

Periphyton-based cage culture of Nile tilapia: An interesting model for small-scale farming



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ABSTRACT

We evaluated the production costs and the profitability of using bamboo substrates to enhance periphyton production in cages, in combination with a restricted diet and reduced stocking densities. Nile tilapia (46.56 ± 2.53 g) were placed in 21 cages, and the inclusion of bamboo substrates was evaluated in three different stocking densities (40, 60, and 80 kg of fish/m³) in association with two feeding schemes (100% and 50% of daily ration). No bamboo substrates were included in the control group. The inclusion of the bamboo substrates in cages increased fish weight gain, shortened the farming cycle length, and improved the feed conversion ratio. The proposed production model of Nile tilapia farming in cages with substrates offers a way for small-scale producers to increase the efficiency of the system with annual operating income up to 57% higher and the profitability index up to 87% higher than the currently used system adopted by Brazilian farmers.

1. Introduction

Most aquaculture products worldwide are produced by small and medium-scale facilities that are owned or rented by the producers, especially in Asia, where 94% of world's population was devoted to aquaculture (FAO, 2016).

Similarly in Brazil, family-based aquaculture significantly contributes to the total volume of fish production. For this reason, the federal government has been developing policy focused on family farmers. Among these actions, the aquaculture planning on public waters was conducted by assigning areas in inland and marine aquaculture parks to fish farmers. The aquaculture areas inside parks are classified as onerous or non-onerous. The owners or renters of non-onerous areas meet criteria such as living in the nearest municipality, having low income, receiving assistance from social program, or participating in professional fishing activities, among others.

Within continental aquaculture parks, the most common form of aquaculture is the production of Nile tilapia in net-cages. The system is classified as intensive and uses stocking densities ranging from 80 to 120 kg/m³ (Garcia et al., 2013; Ayroza et al., 2014). This system is commonly used in large-scale production, in which the production volume compensates for the low profit margin.

In order to make the production of Nile tilapia in cages more

attractive to small-scale producers, the efficiency of the current production model must improve. A previous study showed that reducing the stocking density in this production system not only improved fish health and water quality but also reduced the feed conversion ratio. This resulted in lower production costs, and a higher operating income (Garcia et al., 2013).

Another way of improving the efficiency of the tilapia production system is to reduce the expense of feeding, which represents the highest input cost (Garcia et al., 2013; Ayroza et al., 2014) and energy expenditure (Garcia et al., 2014). Tilapia show opportunistic omnivore feeding behaviour, with a great tendency towards herbivory (Beveridge and Baird, 2000), and have morphological adaptations that allow them to feed on phytoplankton and periphyton (Sanderson et al., 1996). Therefore, if natural food is present, the amount of commercial diet can be reduced.

Studies in ponds showed that it was beneficial to include substrates on which periphyton (a mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that attaches to submerged aquatic surfaces) could grow, as it provides a good source of quality feed for fish (Keshavanath et al., 2004; Saikia and Das, 2009). Previous studies were not able to demonstrate whether it was economically viable to include substrates for periphyton production in cages (Norberg, 1999; Huchette and Beveridge, 2003). However, recent publication of Sakr et al. (2015)

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demonstrated that for juvenile of Nile tilapia (mean weight 2–25 g), the most cost-effective feeding strategy was offer to fish a diet contained 15% crude protein that included periphyton in relation to a diet containing 25% crude protein but no periphyton.

In Brazil, we showed that the inclusion of bamboo substrates inside net-cages in hydroelectric reservoirs allows producing up to 52 kg/m³ of Nile tilapia using 32% less diet in a period almost 20% shorter than in the net-cage with no substrate (Garcia et al., 2016). Thus, the objective of the present paper is to evaluate if this production model of Nile tilapia in net-cages with substrates would enable small-scale producers to increase their income.

2. Materials and methods

The economic analysis of the inclusion of bamboo substrates in cages to produce Nile tilapia *Oreochromis niloticus* (46.56 ± 2.53 g) under three stocking densities and two feeding regimes was evaluated. To determine the best production option for small-scale farmers, the cost of production was calculated per cage and per kg fish produced, considering two possible slaughter weights: 500 g (which is possible market sizes for tilapia in Brazil) and 800 g (the currently size for tilapia sale). Farmers can use these results to scale the number of cages that they require to obtain a desired income.

To obtain this data, growth performance was evaluated when fish reached 500 g. Thus, the experiment goes on and fish were evaluated again when they reached 800 g. For fish with 500 g, the three final biomass were 25, 37 and 50 kg/m³ and for fish with 800 g of final weight, the evaluated biomass were 40, 60 and 80 kg/m³. For each stocking density two feeding schemes were evaluated: two meals a day – 100% of daily ration and one meal a day - 50% of daily ration, with three replicates per treatment. The control group (CTRL) comprised three cages without bamboo substrates, in which fish were stocked at a final density of 80 kg/m³ and fed two meals a day - 100% of daily ration, following the management used by Brazilian fish farmers. The experiment details are described in Garcia et al. (2016).

