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Production and characterization of flour from tambaqui (*Colossoma macropomum*) and babão (*Brachyplatystoma platynema*) residues in southern Amazonas, Brazil

Produção e caracterização da farinha de resíduos de tambaqui (*Colossoma macropomum*) e babão (*Brachyplatystoma platynema*) no sul do Amazonas, Brasil

Producción y caracterización de harina de residuos de tambaqui (*Colossoma macropomum*) y babão (*Brachyplatystoma platynema*) en el sur de Amazonas, Brasil

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Abstract
Fish farming is an activity that brings many economic and social benefits to Brazil, however, it generates large volumes of waste in fish processing, and the inadequate management of these residues is a concerning environmental problem. On the other hand, these residues are an economical source of proteins and other nutrients, allowing their use in obtaining by-products, such as the preparation of flours that can be included in animal feed when processed correctly. Therefore, this study aimed to evaluate and compare the potential for flour production from tambaqui and baboon residues using two treatments: flour production with cooking (T1) and flour production without cooking (T2). The flour yields obtained from the residues of the different treatments were 13.5% and 18.0% for baboon and 12.4% and 18.0% for tambaqui (T1 and T2, respectively). The highest protein contents were observed in the flours obtained from tambaqui residues. Microbiological analyses showed the absence of *Salmonella spp* in the flour samples, complying with current legislation. Based on this study, it is concluded that the obtained flours meet the pre-established standards of crude protein and moisture, complying with the criteria established by RIISPOA for second-quality flours. Furthermore, these flours represent a promising alternative for the reuse of fish residues, which are often improperly discarded in the environment, causing significant negative impacts.
Keywords: Fish meal; Fish waste; Sustainability.

Resumo
A piscicultura é uma atividade que traz muitos benefícios econômicos e sociais para o Brasil, porém gera grandes volumes de resíduos no processamento do pescado e o manejo inadequado desses resíduos é um problema ambiental preocupante. Por outro lado, esses resíduos são uma fonte econômica de proteínas e outros nutrientes, o que permite sua utilização na obtenção de subprodutos, como no preparo de farinhas que podem ser incluídas na alimentação animal desde que processadas corretamente. Portanto, este estudo objetivou avaliar e comparar o potencial de produção de farinha obtida a partir de resíduos de tambaqui e babão utilizando dois tratamentos: produção de farinha com cozimento (T1) e produção de farinha sem cozimento (T2). Os rendimentos da farinha obtida a partir dos resíduos dos diferentes tratamentos foram de 13,5% e 18,0% para o babão, 12,4% e 18,0% para o tambaqui (T1 e T2, respectivamente). Os maiores teores de proteína foram observados nas farinhas obtidas com resíduos de tambaqui. As análises microbiológicas mostraram a ausência de *Salmonella spp* nas amostras de farinha, atendendo à legislação vigente. Conclui-se, com base no presente estudo, que as farinhas obtidas atendem aos padrões pré-estabelecidos de proteína bruta e umidade, adequando-se aos critérios estabelecidos pelo RIISPOA para farinhas de segunda qualidade.

Além disso, essas farinhas representam uma alternativa promissora para o reaproveitamento de resíduos de pescado, os quais, frequentemente, são descartados de forma inadequada no meio ambiente, ocasionando impactos negativos significativos.
Palavras-chave: Farinha de peixe; Resíduos de peixe; Sustentabilidade.

