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Fruit residues as diet ingredients for Symphysodon Discus: nutrient figestibility

Resíduos de frutas e dipodem compor a dieta de acará disco: digestibilidade dos nutrients

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Highlights

The pineapple co-product has a high energy value.
Mango co-product has high protein value and lower energy digestibility.
They have a digestibility coefficient similar to conventional products.
The pineapple, passion fruit, and mango by-products is feasible for discus-fish diet.

Abstract

The selection of ingredients is an important aspect for diets formulation for fish in captivity. The use of fruit industry by-products can be an alternative for inclusion in diets for ornamental fish, as discus fish case, to improve health and reduction of production costs, further to reducing the environmental impacts of fruits industries residues. The objective the studies was to evaluate the bioavailability of fruit industry by-products in the diet for discus fish by coefficients of digestibility. The digestibility of three by-products: pineapple by-product, mango by-product, and passion fruit by-product were evaluated. Thirty-two discus fish (106 ± 26.6 g) were distributed in 4 tanks for feeding and fecal collection, constituting an experimental design in Latin square (4 diets test- x 4 periods of fecal collection x 4 replicates). The three by-products had digestibility coefficients above 80%, 70%, and 69% for dry matter, protein, and fat, respectively, being possible to use them as a source of these nutrients in diets for the discus fish. However, it was

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observed that the mango and passion fruit by-product had the lowest energy digestibility coefficient, with bioavailabilities less than 50% of utilization. The co-products of the fruit processing industry tested in this work have nutritional conditions to be used as food for root discs. The use of these co-products as food for ornamental fish can be an alternative use and value.
Key words: Nutrition. Agricultural residues. Reuse.

Resumo

O uso de coprodutos como componentes de uma ração fornece compostos bioativos, sendo economicamente acessível e ecologicamente viável. Neste sentido, o objetivo do estudo foi avaliar a biodisponibilidade de coprodutos da indústria de frutas na alimentação de acarás disco (Symphysodon aequifasciatus) determinando-se os coeficientes de digestibilidade dos macronutrientes. Foram avaliados a digestibilidade de três coprodutos: coproduto de abacaxi (Co-Ab), coproduto de manga (Co-Mg) e coproduto de maracujá (Co-Ma). Foram utilizados 32 acarás disco (106.0 ± 26.6 g) distribuídos em 4 incubadoras, constituindo-se de um delineamento experimental em quadrado latino (3 dietas-teste x 4 períodos de coleta de fezes x 4 repetições). Os coprodutos apresentaram coeficientes de digestibilidade acima de 82% para matéria seca, proteína e extrato etéreo, sendo possível sua utilização como fonte desses nutrientes em dietas para o acará disco. Porém os coprodutos de manga e de maracujá apresentaram os menores aproveitamentos com relação ao coeficiente de digestibilidade para energia, com biodisponibilidades menores de 50% de aproveitamento. Os coprodutos da indústria processadora de frutas testados neste trabalho possuem condições nutricionais para serem utilizados como alimento para acará disco. A utilização destes coprodutos como alimento para peixes ornamentais podem ser uma alternativa de uso e agregação de valor.
Palavras-chave: Valor nutricional. Resíduos da agroindústria. Reaproveitamento.

The fruit processing industry has a liability, i.e., the waste generated being rich in bioactive compounds (dietary fibers, phenolic compounds, and carotenoids) compared with natural fruits (Galanakis, 2012). These compounds can be used as colorants, texturing additives, antimicrobials, flavoring agents, antioxidants, and functional food ingredients (Campos et al., 2018). Although residue products have nutritional characteristics and bioactive compounds, adequate information is still being sought to add value to the production chain (Kumar et al., 2020). The inclusion of co-products in fish feed can be economically viable and ecologically acceptable (Gomes et al., 2021).