To the economic analysis, growth performance means of each treatment obtained in Garcia et al. (2016) were used. The profitability study considered only the 800-g slaughter weight, because in Brazil, 500-g fish are sold in specific markets and their price vary widely among regions.

To calculate the farming operation cost, we used the structure adopted by the Agricultural Economics Institute (IEA), based on the total operating cost (TOC) proposed by Matsunaga et al. (1976). The effective operating costs (EOC) are the labour expenses and the material consumed. The TOC includes the EOC and other expenses that are calculated as 5% of the EOC, using an interest rate of 5.5% per year on 50% of the EOC. Depreciation was calculated using the straight-line method, proportional to the area of farming in relation to the set of elements that corresponds to the fixed capital of the activity associated with the service life of each good. The economic evaluation period was related to the farming cycle, with prices in 2017 US dollar.

The study used the profitability analysis indicators proposed by Martin et al. (1998), which are defined as follows:

Gross Revenue (GR): constituted by the revenue expected in return for a given amount of production for each treatment, with a pre-defined or effectively received sales price, expressed by $GR = A_p \times U_p$, in which A_p = the production by area unit and U_p = unit price of the product (US\$).

Operating Income (OI): results from the difference between the gross income and the operating expenses. The indicator that results from this index measures the short-term profitability of the activity, considering the financial and operational conditions of the activity through the use of the expression $OI = GR - TOC$.

Profitability Index (PI): shows the relationship between the operating income and the gross revenue in percentage. It is an important

measurement of the profitability in agribusiness because it shows the available income rate after all operating costs are paid. It is expressed as $PI = (OI / GR) \times 100$.

Break-Even Point (BEP): indicates the cost related to the product unit. In other words, it determines the minimum production that is necessary to cover the cost of production given the sales price of a unit. The formula used is $BEP = TOC / U_p$.

Considering that the feed represents around 70% of the production costs, we explored the concept of risk by assuming a 25% increase in the price of feed, then verifying which treatment would be the most resilient to this condition.

Bamboo was used to manufacture the substrates for insertion because it is readily available in rural areas. We calculated the time spent harvesting the stalks, assembling the modules, and installing them on the net tanks, as well as the time spent on maintenance of the modules at the end of each farming cycle. The total number of hours required for each activity was calculated by multiplying the number of hours of each activity by the minimum number of workers that the activity demanded and by the number of days on which it is executed. We assumed that the modules would be replaced every two farming cycles, because they often suffered damage during harvesting and tended to accumulate golden mussels *Limnoperna fortunei* (an invasive bivalve of Asian origin).

3. Results

The total time spent on each fish farm labour activity varied according to the treatment (Table 1). The daily activities that required the highest amount of labour were: feeding, removal of dead fish, and fish weight sampling. For cages maintained at the same stocking density, the treatments that were fed once and twice a day required a similar amount of total labour (Table 1), because the fish that were fed once a day needed more time to reach slaughter weight.

Considering that 500-g whole fish are sold in specific markets with different sale prices, we decided do not include them in the profitability analysis and limited the evaluation of this product to the production costs (Table 2 and Fig. 1). However, it is important to determine the production costs of these fish because rearing them only to this weight allows a higher number of farming cycles per year, which provides the possibility of increasing the profitability index.

The mean daily weight gain of the fish reared to 500 g was 2.95 ± 0.67 g/fish/day and fish reared to 800 g, 3.29 ± 0.49 g/fish/day. Although the production costs per cage were lower for the 500 g fish than the 800 g fish, the production costs per kilogram of fish were higher (Table 2), due to the higher investment in fixed capital and because the costs were insufficiently offset by the higher fish weight.

Considering production up to a weight of 500 g, the highest stocking density treatment that provided 100% of daily ration plus substrates provided the best outcome, with a higher mean daily weight gain, lower feed conversion ratio, lower production cost per kg of fish produced, and higher number of farming cycles per year. When fish reached 800 g, the performance and economical results of this treatment were inferior to those of other treatments with higher stocking density, indicating that there was a limit on the cage's support capacity (Garcia et al., 2016) (Table 2).

At the end of the experiment, the cages with the highest stocking density produced higher gross revenue than the cages with lower densities. However, the intensification of production increased the production cost, raising the break-even point. The stocking density of 40 kg/m³ was less viable economically, as it was associated with lower productivity, operating income, and profitability index (Table 2).