Resumen
La piscicultura es una actividad que aporta muchos beneficios económicos y sociales a Brasil, pero genera grandes volúmenes de residuos en el procesamiento del pescado, y la gestión inadecuada de estos residuos es un problema ambiental preocupante. Por otro lado, estos residuos son una fuente económica de proteínas y otros nutrientes, lo que permite su utilización en la obtención de subproductos, como la preparación de harinas que pueden incluirse en la alimentación animal siempre que se procesen correctamente. Por tanto, este estudio tuvo como objetivo evaluar y comparar el potencial de producción de harina obtenida a partir de residuos de tambaqui y babón utilizando dos tratamientos: producción de harina con cocción (T1) y producción de harina sin cocción (T2). Los rendimientos de harina obtenidos a partir de los residuos de los diferentes tratamientos fueron del 13,5% y 18,0% para babón, 12,4% y 18,0% para tambaqui (T1 y T2, respectivamente). Los contenidos de proteínas más altos se observaron en las harinas obtenidas a partir de residuos de tambaqui. Los análisis microbiológicos mostraron la ausencia de *Salmonella spp* en las muestras de harina, cumpliendo con la legislación vigente. Se concluye, en base al presente estudio, que las harinas obtenidas cumplen con los estándares preestablecidos de proteína bruta y humedad, ajustándose a los criterios establecidos por el RIISPOA para harinas de segunda calidad. Además, estas harinas representan una alternativa prometedora para el aprovechamiento de los residuos de pescado, que a menudo se descartan de manera inadecuada en el medio ambiente, causando impactos negativos significativos.
Palabras clave: Harina de pescado; Desechos de pescado; Sostenibilidad.

1. Introduction

Fish is one of the most abundant and consumed natural resources in the Amazon region (Superintendência da Zona Franca de Manaus, 2003). The state of Amazonas has great potential for the expansion and success of fish farming in the national market thanks to factors favorable to the development of the activity such as: tropical climate, water availability, appropriate topography and variety of species with excellent market value and performance for creation (Lima, 2018).

Despite having factors favorable to fish production, the Amazon still has much to develop in fish production since according to Brazilian Institute of Geography and Statistics (IBGE, 2018) information, the state occupies the 19th position in the ranking of aquaculture production, with production equivalent to 8162.5 tons of fish.

Although it brings many benefits and has great importance for our country, fish farming is an activity that generates large volumes of waste in the processing of fish, so inadequate management of these residues can become a worrying environmental problem (Abreu et al., 2012). On the other hand, these residues have a high content of protein and other nutrients (Feltes et al., 2010), so they can be used in the preparation of flours for animal feed provided that they are processed correctly (Eyng et al., 2010).

Obtaining flour from fish residues is an alternative with great potential because it can be used not only in fish farming, but can also be included in the feeding of other animals, as was verified in a study conducted by Eyng et al. (2010), where the results showed that the addition of Tilapia flour in feed for broilers in the phase of 1 to 42 days, at levels of up to 8% does not impair the performance of birds and also improves economic performance and reduces the concentration of phosphorus and calcium in the bloodstream. In another study, Boscolo et al. (2005) concluded that the waste flour of the tilapia filleting industry can be included in levels of up to 15% in feed for piauçu fingerlings (Leporinus macrocephalus).

Miles & Chapman (2015) point out that high quality fish meal typically has between 60 and 72% crude protein, in line with the Industrial Regulation of Sanitary Inspection of Animal Products (RIISPOA) that classifies fish meal into: a) first quality flour or common type that must contain at least 60% protein and a maximum of 10%, 8%, 5% and 2% moisture, fat, chlorides expressed in NaCl and sand, respectively; and b) second quality flour that must present at least 40% protein and a maximum of 10%, 10%, 10% and 3% moisture, fat, chlorides expressed in NaCl and sand, respectively (Brasil, 1952).

From the above, this article aims to produce and evaluate the centesimal composition of flours obtained from residues of two fish species: tambaqui (*Colossoma macropomum*) and babão (*Brachyplatystoma platynema*), from two different treatments, namely: flour production with cooking (T1) and production of flour without cooking (T2).

2. Methodology

2.1 Production of flour with fish residues

The flours were produced in the Fish Technology Laboratory of UFAM (Manaus-AM), residues of two species were used, tambaqui (Colossoma macropomum) and babão (Brachyplatystoma platynema). Tambaqui residues collected at the Municipal Market of Humaitá and babão residues were used by a local merchant, which were: heads, fins, spine, skins and shavings, both separated according to the species, packed in isothermal boxes during transport. Then, they were stored in a refrigerator at a temperature below 0°C and then transported in isothermal boxes, being thawed at room temperature at the time of flour production.

