silva, 2010).

The tambaqui has an extensive intestine, reaching about 2.5 times the standard length of the fish, being divided into proximal and distal portions (Carr, Weber-Iii, Murphy, & Zwingenberger, 2014). The main digestive enzymes present in the gastrointestinal tract of this species are amylase, maltase, acid protease, trypsin and chymotrypsin, exercising their enzymatic activities in the following organs: esophagus (amylase), stomach (amylase and acidic protease), pyloric cecum, proximal intestine and intestine distal (amylase, maltase, trypsin and chymotrypsin) (Rodrigues, 2014).

The results obtained in this study for WG, DFI, FC, SGR, HSI, SR and PER were satisfactory, demonstrating that the inclusion of up to 150 g kg^{-1} of the agroindustrial residue of guava did not compromise the growth performance of fish. The juveniles of tambaquis presented high zootechnical performance.

Previous studies have demonstrated that substitution of up to 30% of wheat bran by pupunha, plantain and yucca are feasible (Lochmann et al., 2009), 100% of soybean meal by coconut meal (Lemos et al., 2011), inclusion of 12% babassu (Lopes et al., 2010), 50% of the mango (Bezerra et al., 2014) and 8% banana meal (Silva et al., 2020) in rations for tambaqui juveniles, without compromising the growth performance of the fish. The agroindustrial residues of açaí, acerola and passion fruit are also alternative ingredients with the potential for use in the formulation of rations for tambaqui, *C. macropomum* (Silva et al., 2017). Similar to guava residue, these alternative ingredients represent possible energy sources which can be used in feeding this species.

Conclusion

Results of this study enable us to conclude that the agroindustrial residue of guava can be included in rations in proportions of up to 150 g kg^{-1} without compromising the growth performance of tambaqui juveniles.

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