

AGRI-FOOD WASTE AND BYPRODUCTS IN TAMBAQUI AND TILAPIA DIETS: A CIRCULAR ECONOMY PERSPECTIVE FOR SMALL-SCALE FISH FARMING IN THE AMAZON

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ABSTRACT

Fish farming has become a strategic activity for fish production in Brazil. However, the high costs of feed represent an obstacle to the economic viability of the activity, driving the search for alternatives. This study investigated the potential of agri-food waste in the formulation of handmade feed for tambaqui and tilapia, taking into account the socioeconomic aspects of fish farmers, the availability and seasonality of local ingredients, production infrastructure, and scientific evidence on the applicability of these inputs in the nutrition of the species. The research was conducted between 2023 and 2024 in the municipality of Vigia, Pará, covering 30 fish farmers. The methodology included technical visits and the use of structured questionnaires. The results indicated that fish farming is mostly conducted by men (93.3%) and operates in an extensive system (96.6%), using only family labor. Ingredients such as bananas (26.6%), mangoes (20%), açaí (16.6%), and cassava (20%) were the most commonly used alternative fish feeds. However, 90% of fish farmers do not have the infrastructure for the production of handmade feed. A literature review revealed that agro-industrial waste, has a nutritional composition compatible with the needs of tambaqui and tilapia and may partially replace conventional ingredients without compromising zootechnical performance. Our results indicated crops analyzed are intended for the final growth phase for both species, and their feeding habits are omnivorous. However, implementing this approach requires technical training and experimental studies to evaluate the nutritional and physiological effects of the ingredients on the digestibility and feed conversion of species.

Keywords: *Colossoma macropomum*, *Oreochromis niloticus*, fish nutrition, handmade fish diets.

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1. INTRODUCTION

Aquaculture has been identified as one of the main sources of animal protein for humanity in the coming decades, offering an alternative to mitigate the nutritional deficit caused by the disorderly exploitation of wild fish stocks (FAO, 2024). In Brazil, freshwater fish farming stands out as the most developed branch of aquaculture, reflecting a global growth trend (VALENTI et al., 2021). In 2023, national production reached 887,029 tons (PEIXE BR, 2024).

In the Amazon region, where the natural conditions are ideal for aquaculture (with a abundant water resources and diverse ichthyofauna), tambaqui (*Colossoma macropomum*) is the most cultivated native species (IBGE, 2024). This production takes place mainly in excavated ponds and small enterprises that operate on a family economy basis (LIMA et al. 2020; VIANA et al., 2018). Because it is an omnivorous species, tambaqui has zootechnical advantages, such as lower nutritional requirements, satisfactory production performance in different farming systems and wide acceptance of its meat in the consumer market (FRISSO et al., 2020; IZEL-SILVA et al., 2020; RODRIGUES et al., 2024).

Another species present in fish farms in the Brazilian Amazon is the Nile tilapia (*Oreochromis niloticus*) (IBGE, 2024; PEIXE BR, 2024). It is not known exactly when the first specimens arrived, but it is almost certain that this introduction began after the Second World War, in the 1950s, along with the process of agricultural modernization and import of technological packages from world powers of the time, such as the United States (FIUZA, 2023). Currently, tilapia is the most cultivated species in Brazil, present in all regions of the country (VALENTI et al., 2021). Of the total produced by fish farming in the country (USD 1.2 billion; 655.3 thousand tons), tilapia represents 67.5% of the total produced nationally, and with production recorded in the following states of the Brazilian Amazon: Acre, Pará, Amapá, Tocantins, Maranhão and Mato Grosso (IBGE, 2024).

Despite the significant growth in fish farming, the Northern Brazilian production chain remains poorly structured, especially for small producers, who face significant difficulties (HUNGRIA et al., 2024). Among these challenges is the formulation of low-cost balanced feeds, as conventional feeds account for 60 to 70% of the operating costs of aquaculture enterprises (COLT & SCHUUR, 2021). This high cost drives the search for alternative and sustainable

sources of feed ingredients that maintain nutritional quality and provide acceptable productive performance (SAMPATHKUMAR et al., 2023).