Two treatments were performed to produce the flours, adapted by Abreu et al. (2012) and Piasson et al. (2015): flour production with cooking (T1) and flour production without cooking (T2).

In the production of fish waste flour with cooking (Figure 1), after thawing, the residues of tambaqui and babão were cut into smaller parts. Then, they were submerged in 0.05% NaOH solution, in the ratio of 3:1 (water:fish) and at 90°C for 40 minutes. After the disposal of cooking water, the residues were crushed in a knife mill (20 mm). Then, the waste mass was submitted to hydraulic pressure, under pressure of 15 tons, until the oil flow was no longer observed, forming the press pies. Subsequently, the press pies were taken to the circulating air kiln at 60°C for six hours. Finally, the press pies were subjected to grinding in a knife mill (2 mm).

Figure 1 - Stages of the production of fish waste flour. 1A. Cooking; 1B. Pressing; 1C. Press pie; 1D. Dehydration; 1E. Second crushing; 1F. Final product.

Source: Authors (2020).

In the production of waste flour without cooking, the steps were similar to those described in T1, except for the cooking stage, which was not performed. Another point that differed from T1 concerns the time when the press pies remained in the greenhouse, also at a temperature of 60°C, for the dehydration of the material. In the case of tambaqui, the total greenhouse period was twenty-one hours, while in the case of flour produced with babão residues, the material needed to be removed from the greenhouse three times in order to obtain the flow of oil present that hindered its dehydration, so the total period of dehydration of the sample was five days.

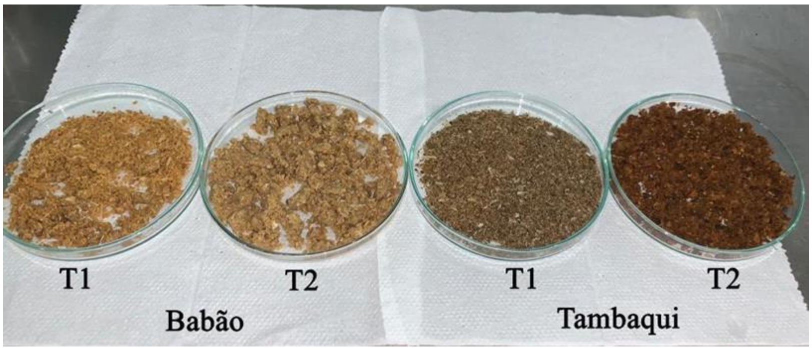
2.2 Physicochemical analyses

Analyses of centesimal composition of the obtained flours were performed (Figure 2), following analytical standards of the Adolfo Lutz Institute (1985) and Association of Official Analytical Chemists-AOAC (1990).

The moisture content was determined by drying in an oven with air circulation, up to constant weight. The ashes were obtained by incineration in a muffle furnace at 550ºC until constant weight. For crude protein detection, total nitrogen was determined by the micro-Kjeldahl method, the amount of crude protein was calculated by applying the nitrogen conversion factor of 6.25. Lipid content was determined by extraction without heating (Bligh & Dyer, 1959).

The total carbohydrates correspond to the nitrogen-free sample, or nitrogen-free extract, and were obtained by difference between 100 and the sum of the percentages of moisture, ash, lipids and protein. The pH was obtained through electrometric determination.

Figure 2 - Flours produced with fish residues. 2A. Babão flour with cooking; 2B. Babão flour without cooking; 2C. Tambaqui flour with cooking; 2D. Tambaqui flour without cooking.



Source: Authors (2020).

2.3 Microbiological analysis

Microbiological analyses of presence/absence of Salmonella spp. were performed in the samples in order to verify the microbiological quality of the flour using the methodology of Moura et al. (2002).

