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Short Communication

Effect of stocking density on economic performance for *Colossoma macropomum* (Cuvier, 1816), juvenile in earthen ponds

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ABSTRACT. The seeding rate is a factor that affects water quality, biological, physiological parameters, incidence of parasites and economic indicators. 72,000 fish of ± 1.9 ± 0.1 cm and 0.4 ± 0.01 g were planted in 12 ponds of 600 m² in densities of 5, 10 and 15 fish m^{-2}. The fish were fed twice a day until apparent satiation, with a commercial feed with 36% crude protein, for 56 days. The cost was determined based on the total production cost and total operational cost, showing unit values per hectare of water surface. Performance indicators were compared with ANOVA test with polynomial regression. The final number of fish showed a positive linear behavior, while the other performance parameters were not affected by density, thus suggesting that the pond's maximum stocking density was not reached. On investment and production costs the most representative items were nursery building and fry acquisition, respectively, which denotes that increasing seeding density positively affected the production process, improving all the economic indicators.

Keywords: *Colossoma macropomum*, tambaqui, fish-farming, performance, economic evaluation, production cost, Brazil.

Efecto de la densidad de siembra sobre el rendimiento económico de juveniles de *Colossoma macropomum* (Cuvier, 1816) en estanques

RESUMEN. La densidad de siembra es un factor que afecta la calidad del agua, indicadores biológicos, parámetros fisiológicos, incidencia de parásitos e indicadores económicos. 72,000 peces de 1,9 ± 0,01 cm y 0,4 ± 0,01 g, fueron sembrados en 12 estanques de 600 m² en densidades de siembra de 5, 10 y 15 peces m^{-2}. Los peces fueron alimentados dos veces al día hasta su aparente saciedad, con alimento comercial con 36% proteína bruta por 56 días. El costo fue determinado con base al costo total y costo operacional de producción, mostrando los valores en unidad por hectárea de superficie de agua. Los indicadores de rendimiento fueron comparados con la prueba de ANOVA con regresión polinómica. El número final de peces mostró un comportamiento lineal positivo, mientras que los otros parámetros de rendimiento no fueron afectados por la densidad de siembra, sugiriendo que la máxima densidad de siembra de los estanques no se alcanzó. En la inversión y en los costos de producción los elementos más representativos fueron la construcción de viveros y la adquisición de alevines, respectivamente. De esta manera, se determinó que el aumento de la densidad de siembra afectó positivamente el proceso de producción, mejorando todos los indicadores económicos.

Palabras clave: *Colossoma macropomum*, cachama negra, piscicultura, rendimiento, evaluación económica, costo de producción, Brasil.

Tambaqui (*Colossoma macropomum*), fish native to the Amazon and Orinoco basin (Honda, 1974), can reach up to 1 m in length and 30 kg (Goulding & Carvalho, 1982). Stocking density is an important factor because it directly influences water quality (Gomes *et al.*, 2003); production performance parameters (Brandão *et*

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al., 2004); physiological parameters and the incidence of parasites (Souza-Filho & Cerqueira, 2003); and farming economic indices (Brandão *et al.*, 2004). There is little information about the conventional excavated ponds system and lack of information regarding economic and biological indices under this system.

In fish farming, production indices along with economic indicators are an important tool to assist managers in the decision making process. Studies have reported on the cost of various production systems (Martin *et al.*, 1995; Pereira *et al.*, 2009) and the various farmed fish species (Martin *et al.*, 1995; Crivelenti *et al.*, 2006). Thus, this study evaluates the influence of stocking density on the economic indices and performance parameters during the growing phase of tambaqui farmed in excavated/earthen ponds.

The 72,000 juveniles, measuring 1.9 ± 0.01 cm long (mean ± standard error) and weighing 0.4 ± 0.01 g (mean ± standard error), were stocked at densities of 5, 10 and 15 fish m^{-2} (T_{05}, T_{10}, T_{15}, respectively) in 12 ponds of 600 m². The experimental design was completely randomized with four replications. The fish were fed twice daily to apparent satiation with a commercial ration containing 36% crude protein (CP), for a period of 56 days. The growth performance of the animals was evaluated based on the values of survival, fish final number (FFN) and feed conversion rate (FCR).

