Production strategy influence on the economic viability of a family fish farm in Pará state, Amazon, Brazil

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Abstract

The objective of this study was to analyze the influence of the adoption of single-phase and two-phase system on the economic feasibility of tambaqui (Colossoma macropomum) family production in the Tracuateua municipality, Pará state. The operational cost methodology and economic efficiency indicators were adopted to compare these rearing systems. The annual production was 4,200 kg and 5,826 kg. The operational costs were R$ 26,169.00 and R$ 34,365.00, the total operational cost was R$ 27,505 and R$ 35,701.00, and the total operational cost per kg was R$ 6.55 and R$ 6.13 for single-phase and two-phase systems, respectively. Regarding the indicators, the net present value was R$ 24,180.70, the internal rate of return was 24%, the cost-benefit ratio was 1.19, and the capital return period was four years in the single-phase system. In the two-phase period, the net present value was R$ 48,582.06, the internal rate of return was 29%, the cost-benefit ratio was 1.25, and the capital return period was 3.6 years. Despite the demand for greater investment, the two-phase system proved to be more profitable than the single-phase system, promoting even a reduction in unit production cost.

Keywords: aquaculture, *Colossoma macropomum*, production cost, two-phase system, single-phase system.

1. Introduction

In 2016, the fish production in Brazil from fish farming was 507.1 thousand tons. Tilapia *Oreochromis niloticus* (Linnaeus, 1758) accounted for 47.1% of the total, followed by tambaqui *Colossoma macropomum* (Cuvier, 1816), at 26.9%; and tambacu and tambatinga hybrids at 8.8%. Rondônia, Paraná, and São Paulo assume a prominent role, with 90.6, 76, and 48.3 thousand tons, respectively (IBGE, 2016).

In the northern region of Brazil, besides Rondônia, two other states could be integrating the first place in the national ranking, given their natural and socio-economic conditions: Amazonas and Pará. Amazonas occupies the eighth position, with 21 thousand tons, and Pará only the twelfth, with 12.9 thousand tons (IBGE, 2016). In this context, fish supply from extractive industries, logistical and infrastructural aspects, such as territorial extension, road trafficability, and access to electric energy, allied to issues that make up the production chain's institutional environment, such as environmental legislation and assistance, has hampered activity development (MPA, 2013).

In Pará state, fish farming is commercially practised predominantly on small farms, which use ponds as a rearing structure and adopt tambaqui as the main species, mostly under monoculture conditions (MPA, 2013). In general, activity is marked by low competitiveness, especially in isolated family initiatives regarding the social organization and poor technical assistance (Brabo et al., 2016 and Brabo, 2014).

The estimated productivity is 0.5 to 1.5 kg/ m^2/year, depending on the production strategy adopted, such as monoculture or polyculture use; commercial, farm-made or alternative food use; emergency or routine aeration; partial replacement of water daily or only replacement of loss due to evaporation and infiltration; direct settlement or phased rearing; among other management forms (Gomes et al., 2010).

In the phased rearing, the single-phase system is characterized by the direct settlement of the young forms in the fattening ponds, where the fish remain until they are removed. The two-phase system is characterized by the use of ponds' nurseries in the rearing and fattening ponds. Some enterprises may employ three-phase systems, where individual fish pass through two structures adopted as primary and secondary nurseries before reaching the fattening ponds. Therefore, the two- or three-phase systems used are detrimental to the single-phase system, making an enterprise more or less profitable and requiring an increase or decrease in business investment.

Considering that tambaqui is the most important species for fish farming in Pará state and the Brazilian Amazon, its production occurs mainly in ponds. The activity presents an expressive growth potential in the region. It is fundamental to understand the influence of the production strategy on the economic indicators of commercial enterprises to grow tambaqui in ponds, especially the total investment, production cost, and activity profitability.

This study aims to analyze the influence of adopting the single- and two-phase system on the economic viability of a family fish farm located in Tracuateua city, Pará state.

2. Materials and methods

The study was conducted at Sítio Bom Gosto (46°56'20.71" S 00°58'26.31"W), a rural property located in the Flexal Community, Tracuateua municipality, Pará Northeastern mesoregion. In addition to fish farming in ponds, other agricultural activities were developed here, such as poultry, cattle rearing, and fruit-growing. The total property area was 35.6 hectares, the labor force used is predominantly the family itself, which was also responsible for the management of economic activities, and this enterprise is categorized as a rural family in accordance with Law No. 11,326 of July 24, 2006 (Brazil, 2006).