2.4 Statistical analysis

The experiment was elaborated in a 2x2 factorial scheme, two fish species and two residue treatments, in a completely randomized design (CRD) with five replications by combination of factors and three subsamples per repetition. The analyses were performed in R programming language (R Core Team, 2019). Variance Analysis (ANOVA) and Tukey test were performed at 5% significance to compare the means of the results.

3. Results and Discussion

The observed yield values of the flours produced without the cooking stage (T2) were higher, being 18.0% for the babão and for tambaqui, when compared to the values of flours produced with cooking (T1), being 13.5% for the babão and 12.4% for tambaqui. This result is probably due to the fact of greater losses in the cooking process of the samples.

According to Nunes (2011), cooking will act through water vapor under pressure, causing the rupture of cell walls with protein coagulation and separation of water and oil, which possibly caused a lower yield of flour. The results observed here were lower when compared to the results obtained using the use of cooking in the production of flours and fish protein concentrate in previous studies (Coradini, 2018; Campos et al., 2020).

For the variable humidity, the means were statistically higher (p-value < 0.01) for treatments with cooking, with values of 3.77% for the babão and 4.32% for tambaqui, in relation to treatments without cooking, with averages of 1.24% for the babão and 1.73% for tambaqui, as shown in Table 1. In addition, these means were significantly higher for the tambaqui species in relation to the babão species (p-value < 0.01).

Possibly the lowest levels observed in the flours obtained without cooking occurred due to the greater humidity loss of these samples when submitted to the dehydration stage in the greenhouse for a longer period of time in relation to the flours obtained with cooking.

The moisture levels in all produced flours were lower than those observed by Petenuci et al. (2010), with a moisture content of 14.20% in tilapia backbone flour; by Souza et al. (2022), with moisture levels of 8.37%, 6.11%, 7.59%, and 9.24% for flours derived from tilapia carcass, salmon, tuna, and sardine, respectively; and by Corrêa et al. (2023), who obtained moisture content of 3.53% and 3.95% for Nile tilapia backbone and corvina flours, respectively.

Table 1 - Mean values and standard deviation of the centesimal composition of flours obtained from residues of the species babão (*Brachyplatystoma platynema*) and tambaqui (*Colossoma macropomum*).

	Humidity (%)		
Treatments	Brachyplatystoma platynema	Colossoma macropomum	p-value
With cooking (T1)	3.77 ± 0.08 Ab*	4.32 ± 0.14 Aa	< 0.01
Without cooking (T2)	1.24 ± 0.09 Bb	1.73 ± 0.17 Ba	< 0.01
p-value	< 0.01	< 0.01	
	Ashes (%)		
Treatments	Brachyplatystoma platynema	Colossoma macropomum	p-value
With cooking (T1)	24.32 ± 0.52 Ab	25.36 ± 1.63 Aa	< 0.01
Without cooking (T2)	10.30 ± 0.45 Bb	14.82 ± 0.89 Ba	< 0.01
p-value	< 0.01	< 0.01	
	Crude Protein (%)		
Treatments	Brachyplatystoma platynema	Colossoma macropomum	p-value
With cooking (T1)	39.67 ± 1.16 Bb	52.69 ± 0.72 Aa	< 0.01
Without cooking (T2)	42.63 ± 0.90 Ab	47.93 ± 1.46 Ba	< 0.01
p-value	< 0.01	< 0.01	
	Lipids (%)		
Treatments	Brachyplatystoma platynema	Colossoma macropomum	p-value
With cooking (T1)	24.53 ± 3.19 Ba	11.48 ± 1.62 Bb	< 0.01
Without cooking (T2)	39.43 ± 2.76 Aa	27.21 ± 2.55 Ab	< 0.01
p-value	< 0.01	< 0.01	
	pH		
Treatments	Brachyplatystoma platynema	Colossoma macropomum	p-value
With cooking (T1)	8.43 ± 0.03 Aa	8.39 ± 0.06 Ab	0.03
Without cooking (T2)	6.34 ± 0.02 Ba	5.28 ± 0.05 Bb	< 0.01
p-value	< 0.01	< 0.01	
	Carbohydrates (%)		
Treatments	Brachyplatystoma platynema	Colossoma macropomum	p-value
With cooking (T1)	7.71 ± 3.62	6.15 ± 2.48	0.16
Without cooking (T2)	6.41 ± 2.64	8.31 ± 3.17	0.09
p-value	0.24	0.06	

Average ± standard deviation. *Different capital letters in the column and different lowercase letters in the row indicate statistical differences according to the Tukey 5% test. Source: Authors (2021).