Ornamental fishes are kept as pets and have a relatively long life span; therefore, their diet should contain substances that provide beneficial effects on their metabolism (Jin et al., 2021). The discus acará fish has a disc-shaped body and bright colors and is very popular in aquariums. In this context, the inclusion of bioactive compounds in their diet can promote welfare responses, decrease oxidative activity, and change the coloration of the fish (Rashidian et al., 2021). However, only a few studies have reported the use of co-products as a part of such ornamental fish feed. Therefore, it is essential to study the digestibility of food components or bioactive compounds to evaluate their viability for use

in the formulation of diets (Jannathulla et al., 2020) and to establish an optimal level of inclusion in diets.

Therefore, this study aimed to evaluate the nutritional value of co-products generated from the fruit processing industry, considering their use as alternative food components for acará disco.

This work was conducted in the Aquaculture Laboratory of Embrapa Tabuleiros Costeiro in Aracaju-SE. Three co-products in the form of flour were provided by Multi Frutas (AGRICOM- Agroindústria e Comércio Anadiense LTDA). The waste produced after processing of pineapple, mango, and passion fruit were dried and ground to form the co-products. The co-products were named pineapple co-product (Co-Ab), consisting of peels and chips after the industrial processing of the fruit; mango co-product (Co-Mg), consisting of seeds and chips; and passion fruit co-product (Co-Ma), consisting of seeds, peels, and chips. These co-products were characterized bromatologically according to the recommendations of the Association of Official Agricultural Chemists [AOAC] (2000).

Co-Ab had a composition of 84,7% dry matter (DM), 8,4% crude protein (CP), 1,2% ether extract (EE), and 3984,0 Kcal Kg-1; Co-Mg had a composition of 92,0% DM, 4,9% CP, 1,9% EE, and 4351,0 Kcal Kg-1; and Co-Ma had a composition of 83,3% DM, 12,4% CP, 1,0% EE, and 4102,0 Kcal Kg-1.

Before the digestibility test, a test diet used to determine the digestibility coefficient was prepared. This was composed of 79% of the reference diet (Poytara Disco Dia a Dia containing : *Commercial Diet disc Day by Day (Pytara LTDA)- basic composition: acai, albumin, corn starch, beta carotene, beetroot, calcium limestone, canthaxanthin, wheat gluten, D and L-methionine, spinach, yeast extract, flaxseed meal, soybean meal, Schizochytrium sp. algae meal, fish meal, salmon meal, wheat meal, guarana, soy protein isolate, lycopene, L-lysine, apple, marapuama, corn, linseed oil, fish oil, paprika, beet pulp, rice grits, salt, and Tenebrio molitor), 0.5% chromic oxide used as an inert marker, and 20% of the test co-product. The diets were extruded (but with sufficient density to sink) and stored in the freezer at -20ºC. The bromatological composition was 94.9% DM; 48.4% CP; 4.6% EE, and 4890.07 Kcal Kg-1.

In previous trials, difficulty in food management in terms of the food exchange of acará disco was observed; therefore, in this study, we decided to add only 20% of the co-product and 0.5% of palatabilizer (shrimp aroma), besides using a specific commercial feed for the discus fish as a reference diet to minimize the effect of food management.

For the digestibility trial, a Latin square experimental design with three treatments, four fecal collection periods with four replicates, and 8 fishes (106.0 ± 26.6 g) per replicate was used.

The fishes (CEUA 03.13.09.002.00.00 and SISGEN AF7C982) were acclimated for 7 days to the recirculation system consisting of four 200-L conical incubators. The incubators were placed in a closed environment in the laboratory with a 12/12-h cycle. During this period, the fishes were fed three times a day (09:00, 13:00, and 17:30) with the reference diet to ensure better acceptance of these test diets. Due to the calm feeding behavior of the discus fish, wherein the animal does not search for food at the surface, we opted for the use of an extruded diet but with enough density

to sink with time. Thus, a feed containment system, which consisting of a plastic plate that also served as a "trough," was used inside each incubator, helping the fish to ingest the feed and preventing the feed from sinking to the conical bottom of the incubator.