The infrastructure and required inputs surveying for tambaqui farming occurred from January to June 2017, through monthly excursions to the enterprise to follow the fish farming routine and interviews with the owner about the management adopted, such as pond preparation, settlement, fish feeding, biometrics, fish removal, and production scheduling. In the same period, a price survey was conducted in the local market. For items that were not available; the price in the supplier city plus shipping was considered, such as for bottom trawl and dynamometric weighing-machine.

The analyzed fish farm had a depth of 4,200 m^2 water, supplied by pumping. The farm was divided into four ponds with 1,404 m^2, 1,287 m^2, 805 m^2, and 704 m^2 areas. The liming of the ponds occurred with quicklime in the proportion of 100 g/m^2 and fertilization with chicken manure tanned in the proportion of 50 g/m^2. The fingerlings were purchased with an approximate weight of 5g from a producer with identified microchip broodstocks located in the Peixe boi municipality. The transport takes three hours by road. Feeding occurred exclusively with extruded commercial feed, feed rate, feed frequency, and grain size criteria. The biometrics were carried out monthly, and the production cycle lasted about a year to obtain a final weight of 1 kg. The commercialization took place mainly in the holy week.

Thus, two production strategies were economically analyzed: 1) the single-phase system, which was already carried out by the entrepreneur, where the direct young forms' settlement occurred in the fattening ponds at a stocking density of 1 individual/m^2 and 20% mortality rate estimate, number of individuals included at the moment of settlement beyond that calculated regarding the pond area; 2) the two-phase system, where the 1,287 m^2 pond was defined as a nursery, with a production cycle of 120 days, a final weight of 400 g in the rearing, a stocking density of 2.5 individuals/m^2 and 20% mortality rate estimate; and 120 days to obtain a final weight of 1 kg in fattening at a stocking density of 1 individual/m^2.

For production cost estimation, the operational cost structure proposed by Matsunaga et al. (1976) was executed using the following items: 1) effective operational cost (EOC) = sum of labor costs, social charges, inputs' acquisition, and equipment maintenance (3% of EOC), that is, actual expenditure (disbursement) by the investor; 2) Total Operational Cost (TOC) = sum of Effective Operational Cost (EOC) with capital goods' depreciation, which in this case was calculated using the straight-line method.

The economic efficiency indicators adopted in work were those defined by Martin et al. (1998): 1) Gross Revenue (GR) = annual production multiplied by the average wholesale sales price; 2) Annual Operational Profit (OP) = difference between Gross Revenue and Total Operational Cost; 3) Monthly Operational Profit (MOP) = Operational Profit divided by the number of months of the year; 4) Gross Margin (GM) = difference between Gross Revenue and Total Operational Cost, divided by Total Operational Cost, represented in percentage; 5) Profitability Index (PI) = Operational Profit divided by Gross Revenue, represented in percentage; and 6) Equilibrium Point (EP): Total Operational Cost divided by the average wholesale selling price.

For the investment analysis, cash flow was elaborated, and economic viability indicators were determined. Cash flow was calculated based on investment spreadsheets, operating expenses (outflows), and revenues (receipts) for a 25-year horizon. Net cash flow (NCF), resulting from the difference between cash inflows and outflows, was used to calculate the following indicators: 1) Net Present Value (NPV) = present value of the benefits less the current value of costs or disbursements; 2) internal rate of return (IRR) = interest rate that equals the total investments or costs to the returns or total benefits obtained during the project life; 3) cost-benefit ratio (CBR) = ratio between the current value of the expected returns and the estimated costs' value; and 4) the capital return period (CRP) = the time required for the sum of future net nominal revenue to equal the initial investment value. The discount rate or minimum attractiveness rate (MAR) adopted for NPV and CBR evaluation was 10%.

3. Results and discussion

The project implementation cost was R$ 21,420.00, with the pond excavation being the most relevant item of the initial investment with a 70% participation (Table 1). In this case, the backhoe used in the earthmoving could move 70 m^3 of material per hour, and the fuel value and the operator compensation embedded were in its price.

Table 1. Implantation Cost of a tambaqui's *(Colossoma macropomum)* family enterprise in ponds with 0.42 hectare of water depth in Pará state, 2017.

