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Generating family farming revenue through juvenile fish production: a case study in native species

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ABSTRACT. In view of the need to improve the development of family production enterprises, zootechnical and economic planning were conducted in a rural settlement in 0.78 ha of water depth for the rearing and marketing of juveniles of the tambatinga hybrid (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) to verify its economic viability. For the zootechnical indicators, a 16-month production cycle was determined, with three juvenile production cycles and two fattening cycles. For the remaining fish that were not sold, the quantity of initial and final fish, stock biomass, average initial and final weight, apparent feed conversion, and mortality rate were determined. For economic planning, a total operating cost methodology was adopted to determine the costs per unit of production, gross revenue, gross margin, net profit, and profitability index. The production of juveniles of many sizes is economically viable for family farming, showing attractive profitability indicators even under adverse zootechnical conditions. This study demonstrated the effectiveness of zootechnical and economic planning on a property that can optimize production and use of the area, as well as showing producers how rewarding it is to farm fish.

Keywords: fish farming; rural settlements; production costs.

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Introduction

Fish farming is increasing in the agricultural sector, as it represents the main productive activity within the aquaculture sector and has been an alternative source of income for rural areas and family farming (Santos-Filho, Vieira-Santos, Silva, & Silva, 2016; Barros et al., 2020b). In 2021, Brazilian fish farming grew by 4.7%, producing 841,000 tons of farmed fish, 31.2% of which was native fish production. The state of Mato Grosso is more representative of the production of the tambatinga hybrid (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) because there is a greater demand for this species (*Associação Brasileira da Piscicultura* [Peixe BR], 2022). This shows the importance of this hybrid and the availability of juveniles to supply fish to farmers in the region.

In Mato Grosso, the river basin offers favorable conditions for fish farming, including the breeding of native species and their hybrids. Accordingly, the fish farming sector has grown in response to the growing demand for fish for consumption (Arêas, Trindade, Lima, Moura, & Almeida, 2014; Padilha, Souza, Galbiatti, & Pierangeli, 2020). However, professionalization of the activity, technological development, and obtaining inputs remain challenges for producers, especially for those producing on a small scale (Dotti, Valejo, & Russo, 2012; Curvo et al., 2020).

Fish farming is one of the most important activities in the supply of animal protein to the populations in word, generating jobs and income, despite being a recent market activity when compared to other activities in the agricultural sector (Food and Agriculture Organization of the United Nations [FAO], 2020). Thus, it can be an alternative for family farming, either as the main source of income or as a supplement to that from other activities. According to *Ministério da Agricultura e Pecuária* (Mapa, 2020), family farming is primarily responsible for producing food available for consumption by the Brazilian population and is made up of small rural producers, traditional peoples and communities, foresters, aquaculturists, extractivists, fishermen, and agrarian reform settlers.

In the 1990s and early 2000s, descriptive and evaluative studies of rural settlements were performed (Guanziroli, 1994; Schimidt, Marinho, & Rosa, 1998; Bittencourt, Castilhos, Bianchini, Silva, & Guanziroli, 1999; Fernández & Ferreira, 2004). The main challenges faced were a lack of infrastructure and difficulty in accessing credit and basic social services. According to National Institute for Colonization and Agrarian Reform (Nicar) report in 2000, the success of a settlement is only achieved when beneficiaries are competitively inserted into the labor market. It is also recognized that for this to happen, it is essential to provide basic services and infrastructure (Alves, Figueiredo, & Bonjour, 2009).

To build a society of equity and equality, agrarian reform and settlers are fundamental in the social and political spheres (D'Incao, 1991) because, despite facing challenges and inequalities, they have contributed to the growth of rural production and are part of debates on the political scene. (Penna & Rosa, 2015). Therefore, it is necessary to plan agricultural projects to demonstrate how to achieve the best development of these agrarian reform settlements. In the case of fish farming, Siqueira, Mello, Jorge, Seixas Filho, and Pereira (2021) added that it is essential to know the economic aspects of the activity, identify the most relevant items in the cost of production, and identify the main parameters influencing profitability.

Considering that economic aspects require zootechnical control and planning, any difficulties and potentialities in the production system must be identified to make decisions that guarantee the economic viability of an enterprise, making it more competitive and prepared for market instability (Barros, Silva, Santo, & Barros, 2020a). Woiski, Kulak, and Morozini, (2023) stated that there is currently a lack of updating and optimization in various rural areas, especially on small farms. Therefore, it can be assumed that controls and planning on farms can help producers make decisions more easily.