After this acclimation period, the fishes were fed with a test diet for 7 days. In each incubator, a test diet was presented to the fish three times a day (09:00, 13:00, and 17:30) until apparent satiation. Once the feeding period was over, feces were collected. During the fecal collection period, the fishes remained in the tanks, with no need to transfer them to other locations. After the last feeding of the day, weighed till 00 h 40 minutes and then each tank was cleaned [brushing, renewal of water (60%), and fitting of the collection tube to the bottom of the digestibility tank], aiming to eliminate any type of remaining residues. A tube attached to the bottom of the tank was used for this collection, where the excreta sedimented, using the modified Guelph method (Abimorad & Carneiro, 2007). The collection was performed in the morning at 30-minute intervals (to avoid losses by leaching) and then stored at -20°C.

The collection of feces was performed daily to reach a quantity of 10 g for each test diet. A Latin square design consisting of four treatments (feeds), ten periods, and four tanks was used to avoid effects between experimental periods, thus allowing all the fishes to feed on all the food in every period.

The excreta was dried and then analyzed for their bromatological composition (AOAC, 2000). Crude energy analyses were determined by burning the samples in a calorimetric pump. The chromic oxide content was determined by digestion with nitric acid and perchloric acid using a spectrophotometer (Furukawa& Hiroko, 1966). The apparent digestibility coefficient of dry matter (CDMS), crude protein (CDPB), ether extract (CDEE), and energy (CDEB) were determined.

The apparent digestibility coefficients of both the reference and test diets were estimated using the following equation (Nose, 1966).

$$CD = 100 - 100 * \left[\frac{\%\ Cr_2O_3 \text{ na dieta}}{\%\ Cr_2O_3 \text{ nas fezes}} * \frac{\%\ \text{nutrientes das fezes}}{\%\ \text{nutrientes da dieta}} \right]$$

To calculate the nutrient digestibility of the feeds, the following equation was used:

$$DAN = \left(\frac{100}{30} \right) * \left[\text{Dieta teste} - \left(\frac{70}{100} * \text{Dieta referência} \right) \right]$$

Where DAN indicates apparent digestibility of nutrients; Test Diet indicates apparent digestibility of nutrients in the test diet; Reference Diet indicates apparent digestibility of nutrients in the reference diet. The mean digestibility coefficients were subjected to the Shapiro-Wilk, homoscedasticity, and Bartlett's normality assumption tests, and then an analysis of the variance was performed with Tukey's posthoc test at 5% significance level.

Water quality was set by the requirement of acará disco (dissolved oxygen 5.7 ± 0.2 mg L^{-1}, temperature 26.27 ± 1.2°C, and pH 7.95 ± 0.03). No mortality was observed

during the experiment. The three co-products showed apparent digestibility coefficients of >82% for dry matter, crude protein, and ether extract, with no significant differences noted among the co-products (Table 1). However, Co-Ma and Co-Mg presented lower utilization for gross energy, with bioavailability <50% of utilization. The gross energy digestibility coefficient of Co-Ab showed a significant difference in comparison with that of others, obtaining values >68%.

Table 1
Digestibility coefficient of dry matter, crude protein, ether extract and gross energy of the different ingredients tested

	Dry matter (%)	**crude protein (%)**	ether extract (%)	Energia bruta (Kcal kg^{-1})
Co-Ab	88,1±0,87	70,87±8,5a	83,36±6,53	68,01±9,85a
Co-Mg	89,05±0,80	82,63±3,9a	69,18±4,51	45,36±5,80b
Co-Ma	82,35±1,09	72,01±8,8b	74,61±9,47	49,66±8,90b

Different letters report a significant difference by Tuckey's test (P<0.05). Co-Ab: pineapple co-product; Co-Mg: mango co-product; Co-Ma: passion fruit co-product.

The results of digestible protein (Figure 1A) and digestible energy (Figure 1B) examination for the diets added to the evaluated products highlight the inclusion of Co-Mg, which presented the highest value of digestible protein, and of Co-Ma for digestible energy.