Item	Unity	Quantity	Unity value (R$)	Total value (R$)	%	Useful life (years)	Annual depreciation (R$)
Area cleaning	Man/day	4	50.00	200.00	0.9	-	-
Topographic survey	Hectare	1	400.00	400.00	1.9	-	-
Pond's excavation	Hour/machine	60	250.00	15,000.00	70.0	25	600.00
Pipes and fittings	Note	-	-	500.00	2.3	5	100.00
Hydraulic pump	Unity	1	3,000.00	3,000.00	14.0	10	300.00
Bottom trawl	Unity	1	1,200.00	1,200.00	5.6	5	240.00
Hand nets	Unity	1	100.00	100.00	0.5	5	20.00
Weighing-machine	Unity	1	150.00	150.00	0.7	5	30.00
Hand Carriage	Unity	1	180.00	180.00	0.8	5	36.00
Plastic bucket	Unity	2	25.00	50.00	0.2	5	10.00
Other costs	Note	-	-	640.00	3.0	-	-
Total	-	-	-	21,420.00	100		1,336.00

Analyzing the implantation cost of zootechnical facilities for fish farming in Pará Northeast, Brabo et al. (2014) identified the difficulty of renting machines for short periods, such as crawler tractors and backhoe loaders for earthmoving service execution and hydraulic work construction. This is due to the cost of moving these machines as it demands auxiliary transport.

Vilela et al. (2013) found a value of R$ 35,053.50 for constructing one water hectare divided into ten ponds for fish farming. Barros et al. (2016) stated that multitudes of structures per water hectare increases the number of used hours/machine, raising the implantation cost. In this study, four ponds formed 0.42 hectares of the flooded area and were built with R$ 15,000.00. This amount can be considered similar to the cited research, even with the time difference between the two works.

Regarding the production cost of single-phase system adoption, the EOC corresponded to R$ 26,169.00, the TOC was R$ 27,505.00, and TOC per kilogram of produced tambaqui totaled R$ 6.55. Regarding the items that were integrated the production cost, the feed was the most representative input, at 71.2% (Table 2).

Table 2. Production cost in the single-phase production of *Colossoma macropomum* in ponds from a family fish farm with 0.42 hectare of water depth in Pará state, 2017.

Item	Unity	Quantity	Unity value (R$)	Total value (R$)	%
Quicklime	Kg	420	2.00	840.00	3.1
Fertilizer	Kg	210	1.00	210.00	0.8
Quicklime and fertilizer shipping	Unity	1	70.00	70.00	0.3
Fingerlings	Thousand	6	250.00	1,500.00	5.5
Fingerlings' shipping	Unity	1	70.00	70.00	0.3
Feed 50%PB	Bag 25 kg	4	149.00	596.00	2.2
Feed 45%PB	Bag 25 kg	21	101.00	2,121.00	7.7
Feed 36%PB	Bag 25 kg	31	74.00	2,294.00	8.3
Feed 32%PB	Bag 25 kg	38	70.00	2,660.00	9.7
Feed 28%PB	Bag 25 kg	202	59.00	11,918.00	43.3
Feed freight	Unity	3	70.00	210.00	0.8
Eventual labor	Man/day	24	50.00	1,200.00	4.4
Fuel	Liter	60	4.00	240.00	0.9
Electricity	Note	-	600.00	600.00	2.2
Maintenance	Note	-	-	820.00	3.0
Other costs	Note	-	-	820.00	3.0
Effective Operational Cost (R$)	-	-	-	26,169.00	95.1
Annual Depreciation (R$)	-	-	-	1,336.00	4.9
Total Operational Cost (R$)	-	-	-	27,505.00	100
Annual production (kg)	-	-	-	4,200	-
Total Operational Cost (R$/Kg)	-	-	-	6.55	-
Wholesale Price (R$/Kg)	-	-	-	7.50	-

According to Brabo (2014), the high price of fish feed in the Pará state is because the region does not have a well-established Local Productive Arrangement (LPAs). The installed feed mills maintain prices equivalent to the traditional brands that are expensive because of the high shipping values as they are produced in other states. Studies such as Sabbag et al. (2011) in São Paulo State and Silva et al. (2012) in Paraná showed much lower prices of this input, due to the grain production availability and logistics in Brazil's Midwest, Southeast, and South regions, such as maize *Zeamays*, soy *Glycinemax,* and wheat *Triticum aestivum*.

In this study, the apparent feed conversion was estimated to be 1.8:1 at the end of the production cycle. Notably, a better feed conversion reduces the offered feed amount, which will consequently reflect the investor's profit. For Dieterich et al. (2013), adequate food management in terms of feed rate and feed frequency allows food waste reduction, reducing this feed's costs.

Regarding the cash flow in single-phase system adoption, positive net flow attested the business economic viability. Revenue was higher than the cost of production. Therefore, the balance was positive between the fourth and fifth year, permissible in a fish farming project in ponds (Sanches et al., 2014; 2013).