In view of the need for better development of family production ventures as they represent ~95% of Brazilian aquaculture farms (Valenti, Barros, Moraes-Valenti, Bueno, & Cavalli, 2021), and a lack of information developed for the production sector in the rearing phase, the quality of production needs to be improved. Therefore, this study aimed to evaluate the zootechnical and economic planning for the rearing and marketing of juveniles of the tambatinga hybrid (♀ tambaqui *C. macropomum* x ♂ pirapitinga *P. brachypomus*) in a rural settlement area to verify its economic viability.

Material and methods

The methods used here are classified as applied research, as the study is interested in the application, use, and practical consequences of knowledge aimed at solving the most varied individual or collective problems, materializing through applied and technological sciences (Assis, 2009).

The zootechnical and economic planning was conducted in the Barra do Marco settlement, in the municipality of Pontes e Lacerda, in the western region of the state of Mato Grosso. The settlement lies at an altitude of 253 m, latitude 15° 14' 3'' South, and longitude: 59° 19' 52'' West. The settlement was created in 2007 by the NICAR, with a total area of ~895 ha, part of which remained as an environmental reserve, and the rest passed on to 107 families with an average area of 2.5 ha per family, so that they could explore various productive activities.

The farm used for implementation of the fish farm has a total area of 9 ha of water, divided into 30 tanks. These were passed on by NICAR to the Barra do Marco Association of Residents and Small Rural Producers. To maintain the ponds, settlers are currently charged a rental of R$50.00 per month per pond, regardless of size, and the ponds are currently used by 10 families. The producer in this study rents 0.78 ha of water, which corresponds to three excavated ponds, one of which has been covered with bird netting and subdivided into three masonry walls: pond 1A: 600; pond 1B: 800; pond 1C: 1,000; pond 2: 2,400; and pond 3: 3,000 m^2.

Using these data, zootechnical and economic planning was conducted to produce juveniles of the tambatinga hybrid for sale to meet the demands of small fish farmers in the region and livestock farmers who have dams on their properties. In the Vale do Guaporé region, there are no breeding and sales stations for juveniles, making it unfeasible to buy them from distant places in small quantities. This renders the activity interesting not only economically but also for the development of the sector in the region.

Microsoft Excel® spreadsheets were used for the planning, and the following parameters were used for the zootechnical indicators: production cycle, initial and final quantity of fish, stocking biomass, average initial and final weight, apparent feed conversion, and mortality rate, based on the following calculations:

- Stock biomass (SB): quantity in kilograms of live weight per square meter of water depth (kg m^{-2}).
- Average final weight: obtained by calculating the total weight harvested divided by the number of fish, expressed in kg.
- Apparent feed conversion (AFC): amount of feed consumed divided by the weight gain in the period.

- Mortality rate: calculated by adding the number of final animals to the number of fish sold divided by the number of animals stocked subtracted by 100, expressed as a percentage.

A 16-month harvest, with three production cycles for juveniles and two fattening cycles (Figure 1) for the remaining fish not sold-a way of making more efficient use of production ponds at times of the year when juveniles are not available.

Fish farmers buy juveniles (2-4 cm) from specialized producers in the area. Because juveniles are sold in installments, there are different sizes of fish at different prices, and they are ready for sale from 5 to 8 cm (Phase I) after the first 30 days of rearing. The remainder will be sold after another 30 days at 8 to 10 cm (Phase II) and then at 12 to 15 cm (Phase III) for another 60 days, completing the 120-day cycle.

In the first cycle, which began in November 2022, all the tanks were used to produce juveniles. At the end of this cycle, any food that had not been sold was placed in pond 3 for fattening between March and October 2023. The second juvenile production cycle began in March 2023 with the purchase of another batch of 2 to 4 cm fingerlings-a period that coincided with the availability of juveniles of this size. Only four ponds were used in this cycle, except for Pond 3, where fattened fish were retained from the first cycle.