The apparent digestibility coefficient indicates the capacity of acará disco to utilize the nutrients of these test diets, predicting the potential of these food components to be included in the formulation of fish diets. In general, the apparent digestibility coefficient of dry matter, crude protein, and ether extract are similar to the digestibility coefficient found for conventional ingredients in other omnivorous species, as in the case of crude protein in the fish meal for tricogaster (*Trichogaster leerii*), with a digestibility coefficient of 82.19%, and for betta (*Betta splendens*), with a digestibility coefficient of 82.19% (Tonini et al., 2012), and for betta (*Betta splendens*), with a digestibility coefficient of 51.15% (Zuanon et al., 2007). The efficient use of vegetal sources of the discus fish above 40% demonstrates the potential of this ingredient in their diets (Chong et al., 2002).

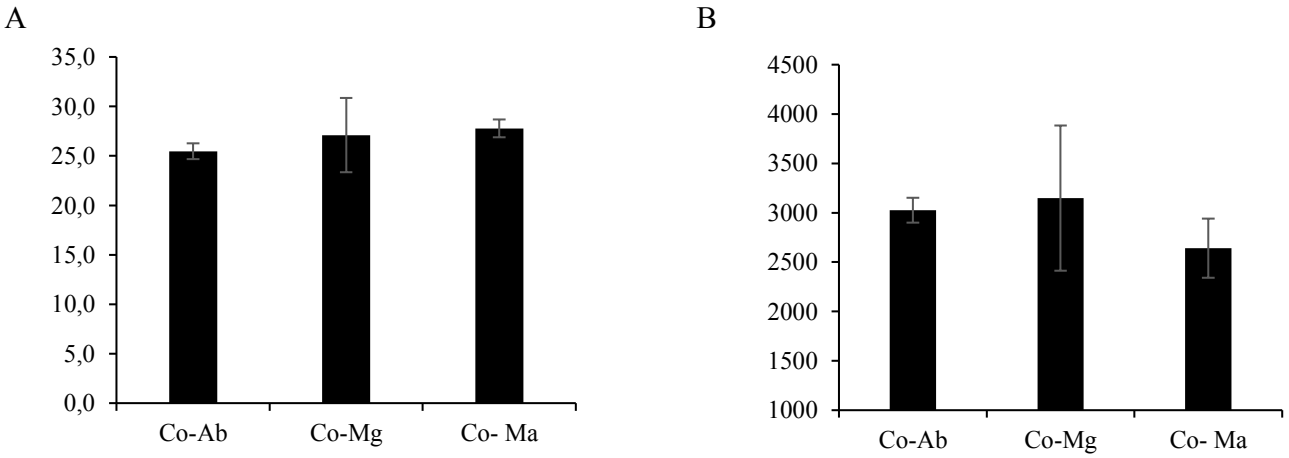

Figure 1. A. Digestible protein (%); B. Digestible energy (Kca kg^{-1}) of diets with fruit by-product flours. Co-Ab: pineapple co-product; Co-Mg: mango co-product; Co-Ma: passion fruit co-product.

In comparison with the conventional ingredients in the diets for acará disco, the co-products presented similar values of digestibility coefficient for dry matter as in the fish meal, wherein the digestibility coefficient for dry matter (CDMS) was 78.15%, for soy bran with 66.22%, and for wheat bran was 49.03% (Chong et al., 2002).

The lowest digestibility was observed for gross energy with Co-Mg, followed by Co-Ma, which might reflect the content and type of fibers that can change the time of passage of the digested food in the digestive tract, altering the utilization of the food components (Honorato et al., 2014). Co-Mg is characterized by higher levels of carbohydrates, such as starch, reducing sugars, and pectic substances that may interfere with the energy utilization of the diet (Bezerra & Melo, 2014; Souza et al., 2012).

Based on the findings of our study, we concluded that Co-Ab, Co-Mn, and Co-Ma provide good digestion when included in the diet of acará disco and do not negatively affect the digestive process. In addition, these co-products are an environmental liability in Brazil, making their utilization feasible and favoring both industries. The utilization rate of these products demonstrates the need to deepen the understanding of the inclusion of such food components in diets and their effects on the metabolism of ornamental fish.

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