Considering the babão species, for the percentage of ashes (Table 1), the means were significantly higher (p-value < 0.01) for the treatment with cooking (24.32%) in relation to treatment without cooking (10.30%). For the tambaqui species, as averages were also significantly higher (p-value < 0.05) for the treatment with cooking (25.36%) in relation to treatment without cooking (14.82%). As means of ash percentage obtained for the tambaqui species were statistically higher than the means obtained for the babão species (p-value < 0.01).

It is important to highlight that the high ash content is one of the concerning factors when dealing with the use of flour derived from fish waste, which will be subsequently used in animal feed formulations, as feeds with high ash content lead to high phosphorus levels and, consequently, potential eutrophication of water resources caused by the high nutrient content (Hardy, 1996; Millamena, 2002; Boscolo et al., 2004). In the literature, information regarding ash levels in flours considered of better quality varies, with those having ash levels below 15% of mineral matter being observed as superior (Gaylord & Gatlin, 1996; Maina et al., 2002; Sales & Britz, 2003), while others have ash content ranging between 17% and 25% (Miles &

Chapman, 2015).

In this study, the observed values for the ash variable corroborate with the results of Oliveira Filho and Fracalossi (2006) and Higuchi (2015). Lower ash content was observed by Petenuci et al. (2010) in flour composed of tilapia backbone and by Boscolo et al. (2008) in flour derived from tilapia filleting industry waste. Only the flour obtained from tambaqui residues with cooking showed a slightly higher content than the limit indicated by Miles and Chapman (2015).

In the crude protein variable (Table 1), the means obtained for the babão species were significantly higher (p-value < 0.01 for treatment without cooking (42.63%) in relation to cooking treatment (39.67%). For the tambaqui species, the results were inverse, with the highest mean protein obtained for the treatment with cooking (52.69%) compared to treatment without cooking (47.93%).

Similar crude protein contents in fish meal were observed by Corrêa et al. (2023), Higuchi (2015), Boscolo et al. (2008) and Vidotti & Gonçalvez (2006), characterizing these flours as protein food. In the work of Higuchi (2015), the highest protein content is related to the composition of the raw material used. In the case of tambaqui, spines containing small amounts of adhered meat were used, providing a higher crude protein content.

The means observed for the percentage of lipids (Table 1) were statistically higher (p-value < 0.01) in treatments without cooking, being 39.43% for babão and 27.21% for tambaqui, compared to the means obtained in the treatment with cooking, 24.53% for babão and 11.48% for tambaqui. The average percentages of lipids found in the flours were significantly higher (p-value < 0.01) for the babão species in relation to the tambaqui species.

It is noted that the highest lipid contents were observed in treatments without cooking, and the absence of the cooking stage is a probable cause for the high levels observed since the application of heat influences the release of lipids (Campos et al., 2020). The lipid contents observed in this study for tambaqui (T2) and babão (T1) flours are close to that observed by Petenuci et al. (2010) (25.30%) and, for babão flour (T2), the lipid content is close to that observed by Stevanato et al. (2007) in tilapia flour (35.50%).

High lipid contents are worrisome because they contribute to the acceleration of flour oxidation, causing off-flavor, called rancid (Fogaça & Sant'ana, 2009), causing a reduction in shelf life and sensory quality of the products to be prepared using flours, such as animal feed. With this, it is essential that the lipid content is reduced so that there is no and/or reduced the need for the use of additives and preservatives in products (Campos et al., 2020).