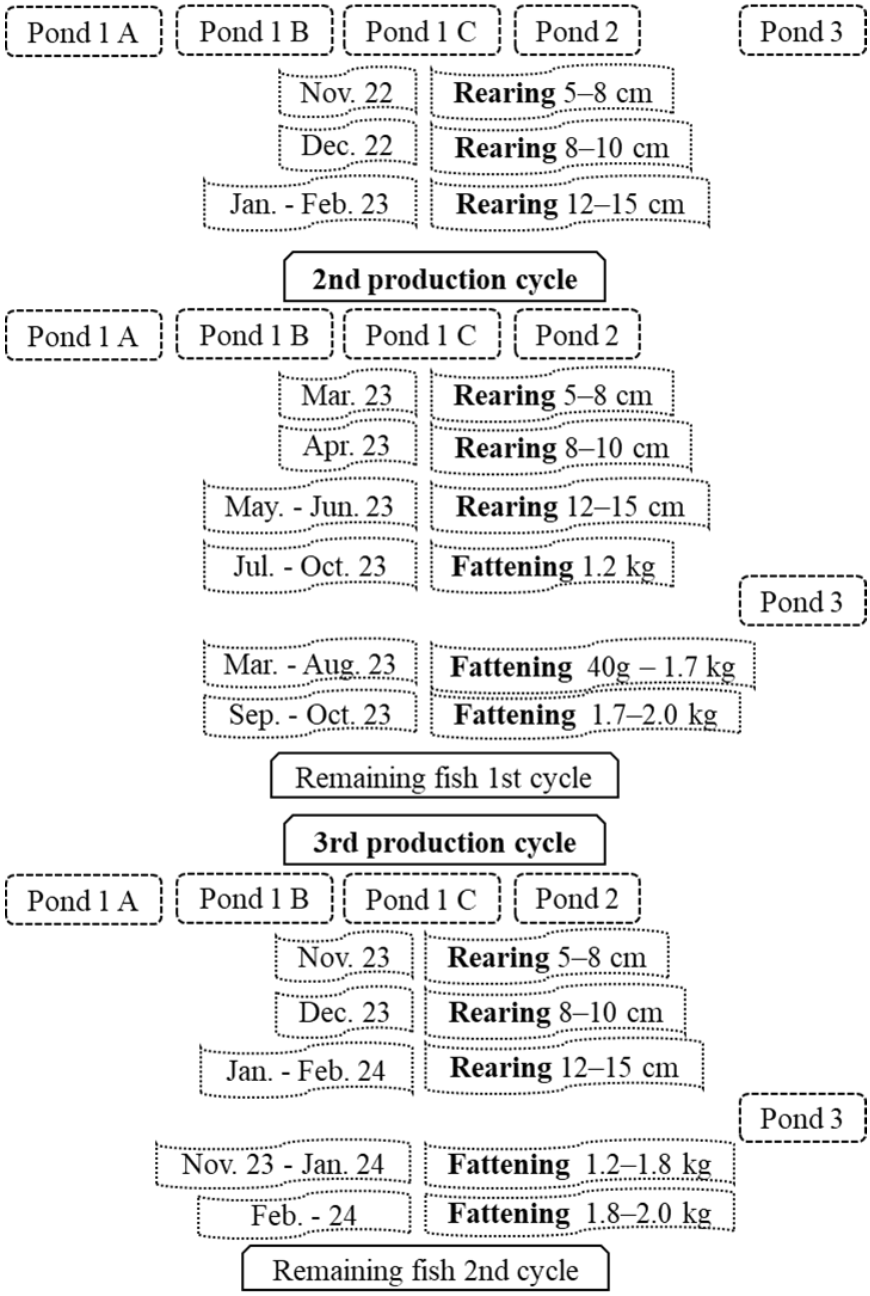

Figure 1. Flowchart of the production of juvenile and fatty fish of the tambatinga hybrid (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in a rural settlement with an area of 0.78 ha of water depth, with a 16-month harvest.

The second cycle was conducted in the same manner, until the juveniles reached 12 to 15 cm (Phase III), that is 40 g. After this period (June 2023) the fish that were not sold remained in the same pond until they reached 1.2 kg (Phase IV) on average in October 2023. Subsequently, they were transferred to the second fattening stage in pond 3 in November 2023. Simultaneously, the third cycle was started until February 2024 with the purchase of another batch of juveniles, with the same zootechnical planning as the first cycle, when the fattening the fish in pond 3 would also end. With sales in installments, not only the juveniles but also the fattened fish favored the entry of working capital and reduced stock biomass, making it adequate until the end of the cycle.

For economic planning, the total operating cost (TOC) methodology proposed by Matsunaga et al. (1976) was adopted and obtained by adding the effective operating cost (EOC, made up of the sum of labor, feed, juveniles, inputs in general, occasional expenses, maintenance of machinery, and improvements), plus family labor, and depreciation. To use the methodology, the monetary values (U$$1 = R$5.17) were obtained from a market survey in October 2023, using the following criteria:

- To determine investment and depreciation, a survey was conducted on all the items used directly and indirectly in fish farming. These were apportioned according to their proportion of use between home, vehicle, shed, and equipment. A value of 10% was also considered to compensate for the value of items that were not described or detailed. The purchase price of land and construction of ponds were not included here, as they were rented/leased.
- The depreciation of improvements, machinery, and equipment was determined using the straight-line method, considering a scrap value of zero.
- For maintenance and improvements, a rate of 2% per year was considered for the value of buildings, machinery, and materials, where this rate was 5% per year of the acquisition value of these assets (Martin, Scorvo Filho, Sanches, Novato, & Ayrosa, 1995).
- The payment for family labor was estimated at three minimum wages per month, considering the workload of the producer to be 2 hours per day at the fish farm.
- As the sale of various weights/sizes of fish produced in the same pond and cycle was done in installments, the cost figures were apportioned according to the time the ponds were used (% of days), feed consumed (kg), labor (value x% of days), plastic bags and dissolved oxygen (number of bags required for a given quantity and size of juvenile) needed for transport.