The two-phase system, the EOC, TOC, and TOC per kilogram were R$ 34,365.00, R$ 35,701.00, and R $ 6.13, respectively. Additionally, the ratio with 75.6% was the most relevant item (Table 3). The production cost values are superior to the single-phase system, but the unit cost was lower, demonstrating a productive process optimization.

Regarding the feed, this result is similar to the values found by Brabo et al. (2013). This author observed an input ranging from 66.27% to 73% in production costs when analyzing the economic viability of fish farming in the Tucuruí Reservoir. This value is close to the results found by Belchior and Dalchiavon (2017). They analyzed the tambaqui production viability in the municipality of Ariquemes/RO, where the feed cost accounted for 73.7% of the operating cost.

Table 3. Production cost in the two-phase rearing of *Colossoma macropomum* in ponds from a family fish farm with 0.42 hectare of water depth in Pará state, 2017.

Item	Unity	Quantity	Unity value (R$)	Total value (R$)	%
Quicklime	Kg	420	2.00	840.00	2.4
Fertilizer	Kg	210	1.00	210.00	0.6
Quicklime and fertilizer shipping	Unity	1	70.00	70.00	0.2
Fingerlings	Thousand	7	250.00	1,750.00	4.9
Fingerlings' shipping	Unity	2	70.00	140.00	0.4
Feed 50%PB	Saco 25 kg	5	149.00	745.00	2.1
Feed 45%PB	Saco 25 kg	28	101.00	2,828.00	7.9
Feed 36%PB	Saco 25 kg	43	74.00	3,182.00	8.9
Feed 32%PB	Saco 25 kg	53	70.00	3,710.00	10.4
Feed 28%PB	Saco 25 kg	280	59.00	16,520.00	46.3
Feed freight	Unity	3	70.00	210.00	0.6
Eventual labor	Man/day	24	50.00	1,200.00	3.4
Fuel	Liter	60	4.00	240.00	0.7
Electricity	Note	-	600.00	600.00	1.7
Maintenance	Note	-	-	1,060.00	3.0
Other costs	Note	-	-	1,060.00	3.0
Effective Operational Cost (R$)	-	-	-	34,365.00	96.3

Annual Depreciation (R$)	-	-	-	1,336.00	3.7
Total Operational Cost (R$)	-	-	-	35,701.00	100
Total Operational Cost (R$/Kg)	-	-	-	6.13	-
Wholesale Price (R$/Kg)	-	-	-	7.50	-

The cash flow from the tambaqui reared in the two-phase system showed that the net flow is negative in the first year due to a single fish removal of individuals stocked in the ponds used in final fattening or finishing. However, the investor balance became positive between the third and fourth year, less than the single-phase system.

Table 4 compares the economic efficiency indicators obtained in the single-phase and two-phase systems, demonstrating the greater profitability of adopting the rearing and fattening phases is detrimental to the direct population.

Table 4. Comparison of production cost and economic efficiency indicators from two production strategies of tambaqui *Colossoma macropomum* ponds in a family fish farm in the Pará state, 2017.

Economic indicators	Production strategies	
	Single-phase	Two-phase
Total Investment (R$)	47,589.00	55,785.00
Total Operational Cost (R$)	27,505.00	35,701.00
Total Operational Cost per kg (R$)	6.55	6.13
Gross Revenue (R$)	31,500.00	43,695.00
Annual Operational Income (R$)	3,995.00	7,994.00
Monthly Operational Income (R$)	332.92	666.17
Gross Margin (%)	14.5	22.4
Profitability Index (%)	12.7	18.3
Equilibrium Point (kg)	3,667.3	4,760.1
Net Present Value (R$)	24,180.70	48,582.06
Internal Rate of Return (%)	24	29
Relation Benefit Cost (R$)	1.19	1.25
Period of Return of Capital (years)	4	3.8

The IRR values found in the two analyzed systems were higher than the minimum attractiveness rate (MAR), estimated at 10%. For Hoji (2010), the investment becomes economically viable when the IRR is higher than the MAR. As a parameter, Brabo et al. (2015) analyzed the economic viability of fingerlings production of rheophilic species in Pará Northeast and found a value of 38% for the IRR.

Finally, this study allows the technicians, fish farmers, and development agencies' reflect on the production strategies adopted in fish farms, as they directly influence their profitability. Thus, fish farms in the planning stage or already in operation should focus on other possibilities of increased productivity and survival, such as compensatory growth of species, construction designed to present staggered production, and aspects related to the young forms and feed quality.

In conclusion, adopting a two-phase system requires a higher investment than the single-phase system for tambaqui rearing in the same infrastructure, mainly because of the difference in the feed amount to be used. However, this system's profitability is also higher, demonstrating the optimization of the structure available in this production strategy.

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