The operational costs were estimated for a production cycle of 80 days, of which 12 days for the nursery preparation, 56 rearing days and 12 days for harvesting the fish. The initial investment considered the construction of a 7200 m² area, with 12 ponds of 600 m² (direct investment) and a support building with an office, accommodation, feed storage and fingerlings cleaning and shipping shed used for the entire fish farming activity (8 ha of ponds). Thus, the proportion of each support item was determined, considering the area of the experiment to the fish farm area ratio, to determine the relative initial investment. The relative values of these investments were then recalculated to be expressed in US\$ ha^{-1}. Investment did not take into account the spending on land acquisition.

The costs were determined based on the structure of the total operacional cost (TOC) and total production cost (TPC) for the production, whose values were expressed per hectare of water surface. The TPC differs from the TOC by considering opportunity costs. These can be defined as the best investment option in land value, fixed and circulating capital and labor of the entrepreneur. Due to the subjectivity and difficulty of their determination, Matsunaga *et al.* (1976) developed a new cost structure that disregard this item. The TOC is the sum of operating cost effective (OCE) and depreciation. OCE are considered as all disbursements necessary for development of the activity. All costs were expressed per hectare of water surface.

Labor cost considered two permanent staff members: a field manager and a helper, with a monthly cost of US$ 874.88 and US$ 473.89, respectively: also, day laborers were hired per contract during ponds preparation and harvesting at a daily cost of US$ 14.78.

The costs of vehicles (tractor and truck) were considered as follows, fuel of diesel, insurance, garage, maintenance and repairs. For mowing, we considered fuel of gasoline, maintenance and repairs. These vehicles and mowing expenses were appropriated per treatment.

Depreciation of infrastructure, equipment and tools was calculated using the linear method. The TPC was calculated by adding fixed costs (FC) and variable costs (VC). The fixed cost was obtained from the sum: compensation of land (rental value per hectare for development of fattening tambaqui obtained in Barros *et al.* (2011); remuneration of the entrepreneur (value U$ 1,477.83 monthly for the entrepreneur for all farmed); remuneration of fixed capital (return rate of 6% per annum on the average value of fixed capital) and the depreciation. The variable cost was obtained by adding the OCE and interest on working capital (at an interest rate of 4% per year related to interest rate funding for aquaculture, on the average value of payment).

After production costs were calculated, the following economic indicators were used for the economic analyses:

Production, initial investment, TOC, TPC, Unitary or Average Costs, Gross Revenue (GR), Operation profit (OP) = GR - TOC, profit (P) = GR - TPC,

$$\text{Profitability index } (\%) = \frac{\text{OP}}{\text{GR}} 100$$

$$\text{Profit margin } (\%) = \frac{\text{P}}{\text{GR}} 100$$

$$\text{Revenue index } (\%) = \frac{\text{GR}}{\text{I}} 100$$

The mean and standard errors were determined for all performance parameters. Data were checked for normality using the Cramer-von Mises ($\alpha = 5\%$) and homogeneity by Levene's test ($\alpha = 5\%$). When the assumptions were met, the results were submitted to ANOVA. Polynomial regression analysis was performed when statistical differences were determined. The statistical analysis was performed using the R 2.15.0 software.

Stocking density influenced only average fish final number (Table 1), which is represented by the following

Table 1. Results of statistical indicators and tambaqui performance parameters during 56 days, at different stocking densities. Significant at $P < 0.05$, FFN: fish final number, FCR: feed conversion rate.

Performance parameters	Density			Statistics	
	T_{05}	T_{10}	T_{15}	*P*	F
Mean final weight (g)	37.10 ± 3.33	35.47 ± 2.58	30.30 ± 4.63	0.194	1.93
Survival (%)	87.84 ± 4.09	93.25 ± 5.73	96.46 ± 14.93	0.5971	0.298
FFN (fish m^{-2})	4.40 ± 0.20	9.30 ± 0.10	12.80 ± 0.60	<0.001	216.50
FCR	0.67 ± 0.08	0.61 ± 0.04	0.58 ± 0.11	0.426	0.68

equation: FFN = 0.4611 + 0.8363 density ($R^2 = 95.59$). This variable has a direct relationship with survival. As the stocking density did not influence survival, the final number of fish increases when fish density increases. For the all densities, the values of FCR were less than one. The survival of *C. macropomum* is affected by exposition to toxic substances (Salazar-Lugo *et al.*, 2011), parasite infestation, predation, declining water quality, plus the possibility of theft (Arbelaez-Rojas *et al.*, 2002). However, none of these factors were observed in this work, showing that in addition to meeting the requirements of the species regarding feed quality and quantity, the growing conditions was also appropriate. As well as the work of Silva *et al.* (2013), who noted there influenciencia of stocking density in tambaquis that were in good growing conditions.