To analyze the need for working capital, a net cash flow was drawn up for the 16 months of the production cycle, resulting from the difference between monthly cash inflows (revenue) and outflows (EOC), with the aim of identifying the times of greatest need for financial contributions, important in planning and ensuring the proper functioning of the activity and, consequently, its productive and economic potential.

To determine the minimum market value, the Average Total Operating Cost (ATOC) was calculated by referring to the cost per unit of production, represented by the relationship between the TOC and quantity produced, expressed in R$ mile^{-1} for juveniles and R$ kg^{-1} for fatty fish.

To define the profitability results, the following indicators were used, according to Martin, Serra, Oliveira, Ângelo, and Okawa (1998):

- Gross Revenue (GR) is the result of the sale of what was produced, this value being obtained by multiplying the quantity sold by the sale price.
- Gross Margin (GM), difference between gross revenue and actual operating costs.
- Operating Profit (OP), the result of the difference between gross revenue and total operating costs.
- Profitability Index (PI), ratio between Operating Profit and Gross Revenue, expressed in%.

Based on these results, simulations were carried out with different survival rates-the biggest obstacle in the production and marketing of juveniles-so that the producer could visualize the risks and potential of the production system and the extent to which variations in zootechnical indicators affect economic indicators. From this perspective, the research was of an applied nature, which aimed to generate knowledge for practical application intended to solve specific problems (Gil, 2022).

Results and discussion

The direct and indirect investment mobilized in support infrastructure for the operation of the fish farm with an area of 0.78 ha of water depth was R$78,157.29 (Table 1), equivalent to R$100,201.65 ha^{-1}. This amount is high, compared to other studies that have investigated the construction of excavated tanks (Barros et al., 2020b; Barros, Silva, Nava, & Macedo, 2021), as the producer invested in a feed store, residence, and masonry partitioning in one of the tanks, which contributed 26.9, 24.5, and 15.3% of the investment, respectively, totaling 66.7% of the total value. This tendency to invest more in support infrastructure occurs in systems operating in reproduction and larviculture (Sanches, Tosta, & Souza-Filho, 2013; Castro et al., 2019).

This information reflects capital tied to infrastructure, machinery, and equipment that overly burdens production costs. An economic analysis should be conducted to determine whether the production system can afford investment and, if not, what, and how much it should produce so that the system remains economically viable.

Table 2 shows the zootechnical indicators for the rearing cycles, which occurred in the same way in the first and third production cycles. There was a difference in the second cycle (Table 3), which lasted until the fish reach 1.2 kg. Table 4 and 5 list the zootechnical indicators for the 1st and 2nd fattening cycles, respectively.

The AFC presented in Table 2 and 3 was better in the rearing phase, with average values of 1.24, when compared to the fattening phase (Table 4 and 5). However, Costa et al. (2016) reported apparent feed conversion values of 0.58 for juvenile tambaqui weighing up to 30 g on average. This shows that it is possible to achieve an even better performance than that achieved here. The same authors explained that this was possible because of the high efficiency with which the feed was transformed into muscle. In addition, natural foods are efficiently used in the rearing environment at this stage of development.

Table 1. List and values of support items used directly and indirectly to run the fish farm with 0.78 ha of water in rented tanks in the Barra do Marco settlement in MT. Values in R$ for the month of October/23 (U$$ 1= R$5.17).

Items	Specifications	Un	Total Value (R$)	Fish farming (R$)	Participation
Main House (m^2)	Masonry/lined	70	84,000.00	21,000.00*	26.9%
Feed Depot (m^2)	Masonry 8m x 16m	128	54,400.00	19,125.00*	24.5%
Pit (m)	Semi artesian	7	5,600.00	840.00*	1.01%
Utility car	S10 Chevrolet 2015/ Manual/ LTZ/ Flex 4x4	1	110,616.00	2,765.40*	3.5%
Motorcycle	Titan Honda 2010/ CG 125/Flex	1	9,179.00	2,294.75*	2.9%
Tow dolly	Open load/metal/1.50 x 1.10 x 0.50	1	2,500.00	625.00*	0.8%
Brushcutters	Husqvarna/gasoline 236	1	2,373.00	711.90*	0.9%
Oxygen Cylinder	10 m^3	1	3,320.00	3,320.00	4.2%
Flowmeter/manometer	Regulating valve	1	628.00	628.00	0.8%
Bird netting installation	Screen 30 m x 100 m/ 5 mm Eucalyptus stake 1.60 m/ diameter 6 an 8 cm Flat oval wire 2.7 mm x 2.2 mm /1,000 m	1	6,992.23	6,992.23	8.9%
Wheelbarrow	Iron/60 L	1	159.00	159.00	0.2%
Tank division (Un)	Masonry 2 x 30 m	2	12,000.00	12,000.00	15.3%
Fishing net	30 m x 2.50 m x 25 mm/ wire 210	1	590.80	590.80	0.8%
Oxygen Cylinder	10 m^3	1	3,320.00	3,320.00	4.2%
Others	10%		29,290.06	7,105.21	9.1%
TOTAL			321,648.09	78,157.29	100%

*These amounts are prorated according to the proportion of use for fish farming.