The use of agro-industrial waste and byproducts, especially those from fruit and food crops, has proven to be an innovative and sustainable solution for reducing production costs. Fruit, vegetables, and tubers account for 40–50% of agri-food waste and loss from farm to end-user, while fish accounts for 35%, cereals for 30%, and oil seeds, meat, and dairy products for 20%, according to UN estimates (PRABAKUSUMA et al., 2023). These residues (such as peels, seeds, and bagasse/bark/pie/flour) are rich in vitamins, fiber, energy and protein, making them viable alternatives to replace conventional ingredients in feed formulations (GULE & GEREMEW, 2022; MARCHÃO et al., 2024; SILVA et al., 2020).

In the Amazon region, the integration of aquaculture and family farming plays a strategic role in the livelihoods of small producers. These production systems combine the cultivation of fruit species with fish farming, as well as the industrialization of fruit for the production of frozen pulp (IBGE, 2024). However, this activity generates a large amount of organic waste, and its improper disposal can result in negative environmental impacts. Using these byproducts as alternative ingredients in the formulation of feed for tambaqui and tilapia is a promising strategy, adding value to local raw materials and contributing to the sustainability of regional fish farming. In addition to reducing feed costs – one of the main obstacles to the economic viability of the activity – this approach can minimize the environmental impacts resulting from the inappropriate disposal of agro-industrial waste (BERTOCCI & MANNINO, 2022).

Given this scenario, this study aimed to investigate the practices of formulating handmade fish feed for tambaqui and tilapia, addressing fundamental aspects such as (i) the socioeconomic characteristics of fish farmers; (ii) the potential for using local ingredients to feed the species; (iii) the infrastructure needed to process alternative rations; (iv) scientific evidence on the use of these inputs in both species nutrition; and (v) the nutritional composition and seasonality of the ingredients available in the region.