The low FCR values found for tambaqui in this work, is because the fingerlings has a greater efficiency in turning food into muscle, justifying lower FCR values during rearing and spawning phases compared to the grow-out. Also when is calculate the FCR not is considered that fish has more humidity that feed, thus the value of FCR is less that one. Similar results were found in the literature for *Gadus morhua* farming, whith value varied between 0.7 to 1.0 (Bjornsson *et al.*, 2012), for tambaqui reared in cages that varied between 0.92 and 1.27 (Brandão *et al.*, 2004) and for tambaqui reared in irrigation channels under differents densities, with values between 0.96 and 1.05 (Silva *et al.*, 2013). However, the results differed from those reported by Arbelaez-Rojas *et al.* (2002) for tambaqui grow-out phase, which were 1.35 and 1.80 when farmed in excavated ponds and stream channels, respectively.

The initial investment for building the 12 ponds and the support structure (for 8 ha of water surface) was estimated at US$130,404.01. Therefore, proportionally, the necessary investment is US$ 54,360.22 for the 12 ponds and US$ 75,500.31 per hectare for the supporting facilities (Table 2). For pond construction the initial investment is high due to the need for heavy machinery to clean the area, earthmoving, formation of embankments and compaction of the ponds. The construction of supply and drainage systems, depending on the model used, can further increase costs (Martin *et al.*, 1995). This item can represent between 27 and 84% of the initial investment, depending on the area of installation, the supply and drainage system used, the size of fish farms and the degree of soil movement needed (Martin *et al.*, 1995; Cavero *et al.*, 2009; Pereira *et al.*, 2009; Barros & Martins, 2012). However, in this study, the pond construction represented 86.16% of the initial investment. This was due to the construction of a greater number of ponds per area, compared to fish grow-out ponds, plus the need for installing a net cover to protect the fish against winged predators, a necessity during fingerling and rearing stages.

Values of TOC and TPC increased with increasing stocking density (Table 3). The purchase of fingerlings was the largest participation item in the cost composition, increasing with fish density. All other costs, with the exception of feeding and fingerlings acquisition, decreased with increasing stocking density. Feeding costs was the biggest participation item in the cost composition for the density of 10 fish m^{-2}. Between 5 and 10 fish m^{-2} densities, TOC increased 38.9% while between 10 and 15 fish m^{-2}, TOC increased 14.5% only. Moreover, between the lowest and highest density, TOC increased 59.0%.

Feeding costs have relatively low participation in the cost composition, which results from the small quantities of feed required to feed fingerlings that display high growth rate, using available food very efficiently. Also, total feed requirement is less compared to the grow-out phase because the production cycle is shorter. Jomori *et al.* (2005) reported that feed expenditures are directly related with the cultivation time; increasing the longer the fish remain in the production system.

This study showed that in tambaqui farming, the purchase of fingerlings is the most costly item of the production cost composition, especially because development during this phase is faster and feeding requirements are lower when compared to the grow-out phase. Fingerlings expenditure is influenced mainly by existing breeding techniques, *i.e.*, species that have well

Table 2. Investment for a tambaqui farm. August 2012, (US$ 1 = R$ 2.03).

Itemization	Value (US$ ha^{-1})	%
Supporting structure		13.84
House (office, accommodation, toilets)	1,456.89	1.91
Feed deposit	492.61	0.65
Fingerlings cleaning and distribution shed	1,477.83	1.96
Equipment, tools and appliances	2,396.32	3.17
Vehicles	4,646.70	6.14
Ponds	65,054.73	86.16
Total	75,500.31	

Table 3. Production cost and economic indicators for a tambaqui farm during a 80-day growing period. August 2012. (US$ 1 = R$ 2.03).