Table 2. Zootechnical indicators to produce tambatinga juveniles (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in an excavated pond system in an area of 0.78 ha of water depth in the 1st cycle and only in 0.48 ha in the 3rd production cycle.

Zootechnical parameters	Un.	Phase I	Phase II	Phase III	Results
Period	Month	Nov/22	Dec/22	Jan-Feb/23	
Cultivation period	Days	30	30	60	120
Initial fish quantity **	Nº	416,524	112,461	32,052	416,524
Final fish quantity **	Nº	374,872	106,838	31,410	2,175
Average initial weight	kg	0.004	0.006	0.013	0.004
Average final weight	kg	0.006	0.013	0.040	0.040
Average initial size	cm	2-4	5-8	8-10	2-4
Average final size	cm	5-8	8-10	12-15	12-15
Final stock biomass	kg m^{-2}	0.300	0.184	0.161	0.161
Final stocking density	Nº m^{-2}	48	14	4	4
Mortality rate	%	10.0	5.0	2.0	11.5*
Apparent feed conversion	kg	1.10	1.20	1.40	1.24*
Quantity sold **	%	70.0	70.0	90.0	88.0
	Nº	262,410	74,787	29,236	366,433

*Average result; **Quantity calculated for 0.78 ha of water depth. These values are lower for the 0.48 ha used in the 3rd cycle.

Table 3. Estimated zootechnical indicators to produce tambatinga juveniles (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in an excavated pond system with 0.48 ha of water depth, in the 2nd production cycle.

Zootechnical parameters	Un.	Phase I	Phase II	Phase III	Phase IV	Results
Period	Month	Mar/23	Apr/23	May-Jun/23	Jul-Oct/23	
Cultivation period	Days	30	30	60	120	240
Initial fish quantity	Nº	256,322	69,207	19,724	1,933	256,322
Final fish quantity	Nº	230,690	65,747	19,330	1,933	1,933
Average initial weight	kg	0.004	0.006	0.013	0.040	0.004
Average final weight	kg	0.006	0.013	0.040	1.200	1.200
Average initial size	cm	2-4	5-8	8-10	12-15	2-4
Average final size	cm	5-8	8-10	12-15	-	-
Final stock biomass	kg m^{-2}	0.300	0.184	0.161	0.483	0.483
Final stocking density	Nº m^{-2}	48	14	4	0,4	0,4
Mortality rate	%	10.0	5.0	2.0	0.0	11.5*
Apparent feed conversion	kg	1.10	1.20	1.40	1.60	1.46*
Quantity sold	%	70.0	70.0	90.0	0.0	88.0
	Nº	161,483	46,023	17,397	0	224,902

*Average result.

Table 4. Estimated zootechnical indicators for the fattening phase of tambatinga (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in an excavated pond system with 0.3 ha of water depth, 2nd cycle and 1st fattening.

Zootechnical parameters	Un.	Rearing		Fattening		Results
Period	Month	Mar/23	Apr-Jun/23	Jun-Aug/23	Sep-Oct/23	
Cultivation period	Days	30	90	60	60	240
Initial fish quantity	Nº	2,175	2,153	2,142	1,385	2,175
Mortality rate	%	1.0	0.5	0.5	0.0	1.99*
Average final size	Nº	2,153	2,142	2,131	1,385	1,385
Average initial weight	kg	0.040	0.150	1.000	1.700	0.040
Average final weight	kg	0.150	1.000	1.700	2.000	2.000
Final stock biomass	kg m^{-2}	0.108	0.714	1.208	0.924	1.346*
Apparent feed conversion	kg	1.30	1.70	2.00	2.00	1.82*
Quantity sold	kg	0	0	1,268	2,771	4,039

*Average result.

Table 5. Estimated zootechnical indicators for the fattening phase of tambatinga (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in excavated tank systems with 0.3 ha of water depth (Tank 3), 3rd cycle 2nd fattening.