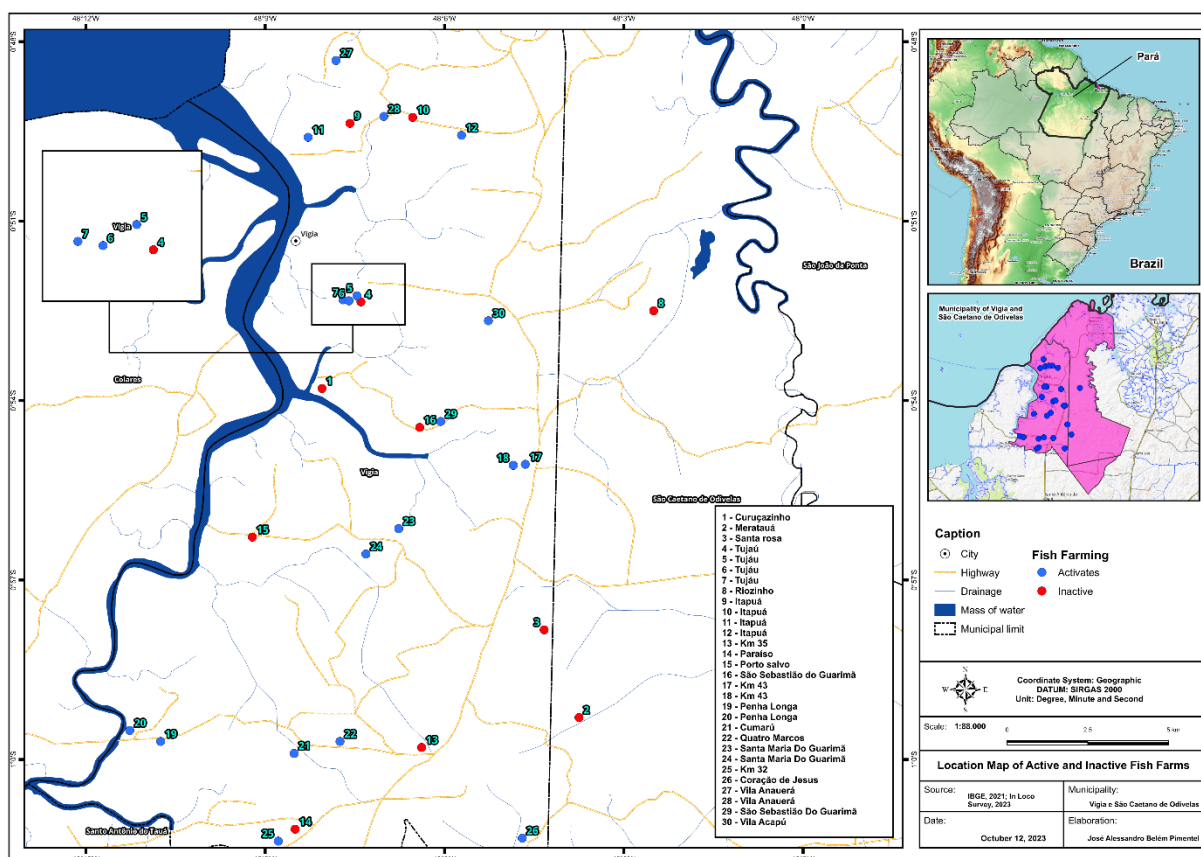
2. MATERIAL AND METHODS

2.1 Study area

The state of Pará, located in the northern region of Brazil, has a territorial extension of 1,248,042 km², distributed among 144 municipalities. The study was carried out in the municipality of Vigia (Figure 1), which is located 77 km from Belém and has an area of 539.1 km² and a population of 50,832 inhabitants (IBGE, 2022).

Vigia is a fishing center with favorable conditions for aquaculture, and the local population is also involved in agri-food production.

Figure 1 - Geographical location of the properties of small-scale fish farmers in the municipality of Vigia (state of Pará, Brazil).



Source: Authors (2025).

2.1.2 Data collection and analysis

All 30 fish farmers active in 2023 and 2024 were included in the study, representing 100% of the municipality's fish farmers. Data collection was carried out in three stages: pre-field, field and post-field. Initially, exploratory bibliographic and documentary research was carried out on fish feeding and nutrition, with an emphasis on the use of nonconventional ingredients in feed formulations.

The investigation adopted a qualitative–quantitative approach, and it was conducted after approval by the Research Ethics Committee (REC), no. 71.158.845, following the guidelines of Resolution no. 510/16 of the National Health Council of Brazil.

Between 2023 and 2024, technical visits were made to the properties of fish farmers. To identify the participants, the “snowball sampling” technique was used, which is a non-probabilistic method in which the first interviewees indicate new participants until the inclusion of new respondents does not provide new information, characterizing sample saturation (ANANG et al., 2024).

The structured questionnaires applied covered socioeconomic and production aspects of the fish farmers, including gender, farming system, labor, species raised, types of feed used and perceptions of the impact of feed costs. In addition, information was collected on the use of local ingredients in fish feed, the frequency of use and the availability of these inputs in the region.

The infrastructure needed for feed production was analyzed via a checklist that assessed the presence of equipment such as grinders and mixers, as well as the storage conditions for the ingredients. Direct observation and photographic documentation of the facilities made it possible to identify structural bottlenecks and the need for investment.

To assess the nutritional viability of the alternative ingredients, a literature review was carried out on scientific databases such as SciELO and Web of Science, using descriptors related to tambaqui and tilapia feed. Scientific evidence of the digestibility, nutritional value and zootechnical performance of the species when consuming these inputs was analyzed. In addition, the nutritional composition and seasonality of the local ingredients, including protein,

lipid, carbohydrate, fiber, mineral and gross energy contents, were analyzed. Seasonality was determined by interviewing fish farmers and consulting scientific sources to record the harvest and off-season periods of the main plant inputs used.

The data were analyzed via descriptive statistics, ZAR (1999) and tabulated via adequate statistical software to construct tables and graphs that facilitated the interpretation of the results.

3. RESULTS

3.1 Socioeconomic and production characteristics

Fish farming in the region is predominantly conducted by men (93.3%), operates under the extensive system (96.6%), and uses only family labor (100%). With respect to the farmed species, 33.3% of the producers raised only tambaqui (*Colossoma macropomum*), whereas 23.3% opted exclusively for Nile tilapia (*Oreochromis niloticus*), (Table 1).

The majority of fish feed is based on the use of commercial feed (73.3%), although 26.6% of producers supplement their diet with alternative ingredients. The high cost of feed was identified as the main economic obstacle to the activity and was mentioned by 100% of the interviewees. In this context, all the fish farmers were interested in producing artisanal feed as an alternative to reduce costs and minimize dependence on commercial inputs.

Table 1 - Socioeconomic and productive profile of small-scale fish farming units analysed.