It is noteworthy that the lipid content observed for babão flour without cooking corroborates what was observed during its production, where a quantity of oil was obtained higher than the other yields (dehydration stage), in relation to the time of production, since the dehydration of the sample was slow.

Aiming at reducing the lipid content in the flours obtained without cooking and increasing shelf time of these products, a possible low-cost alternative would be the adoption of cooking in the production process because it is an efficient method of delipidification as verified by Campos et al. (2020), in which the comparison of tambaqui carcasses into pieces is carried out, cooked and dried (CPP2) and crushed, cooked and dried carcasses (CPP3) to dry-only whole carcasses (CPP1), there was a reduction of 51.06% and 56.34% of lipid contents, respectively for CPP2 and CPP3, in relation to the average value observed for CPP1.

For the pH values (Table 1), the treatment with cooking presented higher averages (p-value < 0.01) for the species babao (8.43) and tambaqui (8.39), compared to the treatment without cooking for the babão (6.34) and tambaqui (5.28) species. The mean pH values were statistically higher for the species babão in relation to the tambaqui species (p-value < 0.05).

There were no significant differences for the means of the percentage of carbohydrates between tambaqui and babão species within the treatment with cooking (p-value = 0.16) and within the treatment without cooking (p-value = 0.09).

Similarly, there were no significant differences for the means of treatments with and without cooking within the babão species (p-value = 0.24) and within the tambaqui species (p-value = 0.06).

The carbohydrate contents for babão and tambaqui flours for both treatments were higher than those found by Higuchi (2015) who obtained 3.54 and 0.36% for patinga and real painted flours, respectively.

In addition to providing an excellent profile of essential fatty acids, lipids in fish meal also provide a high energy content for the diet when included in feed rations, since the carbohydrate contents present in fish meal are low as observed in the present study, so the amount of energy present in these flours is directly related to the percentage of protein and oil present (Miles & Chapman, 2015).

Fish residue meal is an alternative source of protein in the formulation of fish feed, it is highlighted that fish need the amino acids present in the protein of food so that they can grow properly (Guilherme, Cavalheiro & Souza, 2006). The total protein levels contained in typical fish diets can range from 32% to 45% of total protein by weight, while the inclusion of fishmeal in diets for terrestrial animals usually occurs at levels of 5% or lower (Miles & Chapman, 2015).

The results of the microbiological analysis showed the absence of Salmonella spp. in all samples analyzed, showing to be in accordance with Brazilian Normative Instruction 34/2008 in which, it is stated that periodic analyses should be provided to ensure the absence of Salmonella spp. in 25 (twenty-five) grams of the finished product, so the flours obtained for both species and treatments were in accordance with the legislation.

4. Conclusion

The flours produced from tambaqui and babão residues proved to be an excellent alternative for the supply of proteins and minerals in the formulation of animal feed, especially tambaqui waste flour (T1), which presented the highest protein content. However, it is worth mentioning that to obtain animal feed using the flours obtained in the present study, it is essential that techniques be adopted in order to reduce the lipid contents of babão flours (T1 and T2) and tambaqui (T2) so that the shelf life of the products to be obtained is extended.

It is also noteworthy that the flours obtained in the present study meet the standards of crude protein and moisture pre-established for second quality flours according to RIISPOA.

Therefore, it was found that the reuse of fish residues to obtain flour is a promising and low-cost alternative that can be applied in order to minimize negative environmental impacts that are caused by the inadequate disposal of these residues, as has been occurring not only in the south of the Amazon, but also in other Brazilian states. Knowing the need to make the fish production chain more sustainable, the adoption of this practice can be one of the paths to sustainability in this activity.

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References

Abreu, L. F., Ribeiro, S. da C. do A., & Araújo, E. A. F. de. (2012). *Processo agroindustrial:* Elaboração de farinha de resíduos de Tambaqui (*Colossoma macropomum*) para uso como ingrediente de rações de pescado videira. Belém: Embrapa Amazônia Oriental.