Zootechnical parameters	Un.	Fattening				Result
Period	Month	Nov/23	Dec/23	Jan/24	Feb/24	
Cultivation period	Days	30	30	30	30	120
Initial fish quantity	Nº	1,933	1,914	1,904	1,231	1,933
Mortality rate	%	1.0	0.5	0.5	0.0	1.99*
Average final size	Nº	1,914	1,904	1,895	1,231	0
Average initial weight	kg	1.200	1.400	1.700	1.800	1.200
Average final weight	kg	1.400	1.700	1.800	2.000	2.000
Final stock biomass	kg m^{-2}	0.893	1.079	1.137	0.821	1.219*
Apparent feed conversion	kg	1.70	1.80	1.90	1.90	1.80*
Quantity sold	kg	0	0	1,194	2,463	3,656

*Average result.

In fish farming, many factors can influence AFC, including the rearing stage of the animal, as mentioned above, and the stocking biomass (Table 4 and 5), which, in this study, was controlled with partial sales during the rearing period, contributing noticeably to maintaining the ideal stocking biomass and, consequently, adequate apparent feed conversion. The greater the stocking biomass, the worse the water quality, which can lead to animal stress, reducing intake, food utilization, and average weight gain (Gomes, Araujo-Lima, Roubach, & Urbinati, 2003; Costa et al., 2016). The average apparent feed conversion of tambaqui is ~1.8 during the fattening phase (Barros et al, 2020b), which shows that this indicator can be improved in future cycles, helping to increase profitability.

In Phase I, the stocking density was 48 fish m^{-2}, decreasing in the next phases to smaller quantities, which has already been tested by other authors (Costa et al., 2016), who found that there was no negative influence on fish growth. Although larger quantities are commonly used in commercial fish farms without any zootechnical or economic evaluation, it is necessary to check the maximum quantity suitable for each farming condition, species, and fish size. Stocking density also directly affects the profitability of a production system, making it viable.

The average mortality rate stipulated for the rearing phase was 11.5% (Table 1 and 2) because of the use of bird-protection netting, which mitigated predation at this stage of production. However, inadequate handling during harvesting and transportation of fish during partial sales can lead to high mortality rates among juveniles. During fattening, partial sales were also conducted during the cycle (Table 4 and 5) to remove larger fish and reduce the stock biomass so that smaller fish could develop, thus obtaining a higher final average productivity. This also benefits the producer, with working capital entering several months into the cycle.

The EOC for the entire harvest was R$400,493.83 (Table 6). However, it is important to note that in the cash flow (Table 8), the effective monetary value needed to start the first cycle was R$139,707.38, with an inflow/income of R$131,205.04 after 30 days, which covers most expenses. Expenses are inevitably incurred; however, there is successive income from the sale of juveniles throughout the production cycle, as shown in Table 8. This is important because it means that the producer does not require much working capital.

The most representative expense is the purchase of juveniles, accounting for 69.7% of the EOC because the activity involves selling juveniles (Costa et al., 2016). This is contrary to what occurs when the main activity is fattening fish, in which feed is more representative of the cost of production (Brabo et al., 2017; Costa, Gomes, Sabbag, & Martins, 2017; Barros et al., 2020a; Nass, Povh, Fornari, Ribeiro, & Brumatti, 2020; Barros et al., 2021; Botelho et al., 2022). When the activity is reproduction or larviculture, the most representative expenditure item is labor (Jomori, Carneiro, Martins, & Portella, 2005; Guerreiro, Streit Jr., & Rotta, 2014).

Table 7 shows the economic and zootechnical indicators obtained at the end of the production cycle, including the average size of the marketed juveniles and the average weight of the fat fish/slaughter point. This table shows that the most economically attractive phase is the production and marketing of fry 5 and 8 cm in length. This is due to the short production cycle of ~30 days and the greater feed efficiency of the initial phase, which resulted in a 28.0 and 54.4% lower TOC when compared to juveniles between 9 and 11 cm, and 12 and 15 cm, respectively. This result is similar to that of Guerreiro et al. (2014), who found a lower TOC in the initial stages. However, in their study, the difference in cost between the smallest size and the largest was up to seven times greater. Here, comparing the same sizes, it was up to 2.7 times greater, considering the purchase price of juveniles (2-4 cm) of R$300.00 per thousand. This highlights the importance of planning with expertise to identify the best time to sell.

These differences in values highlight the importance of the two indicators-cycle and apparent feed conversion-on the cost of production and, consequently, on the profitability indices of the production system.

Table 6. List and values of operating costs to produce juveniles and fathead minnows (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in an excavated tank farm with 0.78 ha of water depth, with a 16-month harvest and 3 production cycles. Values in R$ for the month of Oct/23 (U$$ 1.00 = R$ 5.17).