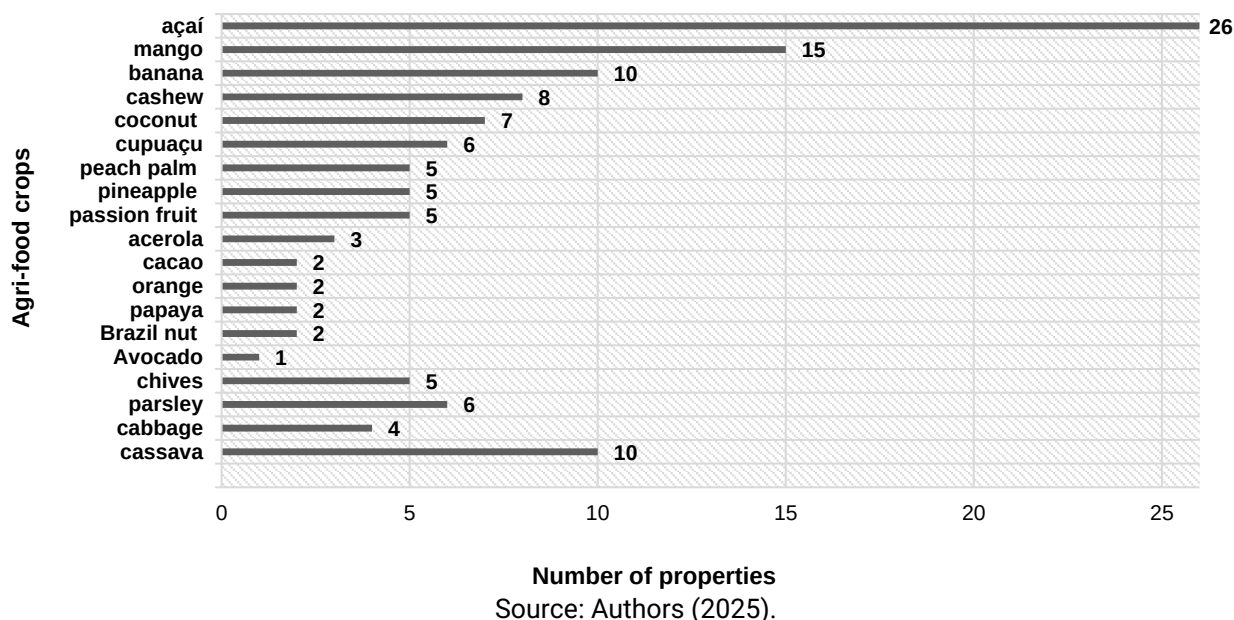
Categories	Total sample	
	Absolute frequency (N)	Relative frequency (%)
Gender		
Male	28	93,3
Female	02	6,6
Production system		
Extensive	29	96,6
Semi-intensive	1	3,3
Manpower		
Family	30	100
Farmed fish species		
Only tambaqui	10	33,3
Only tilapia	7	23,3
tambaqui and tilapia	13	43,3
Type of food offered		
Commercial fish feed	22	73,3
Commercial fish feed + alternative feed	8	26,6
Does commercial feed increase production costs?		
Yes	30	100
Are you interested in handmade fish feed?		
Yes	30	100

Source: Authors (2025).

3.2 Occurrence of ingredients for family aquaculture

Açaí (*Euterpe oleracea*) was the most cultivated ingredient on the farms analyzed, present in 86.6% of the areas, followed by mango (*Mangifera indica*, 50%) and banana (*Musa spp.*, 33.3%). Cashew (*Anacardium occidentale*, 26.6%), coconut (*Cocos nucifera*, 23.3%) and cupuaçu (*Theobroma grandiflorum*, 20%) were also frequently recorded. Other species, such as peach palm (*Bactris gasipaes*), pineapple (*Ananas comosus*) and passion fruit (*Passiflora edulis*), presented 16.6% of the properties, whereas acerola (*Malpighia emarginata*), cacao (*Theobroma cacao*), orange (*Citrus sinensis*), papaya (*Carica papaya*) and Brazil nut (*Bertholletia excelsa*) showed less distribution. Avocado (*Persea americana*) was identified on only one property (3.33%) (Figure 2). The observed agricultural diversity indicates significant potential for the use of byproducts to formulate alternative feed for tambaqui and tilapia.

Figure 2 - Distribution of agri-food crops found on the properties of aquaculture farmers.



3.3 Use of waste in fish feed

In the region studied, bananas were the most commonly used fruit ingredient for fish feeding. Vegetables such as parsley, chives and cabbage were also used. However, fruits such as avocado, Brazil nuts, cocoa, coconut, cupuaçu, orange, papaya, passion fruit, peach palm and pineapple have not yet been used in fish feeding in the region (Table 2).