Association of Official Analytical Chemists (AOAC). (2000). Official methods of analysis of AOAC International (17th ed.). AOAC International, Arlington.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, 37, 911.

Brasil. Decreto nº 30.691, de 29 de março de 1952. Regulamento da Inspeção Industrial e Sanitária de Produtos de Origem Animal - RIISPOA. Diário Oficial da União.

Boscolo, W. R., Hayashi, C., Feiden, A., Meurer, F., & Signor, A. A. (2008). Composição química e digestibilidade aparente da energia e nutrientes da farinha de resíduos da indústria de filetagem de tilápias, para a tilápia do Nilo (*Oreochromis niloticus*). *Ciência Rural,* 38(9), 2579-2586.

Boscolo, W. R., Hayashi, C., Meurer, F., Feiden, A., & Bombardelli, R. A. (2004). Digestibilidade aparente da energia e proteína das farinhas de resíduo da filetagem da tilápia do Nilo (*Oreochromis niloticus*), da corvina (*Plagioscion squamosissimus*) e farinha integral do camarão canela (*Macrobrachium amazonicum*) para a tilápia do Nilo. *Revista Brasileira de Zootecnia,* 33(1), 8-13.

Boscolo, W. R., Signor, A., Feiden, A., Signor, A. A., Schaefer, A., & Reidel, A. (2005). Farinha de resíduos da filetagem de tilápia em rações para alevinos de piauçu (*Leporinus macrocephalus*). *Revista Brasileira de Zootecnia*, 34(6), 1819-1827.

Campos, J. M. de, Cassol, G. Z., Rezende, J. H. S. de, Bruno, V. C. F. G. de S., Fogaça, F. H. dos S., Savay da Silva, L. K., ... Zuffo, A. M. (2020). Cocção como método de deslipidificação de concentrado proteico de tambaqui (*Colossoma macropomum*). In A. M. Zuffo, J. G. Aguilera, & W. V. Nogueira (Eds.), *Tópicos em ciências dos alimentos* (pp. 6-20). Nova Xavantina: Pantanal Editora.

Coradini, M. F. (2018). *Farinhas de tilápia do Nilo e salmão elaboradas por diferentes metodologias e sua aplicação em produto alimentício* (Dissertação de Mestrado). Universidade Estadual de Maringá, Maringá, Paraná.

Corrêa, S. S., Oliveira, G. G., Franco, M. C., Gasparino, E., Feihrmann, A. C., Siemer, S., Dantas Filho, J. V., Cavali, J., Schons, S. V., & Souza, M. L. R. (2023). Quality of *Oreochromis niloticus* and *Cynoscion virescens* fillets and their by-products in flours make for inclusion in instant food products. *Plos One*, 18(2), e0279351.

Eyng, C., Nunes, R. V., Pozza, P. C., Silva, W. T. M., Navarini, F. C., & Henz, J. R. (2010). Farinha de resíduos da indústria de filetagem de tilápias em rações para frangos de corte. *Revista Brasileira de Zootecnia*, 39(12), 2670-2675.

Feltes, M. M. C., Correia, J. F. G., Beirão, L. H., Block, J. M., Ninow, J. L., & Spiller, V. R. (2010). Alternativas para a agregação de valor aos resíduos da industrialização de peixe. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 14(6), 669-677.

Gaylord, T. G., & Gatlin III, D. M. (1996). Determination of various feedstuffs for red drum (*Sciaenops ocellatus*). *Aquaculture*, 139, 303-314.

Guilherme, R. F., Cavalheiro, J. M. O., & Souza, P. A. S. (2006). Caracterização química e perfil aminoácidico da farinha de Silagem de cabeça de camarão. *Cienc. Agrotec.*, 31, 793-797

Fogaça, F. H. S., & Sant'ana, L. S. (2009). Oxidação lipídica em peixes: mecanismo de ação e prevenção. *Archives of Veterinary Science,* 14(2), 117-127.