Items	Un.	Unit Value (R$)	Total Value (R$)	Participation
Lease of 3 tanks with 0.78 ha of water depth (Month)	16	150.00	2,400.00	0.60%
Labor/day (Nº)	59.3	150.00	8,897.14	2.23%
Plastic bags 30 x 90cm/type:13	5,454	0.95	5,181.75	1.30%
Cylinder refill O_2	40	250.00	10,000.00	2.50%
Juvenile 2-4 cm (Thousand)	929	300.00	278,750.63	69.72%
Urea/bag 50 kg	6.8	280.00	1,904.00	0.48%
Salt/bag 20 kg	13.6	28.00	380.80	0.10%
Quicklime/bag 20 kg	34	30.00	1,020.00	0.26%
Rice bran/bag 30 kg	34	65.00	2,210.00	0.55%
Feed 40% BW/2-3 mm (kg)	3,807	4.62	17,587.89	4.40%
Feed 40% BW/4-5 mm (kg)	9,366	4.08	38,211.72	9.56%
Feed 28% BW/6-7 mm (kg)	4,907	3.78	18,528.69	4.63%
Feed 28% BW/9-11 mm (kg)	1,299	3.27	4,249.87	1.06%
Occasional Expenses (Month)	2%		7,786.45	1.95%
Maintenance/Repairs (Month)	16	211.56	3,384.89	0.68%
Effective Operating Cost	Sub-total		400,493.83	100%
Depreciation (Month)	16		8,170.31	
Family labor (Month)	16		14,544.00	
Total Operating Cost	Total		423,208.14	

Table 7. Zootechnical and economic indicators of the production of juveniles and fatty fish of tambatinga (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in an excavated tank farm with 0.78 ha of water depth, 16-month harvest with 3 production cycles. Values in R$ for the month of Oct/23 (U$$ 1.00 = R$ 5.17).

Zootechnical and economic indicators	Unit	Total	5-8 cm	9-11 cm	12-15 cm	1.7 kg	2.0 kg	1.8 kg	2.0 kg
Juvenile production	Thousand	822	836	238	70	2.2	1.4	1.9	1.2
Juvenile sales	Thousand	818	585	167	66				
Sell fatty fish	kg	7,695				1,268	2,771	1,194	2,463
Effective Operating Cost	R$		372.91	467.07	718.94	7.62	9.18	7.30	9.18
Total Operating Cost			377.32	482.56	824.30	7.93	9.59	8.13	10.33
Average selling price	R$ Thousand^{-1}		500.00	600.00	1,000.00				
	R$ kg^{-1}					8.50	10.50	9.00	10.50
Gross revenue (GR)	R$	535,224.22	292,688.16	100,099.35	65,962.02	10,779.31	29,092.95	10,742.01	25,860.40
Gross profit (GR - EOC)		135,408.53	75,503.88	22,176.33	18,538.97	1,116.10	3,656.41	2,034.99	3,260.38
Net profit (GR - TOC)		112,694.23	71,812.80	19,592.58	11,589.56	718.60	2,520.69	1,041.23	421.09
Profitability index		21.06%	24.54%	17.04%	20.07%	2.50%	9.49%	3.76%	1.66%

Table 8. Cash flow from the production of juveniles and fatty fish of tambatinga (♀ tambaqui *Colossoma macropomum* x ♂ pirapitinga *Piaractus brachypomus*) in an excavated tank farm with 0.78 ha of water depth, 16-month harvest with 3 production cycles. Values in R$ for the month of Oct/23 (U$$ 1.00 = R$ 5.17).

Category	Un.	Dec/22	Jan/23	Feb/23	Mar/23	Apr/23	May/23	Jun/23	Jul/23	Aug/23	Sep/23	Oct/23	Nov/23	Dec/23	Jan/24	Feb/24	Mar/24
		Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)	Value (R$)
Juvenile (cm)	5-8	131,205.04			80,741.56								80,741.56				
	8-10		44,872.12			27,613.61								27,613.61			
	12-15			29,235.91			17,396.58									19,329.53	
Fatty fish 1st Cycle (kg)	1.700									10,779.31							
	2.000											29,092.95					
Fatty fish 2nd Cycle (kg)	1.800														10,742.01		
	2.000																25,860.40
Revenue		131,205.04	44,872.12	29,235.91	80,741.56	27,613.61	17,396.58	0.00	0.00	10,779.31	0.00	29,092.95	80,741.56	27,613.61	10,742.01	19,329.53	25,860.40
Juvenile (cm)	2-4	124,957.18			76,896.73								76,896.73				
Feed (kg)		12,094.77			21,468.25			27,452.70					7,598.62		9,963.82		
Others*		2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43	2,655.43
Expenses or costs		139,707.38	2,655.43	2,655.43	101,020.41	2,655.43	2,655.43	30,108.13	2,655.43	2,655.43	2,655.43	2,655.43	87,150.78	2,655.43	12,619.25	2,655.43	2,655.43
Balance		-8,502.34	33,714.35	60,294.83	40,015.98	64,974.17	79,715.31	49,607.18	46,951.75	55,075.63	52,420.20	78,857.73	72,448.51	97,406.70	95,529.46	112,203.56	135,408.53

As shown in Table 7, the best profitability index was obtained by marketing juveniles aged 5-8 cm. The second-best profitability index was the 12-15 cm phase, owing to the greater difference found between the TOC and the average sale price; that is, better sale prices are important for improving and even making the activity economically viable.