Table 2 - Agri-food crops found on the properties of small-scale fish farmers and their use for fish feeding.

Fruit		Frequencies							
Common name	Scientific name	Have you ever fed tambaqui or tilapia this fruit?				Would you like to feed your fish with this waste?			
		AF	RF (%)	AF	RF (%)	AF	RF (%)	AF	RF (%)
açaí	<i>Euterpe oleracea</i>	Yes (5)	16.6%	No (25)	83.3%	Yes (30)	100.0%	No (0)	0.0%
acerola	<i>Malpighia puniceifolia</i>	Yes (2)	6.6%	No (28)	93.3%	Yes (30)	100.0%	No (0)	0.0%
avocado	<i>Persea americana</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
banana	<i>Musa spp.</i>	Yes (8)	26.6%	No (22)	73.3%	Yes (30)	100.0%	No (0)	0.0%
Brazilian nut	<i>Bertholletia excelsa</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
cabbage	<i>Brassica oleracea</i>	Yes (2)	6.6%	No (28)	93.3%	Yes (30)	100.0%	No (0)	0.0%
cashew	<i>Anacardium occidentale</i>	Yes (1)	3.3%	No (29)	96.6%	Yes (30)	100.0%	No (0)	0.0%
cassava	<i>Manihot esculenta</i> Crantz	Yes (6)	20.0%	No (24)	80.0%	Yes (30)	100.0%	No (0)	0.0%
chives	<i>Allium schoenoprasum</i>	Yes (4)	13.3%	No (26)	86.6%	Yes (30)	100.0%	No (0)	0.0%
cocoa	<i>Theobroma cacao</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
coconut	<i>Cocos nucifera</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
cupuaçu	<i>Theobroma grandiflorum</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
mango	<i>Mangifera indica</i>	Yes (6)	20.0%	No (24)	80.0%	Yes (30)	100.0%	No (0)	0.0%
orange	<i>Citrus sinensis</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
papaya	<i>Carica papaya</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
parsley	<i>Petroselinum crispum</i>	Yes (5)	16.6%	No (25)	83.3%	Yes (30)	100.0%	No (0)	0.0%
passion fruit	<i>Passiflora edulis</i> Yess	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
peach palm	<i>Bactris gasipaes</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%
pineapple	<i>Ananas comosus</i>	Yes (0)	0.0%	No (30)	100.0%	Yes (30)	100.0%	No (0)	0.0%

Note: (AF) = absolute frequency; (RF) = relative frequency
Source: Authors (2025).

3.4 Seasonal calendar

Crops such as bananas, cabbage, cassava, chives, cocoa, coconut, parsley, and passion fruit are continuously harvested throughout the year (Table 3). Another fruit and agri-food has a production cycle concentrated in the second semester of the year (dry season, from July to December), the easiest time of the year to harvest agroforestry products in the Amazon.

Table 3 - Agri-food crops found on the properties of small-scale fish farmers and their use for fish feeding.

Common name	Scientific name	J	F	M	A	M	J	J	A	S	O	N	D
açaí	<i>Euterpe oleracea</i>												
acerola	<i>Malpighia puniceifolia</i>												
avocado	<i>Persea americana</i>												
banana	<i>Musa spp.</i>												
brazilian nuts	<i>Bertholletia excelsa</i>												
cabbage	<i>Brassica oleracea</i>												
cashew	<i>Anacardium occidentale</i>												
cassava	<i>Manihot esculenta</i> Crantz												
chives	<i>Allium schoenoprasum</i>												
cocoa	<i>Theobroma cacao</i>												
coconut	<i>Cocos nucifera</i>												
cupuaçu	<i>Theobroma grandiflorum</i>												
mango	<i>Mangifera indica</i>												
orange	<i>Citrus sinensis</i>												
papaya	<i>Carica papaya</i>												
parsley	<i>Petroselinum crispum</i>												
passion fruit	<i>Passiflora edulis</i> Yess												
peach palm	<i>Bactris gasipaes</i>												
pineapple	<i>Ananas comosus</i>												

Note: The harvesting period is shown in gray. Source: Authors (2025).

3.5 Aquaculture Farmers' preferences for agri-food crops for fish

All the fish farming units analyzed (100%) focused on the final growth phase for commercialization. Research has revealed that farmers adopt alternative ingredients in their fish feed, relying on empirical methods to reduce operating costs. However, the lack of technical knowledge and training was identified as one of the main challenges, highlighting the need for targeted training, which can be carried out both on farms and through initiatives promoted by local associations.