Itemization	Stocking densities		
	T_{05}	T_{10}	T_{15}
A-effective operating cost (US$)	7,095.26	10,743.92	12,625.41
Fingerlings	2,463.05	4,926.11	6,568.14
Feed 36%	1,168.14	2,158.73	2,201.99
Vehicles and equipment expenditures	635.82	635.82	635.82
Lime	100.99	100.99	100.99
Urea	10.10	10.10	10.10
Wheat meal	620.69	620.69	620.69
Superphosphate	19.21	19.21	19.21
Office materials	32.33	32.33	32.33
Consumables	119.05	119.05	119.05
Labor	1,925.89	2,120.91	2,317.10
B-Depreciation	1,137.73	1,137.73	1,137.73
C=A+B-Total operating cost (US$)	8,232.99	11,881.66	13,763.15
D=A+D1-Variable cost	5,467.08	9,127.72	10,986.92
D1-Interest on working capital	58.92	98.55	118.53
E=B+E1-Fixed cost	3,460.93	3,460.93	3,460.93
E1=Opportunity costs	2,323.20	2,323.20	2,323.20
F=D+E-Total production cost (US$)	8,928.01	12,588.65	14,447.85
Initial investment (US$)	75,500.31	75,500.31	75,500.31
Production (number of fingerlings)	43,920.00	93,250.00	127,550.00
Average TOC (US$/fingerling)	00.19	00.13	00.11
Average TPC (US$/fingerling)	00.20	00.13	00.11
Revenue (US$)	10,817.94	22,967.98	31,416.26
Operating profit (US$)	2,937.84	11,086.32	17,653.11
Profit (US$)	1,889.93	10,379.33	16,968.41
Profitability index (%)	13.4	43.3	52.60
Profit margin (%)	17.47	45.19	54.01
Revenue index (%)	14.33	30.42	41.61

developed breeding technologies also have increased fingerling availability, thus lower prices and rearing costs compared to species whose technology is still being developed. Because tambaqui species is easy to reproduce and to obtain fingerlings, the purchase cost of fingerlings in grow-out ponds does not represent more than 12% of the TOC (Merola & Paganfont, 1988; Barros & Martins, 2012; Loose *et al.*, 2014).

For tambaqui farming, the practice of liming and fertilization of ponds is extremely important to generate suitable conditions for fish farming and feeding. But the cost of these items, despite their importance for cultivation, is not significant and represents only 3.56% of TOC and 2.6% of the TPC, as reported by Merola & Paganfont (1988) respectively, during the grow-out phase. However, Loose *et al.* (2014) found a greater participation in the cost of this item (7%), but this fact can be associated that the authors considered as expenses only, depreciation, purchase of fingerlings, food, liming, fertilizing and cleaning of the tanks.

The manpower/labor cost represented between 15 and 24% of costs, corroborating the results of Scorvo-Filho *et al.* (2008), who reported that the item represents from 18 to 22% of OCE, depending on the management technique adopted. During tambaqui grow-out phase in ponds, labor accounts for 5.07% of TOC and 4.2% of TPC by Merola & Paganfont (1988), respectively. On the other hand, Jomori *et al.* (2005) reported that labor participation in TOC ranged from 32.7% to 56.0% for pacu larvae, depending on the management adopted and food supplied. The intensive production systems have been continuously attracting more investors; however, one must consider that the risks also increase, while it becomes necessary to hire specialized labor, to understand the technology and keep close control of water quality (Arbelaez-Rojas *et al.*, 2002). A very important component for the success of the activity is to count on skilled labor that for small production units may be the most participating item in the cost composition (Martins *et al.*, 2001).

The increasing stocking density optimized the use of infrastructure and reduced average costs due to increasing production. This result agrees with a common observation for every enterprise, variable costs gain importance as the production process is optimized. Conversely, the fixed costs participation tends to decrease in the cost composition because their use is optimized (Gomes *et al.*, 2006; Bjornsson *et al.*, 2012).

Revenue increased 112.31% when stocking density increased from T_{05} to T_{10}, 36.78% when density increased from T_{10} to T_{15}, and 190.41% between the T_{05} and T_{15} densities (Table 3). Profitability and revenue indicators increased with stocking density. Thus, the increase of stocking density is desirable since it translates into increased yield per unit area/volume and reduced costs thus yielding better economic indicators. Gomes *et al.* (2006) also stated that profitability and revenue indicators increase with stocking density; however, when density starts to affect production negatively, these indicators also tend to be affected by increasing at a slower pace, stabilizing and even decreasing. Despite the fact that low stocking densities provide better growth rates, in most fish species (Souza-Filho & Cerqueira, 2003; Santos *et al.*, 2007), productivity tends to be low, thus making the activity less profitable (Gomes *et al.*, 2006).

The increasing stocking density did not affect fish performance and improved the production process while positively impacting all economic indicators. The highest density (T_{15}) showed the highest profit and lowest average TPC, as was to be expected since the maximum density was not obtained in this work. The 50% density increase (T_{10} to T_{15}) was sufficient to reduce by 16% the average operation production cost and increase the profit by 63.48%.

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