These results also show that it is advantageous for producers to sell most of their fry during the first phase. This is because it avoids holding juveniles for longer production, reduces feed costs, and reduces the mortality rate.

Table 7 also shows the ATOC per thousand juveniles, which also represents the minimum value marketing juveniles in unfavorable times, since it would be possible to pay all operating expenses, guarantee the remuneration of family labor, and have the monetary value of depreciation in cash, thus guaranteeing the short-term maintenance of the system.

During fattening, the ATOC was 8.50, 10.50, 9.00 and R$10.50 for fish with average weights of 1.7, 2.0, 1.8, and 2.0 kg, respectively. Therefore, it is clear that the heavier the fish, the higher the selling price. These results are important for guiding the marketing of fish of the same species of different sizes. It is known that they differ; however, this difference (30.2%), has not yet been determined. Once again, the influence of SB on economic indicators is evident in the case of the 2.0 kg fish obtained with different TOC (Table 7), due to the 1st fattening cycle having 10.5 higher SB and 0.9% better AFC, resulting in a 7.15% lower TOC.

The better the control and management of production costs, the more often it will be possible to price the fish differently according to weight because the producer will know exactly what it costs to produce a kilogram of fish, making it easier to determine and/or negotiate the selling price. The total net profit (NP) obtained (Table 7) was R$108,359.83 ha/year, allowing the producer to make an average profit of R$7,043.39/month on 0.78 ha. This shows that rearing juvenile tambatinga provides a favorable economic return for the producer during the rearing period, allowing it to be the main activity of family farming; however, aquaculture is often considered a secondary activity (Valenti et al., 2021).

In southern Brazil, tilapia farming by small producers has shown positive profitability rates in various production situations (Castilho-Barros, Owatari, Mouriño, Silva, & Seiffert, 2020). However, the NP in this study was higher than those in studies conducted on the small properties of excavated tanks producing tilapia (Castilho-Barros et al., 2020; Siqueira et al., 2021) and native fish (Costa et al., 2017; Barros et al., 2020a; 2020b; Costa, Sabbag, & Martins, 2020; Botelho et al., 2022). In the sensitivity analysis, simulations were carried out with a mortality rate of 20%, which can occur because the initial phase is more critical owing to various factors such as inadequate juvenile handling, incorrect or inappropriate (cold days) transportation, poorly executed harvesting, or too many juveniles per tank, which can damage the quality of the pond water.

The results with the highest mortality rate show a 26.86% reduction in profit, with an NP of R$5,151.31/month; however, this is still profitable for the producer. In this way, the work conducted demonstrates how zootechnical and economic planning can optimize the use of an area and allow more to be produced on it, allowing producers to increase their income, and consequently proving to be economically viable even in adverse simulations of zootechnical indicators. Simulations with different marketing prices are not necessary, as Table 7 shows the average TOC, which is the minimum value that should be used by the producer because it guarantees remuneration for labor and the funds to pay all expenses and replace the items invested.

Implementation feasibility is crucial in family farming, especially in rural settlements (Brasil, 2020). Projects in this scenario depend not only on individual producers, but also on an entire interconnected system, including production, technical assistance, and marketing. Although these results are important to disseminate the implementation feasibility, it is essential that there are government incentives at the municipal, state, and federal levels.

According to Padilha (2020), the municipality of Colíder created an incentive in 2014 to help small producers earn extra income from fish farming. Twenty-five small-scale farmers were included, and technical assistance was provided for the production process, pond construction, fingerling and feed purchases, treatment dosages, and marketing. According to the same authors, in 2016 the municipality's Department of Agriculture, supported by Mato Grosso Research, Assistance and Rural Extension Enterprise, continued the project by donating 10,000 fingerlings to small producers. Projects such as these should be encouraged because fish farming, when well planned and executed, can be a profitable activity, even in the context of family farming and land reform.

Conclusion

The production of juveniles of many sizes is economically viable for family fish farming, showing attractive profitability indicators even under adverse zootechnical conditions. The effectiveness of conducting zootechnical and economic planning on a property has been demonstrated, which can optimize production and use of the area, as well as show to fish farmers how rewarding it is to farm fish.

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