The available infrastructure proved to be insufficient for all the enterprises evaluated, making it difficult to adopt more efficient practices for using alternative ingredients. With respect to

the agri-food crops used in the formulation of handmade fish feed, the fish farmers mentioned different plant species, considering their impact on aquaculture activity from different perspectives.

From a socioeconomic point of view, ingredients such as açai (*Euterpe oleracea*) were recognized as elements of productive inclusion and strengthening of the local economy. In zootechnical terms, mango was identified as an input that favors fish growth, resulting in satisfactory performance rates. In economic terms, bananas and cassava stand out for their ability to reduce feed costs. From an environmental perspective, cashew and orange are valued for their potential to minimize waste and encourage sustainable practices (CORDEIRO et al., 2024; MARCHÃO et al., 2024; SILVA et al., 2020; XAVIER et al., 2022).

The strategic incorporation of these ingredients into fish feeding could strengthen a more accessible and sustainable aquaculture model, reducing the dependence on industrial inputs and adding value to regional production chains (LOURENÇO et al., 2025). However, the improvement of formulations requires a greater technical basis, and scientific studies are needed to assess the nutritional viability of these ingredients, as well as their effects on the digestibility, feed conversion, and productive performance of the species (DAWOOD et al., 2022).

3.6 Handmade fish feed production

The fish farmers described handmade fish feed production as a process adapted to local conditions and structured in multiple stages. The formulation is based on the acquisition of inputs from agricultural stores, such as fishmeal, cornmeal, soybean meal, and wheat bran, whereas supplements such as soybean oil and salt are obtained from the local market.

In addition to these ingredients, vegetables grown on these properties are incorporated, promoting the use of regional resources and reducing dependence on industrialized inputs (SILVA et al., 2017).

4. DISCUSSION

In our study, the predominance of males among fish farmers was observed. This characteristic is frequently reported in scientific and technical literature, reflecting a common reality in several world regions. The gender disparity raises sociocultural issues, given that the activity requires greater physical effort, which is traditionally associated with male labor, resulting in low female representation (ELIAS et al., 2024; KRUIJSSEN et al., 2018).

The extensive system was the most widely adopted system among aquaculture farmers. This preference can be attributed to the characteristics of the system, which demand less infrastructure, are economically less expensive, and require few or no management practices. Despite the lower productivity, the adoption of the extensive system is probably related to the lower implementation cost, making it compatible with the economic and social conditions of the communities studied (LANGA et al., 2024).

It was found that production is predominantly carried out with family labor. Among the farmed species, tambaqui is the most farmed, although some aquaculturists choose exclusively tilapia or combine the farming of both in this study area. This diversification probably arises as a strategy to serve different markets. The results corroborate past studies, which indicate that tambaqui is the most farmed native species in Brazil, with a strong use of family labor (FRISSE et al., 2020; HUNGRIA et al., 2024; LIMA et al., 2020).

In the communities investigated, most aquaculturists use commercial feed as the main source of food for the fish, while a smaller portion supplements the diet with alternative or supplemental foods. All the interviewees agreed that commercial feed makes the activity more expensive, becoming a challenge for family fish farming.

BRABO et al. (2021), investigated the production cost of alternative feeds for omnivorous fish in the state of Pará and reported that these feeds have a lower price per kilo than industrialized feeds do, making them more affordable. Given this scenario, there was unanimous interest in adopting handmade fish feed, highlighting the demand for more affordable alternatives. In many cases, these alternative feeds are composed mainly of byproducts from agribusiness and livestock farming because of their low cost, available volume, and continuous supply (CASTRO et al., 2020).

Several studies have explored the use of unconventional ingredients as substitutes for traditional inputs, as long as they do not compromise water quality, productive performance, or fish fillet quality (PEREIRA-JUNIOR et al., 2013; SANTOS et al., 2023; SILVA et al., 2020). In addition, our work identified the potential for the use of agri-food and byproducts, such as fruit residues (açaí, mango, and banana) and agricultural crops (cassava), in fish farming feed. These byproducts stand out as sustainable alternatives, with the potential to reduce costs and minimize environmental impacts (BERTOCCI & MANNINO, 2022).