Hardy, R. W. (1996). Alternate protein sources for salmon and trout diets. *Animal Feed Science and Technology,* 59, 71-80.

Higuchi, L. H. (2015). *Produção, caracterização nutricional e utilização de farinhas e óleos de resíduos de peixes neotropicais em dietas para Tilápia do Nilo* (Tese de doutorado). Universidade Estadual Paulista, Jaboticabal, São Paulo.

Instituto Adolfo Lutz. (1985). Métodos físico-químicos para análise de alimentos (3a ed.). São Paulo.

Instituto Brasileiro de Geografia e Estatística. (2018). Pesquisa da Pecuária Municipal. Recuperado de https://sidra.ibge.gov.br/tabela/3940#resultado

Lima, C. A. S. (2018*). Caracterização e diagnóstico do perfil socioeconômico da piscicultura no estado do Amazonas* (Dissertação de Mestrado). Universidade Federal do Amazonas, Manaus, Amazonas.

Maina, J. G., Beames, R. M., Higgs, D., Mbugua, P. N., Iwama, G., & Kisia, S. M. (2002). Digestibility and feeding value of some feed ingredients fed to tilapia *Oreochromis niloticus* (L.). *Aquaculture Research*, 33, 853-862.

Millamena, O. M. (2002). Replacement of fish meal by animal byproduct meals in a practical diet for grow-out culture of grouper *Epinephelus coioides*. *Aquaculture*, 204, 75-84.

Moura, R. de A., Wada, C. S., Purchio, A., & Almeida, T. V. de. (2002). *Técnicas de Laboratório* (3ª ed.). São Paulo: Atheneu.

Miles, R. D., & Chapman, F. A. (2015). *The benefits of Fish Meal in Aquaculture Diets.* Fisheries and Aquatic Sciences Department UF/IFAS Extension. Recuperado de https://edis.ifas.ufl.edu/pdffiles/FA/FA12200.pdf

Nunes, M. L. (2011). Farinha de Pescado. In A. A. Goncalves (Org.), *Tecnologia do pescado: ciência, tecnologia, inovação e legislação* (1ª ed., pp. 362-371). São Paulo: Atheneu.

Oliveira, P. R. C., F. & Fracalossi, D. M. (2006). Coeficientes de digestibilidade aparente de ingredientes para juvenis de jundiá. *Revista Brasileira de Zootecnia,* 35(4), 1581-1587.

Petenuci, M. E., Stevanato, F. B., Morais, D. R., Santos, L. P., Souza, N. E., & Visentainer, J. V. (2010). Composição e estabilidade lipídica da farinha de espinhaço de tilápia. *Ciênc. agrotec.,* 34(5), 1279-1284.

Piasson, M. B., Senger, P., Piccoli, L. Q., Farias, M. B., Zanetti, M., Hauotili, L., Padilha, S. T. M., & Netto, P. D. (2015). Composição química de subprodutos da indústria de camarão. In Anais do *15º Congresso Brasileiro de Zootecnia*. Fortaleza: Associação Brasileira de Zootecnistas.

Sales, J., & Britz, P. J. (2003). Apparent and true availability of amino acids from common feed ingredients for South African abalone (*Haliotis midae L.*). *Aquaculture Nutrition,* 9, 55-64.

Souza, M. L. R., Gasparino, E., Goes, E. S. R., Coradini, M. F., Vieira, V. I., Oliveira, G. G., Matiucci, M. A., Castro, A. C. V. J., Siemer, S., & Fernandes, V. R. T. (2022). Fish carcass flours from different species and their incorporation in tapioca cookies. *Future Foods,* 5, 100132.

Superintendência da Zona Franca de Manaus. (2003). *Estudo de Potencialidades – Estudo de Viabilidade Econômica.* Piscicultura, Sumário Executivo. Superintendência da Zona Franca de Manaus, 8, 1-18. http://www.suframa.gov.br/publicacoes/proj_pot_regionais/sumario/piscicultura.pdf