Studies have shown that incorporating freeze-dried açaí (5% to 10%) into tambaqui diets can reduce oxidative stress during (SILVA et al., 2024). Mango flour, which is rich in carbohydrates, can replace up to 16% of corn flour without compromising the growth of juveniles (MARCHÃO et al., 2024). Cassava and its byproducts also have high nutritional value and can fully replace corn in tambaqui diets without compromising zootechnical performance (PEREIRA-JUNIOR et al., 2013). Furthermore, fish growth was unaffected by up to 8% of whole banana flour added to the tambaqui fingerlings' diet (SILVA et al., 2020).

For tilapia, the results involving the use of agri-food waste are also quite attractive. MENDES et al. (2024) demonstrated that tilapia showed preference (acceptability, behavioural response, feed intake regulation and dietary preferences) for the diet formulated from alternative ingredients, such as single-cell microorganisms, sunflower, quinoa, rapeseed, and pea protein concentrate. KLAHAN et al. (2023), through the study of the effects of compensatory growth in monosex batches of red tilapia (*Oreochromis niloticus* L.), determined a 30% reduction in fish feed costs with the aid of handmade fish feed containing cassava.

Local aquaculture farmers have shown great interest in adopting handmade fish feeds as a strategy to mitigate the high costs of commercial feeds. However, the viability of this strategy requires agricultural planning to optimize the use of seasonal crops, such as açaí, mango and Brazil nuts. One recommended approach is to collect and store these fruits during the months of greatest abundance for later use (SILVA et al., 2017).

The nutritional value of several feeds has been investigated in Brazil and worldwide, and the use of alternative sources should not result in negative effects on performance, fish health, or water quality (MAGBANUA & RAGAZA, 2024). Despite advances in research on plant sources

for aquaculture, there are still challenges to overcome, such as the presence of antinutritional substances, which can negatively affect growth and feed conversion (SAMPATHKUMAR et al., 2023). Therefore, even alternative feeds must be carefully balanced to provide sufficient macro- and micronutrients to meet the biochemical, physiological, and metabolic demands of fish (FERREIRA et al., 2021; XAVIER et al., 2016).

The present study investigated aquaculture farmers' preferences regarding the use of different agri-food crops in tambaqui and tilapia feeding and nutrition. Our results indicated that all the crops analyzed are intended for the final growth phase for both species, and their feeding habits are predominantly omnivorous. Family fish farming stands out as the main activity, with producers seeking to reduce operating costs through the use of alternative ingredients for feed formulation.

Training for feed production is highlighted as necessary by fish farmers and is carried out both on property and through local associations (LANGA et al., 2024). However, the lack of basic infrastructure was a limitation identified in all the properties analyzed, suggesting the need for investments to implement feed production systems. Initial investment can be a problem for smaller enterprises because of the relatively high price of some essential equipment for this purpose (BRABO et al., 2021).

Our study also revealed that fish farmers are willing to adopt agri-food crop residues as an alternative to reduce costs in tambaqui production, as long as training and improvements in feed production infrastructure are made available. The adoption of these practices has the potential to generate social, productive, economic, and environmental benefits, making family fish farming more sustainable and accessible.

Therefore, it is essential to evaluate the nutritional value of plant-based foods and validate their effectiveness through controlled experiments. Studies such as these are essential to provide knowledge that helps in the formulation of efficient and safe diets and practices for world aquaculture and small-scale fish farming in Amazon region (BERTOCCI & MANNINO, 2022; BRABO et al., 2021; HUNGRIA et al., 2024; LIMA et al., 2020; MARCHÃO et al., 2024).

5. CONCLUSION

The present study investigated aquaculture farmers' preferences regarding the use of different agri-food crops in tambaqui and tilapia feeding and nutrition. Our results indicated that all the crops analyzed are intended for the final growth phase for both species, and their feeding habits are predominantly omnivorous.

The lack of experimental studies evaluating the impact of these ingredients on digestibility, feed conversion and fish health still represents a significant obstacle to the widespread adoption of this practice.

Given these limitations, new studies are essential to validate the technical and economic feasibility of including alternative ingredients in tambaqui feed, considering not only the zootechnical performance of the species at different stages of development but also the environmental and socioeconomic impacts of this approach. Scientific advances in this field can strengthen the fish farming production chain in the Brazilian Amazon, mainly for tambaqui and tilapia, boosting sustainable aquaculture and ensuring greater productive autonomy for local circular bioeconomy.

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