The treatments that provided greater advantage for fish reared to a slaughter weight of 800 g, producing a higher operating income and higher profitability index, were those with substrate at the highest stocking density fed 50% of daily ration followed by density of 60 kg/

Table 1

Labour (total hours spent by cage) for each activity to rear Nile tilapia in cages in a hydroelectric reservoir with or without the use of substrates with or without feed restrictions in three different stocking densities.

	Hours per cage							Fish weight
	With bamboo substrates for periphyton						No bamboo substrates	
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	25 kg/m ³		37 kg/m ³		50 kg/m ³			
Manufacture of substrates	2.0	1.3	2.0	1.3	2.0	1.3	–	500 g
Installation of substrates inside the cages	2.7	2.7	2.7	2.7	2.7	3.6	–	
Initial stocking of fish	2.3	2.3	2.9	2.9	3.4	3.4	3.4	
Feeding and removal of dead fish	4.5	5.8	4.5	6.0	4.5	6.0	8.6	
Fish weighting for feed adjustment	4.8	3.1	4.8	3.2	4.8	3.2	4.6	
Harvest of fish	2.3	2.3	3.4	3.4	4.6	4.6	4.6	
Cleaning and conservation of cages and substrates	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
Total	19.7	18.5	21.4	20.5	23.1	23.1	22.3	

	Hours per cage							Fish weight
	With bamboo substrates for periphyton						No bamboo substrates	
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	40 kg/m ³		60 kg/m ³		80 kg/m ³			
Manufacture of substrates	2.6	1.9	2.7	2.0	2.5	2.2	–	800 g
Installation of substrates inside the cages	2.7	2.7	2.7	2.7	2.7	3.6	–	
Initial stocking of fish	2.3	2.3	2.9	2.9	3.4	3.4	3.4	
Feeding and removal of dead fish	6.0	8.7	6.2	9.0	5.8	10.3	9.7	
Fish weighting for feed adjustment	6.4	4.6	6.6	4.8	6.2	5.5	5.2	
Harvest of fish	2.3	2.3	3.4	3.4	4.6	4.6	4.6	
Cleaning and conservation of cages and substrates	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
Total	23.4	23.6	25.5	25.9	26.4	30.8	24.0	

Table 2

Productive performance, cost of production and profitability indicators of Nile tilapia production in cages system in hydroelectric reservoir with or without the use of substrates with or without feed restriction in three different stocking densities.

	With bamboo substrates for periphyton						No bamboo substrates	Fish weight
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	25 kg/m ³		37 kg/m ³		50 kg/m ³			
	Total production per cage (kg)	150.00	150.00	222.00	222.00	300.00	300.00	
Daily weight gain (g/fish/day)	2.39	3.74	2.39 ± 0.02	3.64	2.40 ± 0.01	3.61	2.50	
Feed conversion ratio	1.09	1.05	1.07 ± 0.07	1.22	1.27 ± 0.00	1.08	1.60	
Total operating cost (US\$/cage)	228.00	211.50	295.26	295.26	390.00	348.00	411.00	
Total operating cost (US\$/kg)	1.52	1.41	1.33	1.33	1.30	1.16	1.37	
Farming cycle per year (days)	1.92	3.02	1.92	2.92	1.92	2.92	2.03	

	With bamboo substrates for periphyton						No bamboo substrates	Fish weight
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	40 kg/m ³		60 kg/m ³		80 kg/m ³			
	Total production per cage (kg)	214.54	209.45	323.03	343.87	417.84	372.38	
Daily weight gain (g/fish/day)	3.07	3.91	2.68	3.53	2.66	3.62	3.56	
Feed conversion ratio	1.06	1.59	1.22	1.61	1.29	1.79	1.84	
Gross revenue (US\$/cage)	330.06	322.23	496.97	529.03	642.83	572.90	633.53	
Total operating cost (US\$/cage)	279.98	306.76	373.06	418.76	444.70	537.53	528.95	
Total operating cost (US\$/kg)	1.31	1.46	1.15	1.22	1.06	1.44	1.28	
Operating income (US\$/cage)	50.08	15.47	123.91	110.27	198.13	35.37	104.58	
Profitability index (%)	15.17	4.80	24.93	20.84	30.82	6.17	16.51	
Break-even point (kg)	181.81	199.19	242.25	271.92	288.77	349.05	343.47	
Farming cycle per year (days)	1.45	2.01	1.41	1.93	1.49	1.68	1.80	
Operating income (US\$/year)	72.53	31.02	174.62	212.96	295.17	59.49	188.03	

Sale price of fish (800 g) = US\$1.54/kg.
 US\$1.00 = R\$3.25 (May 2017).

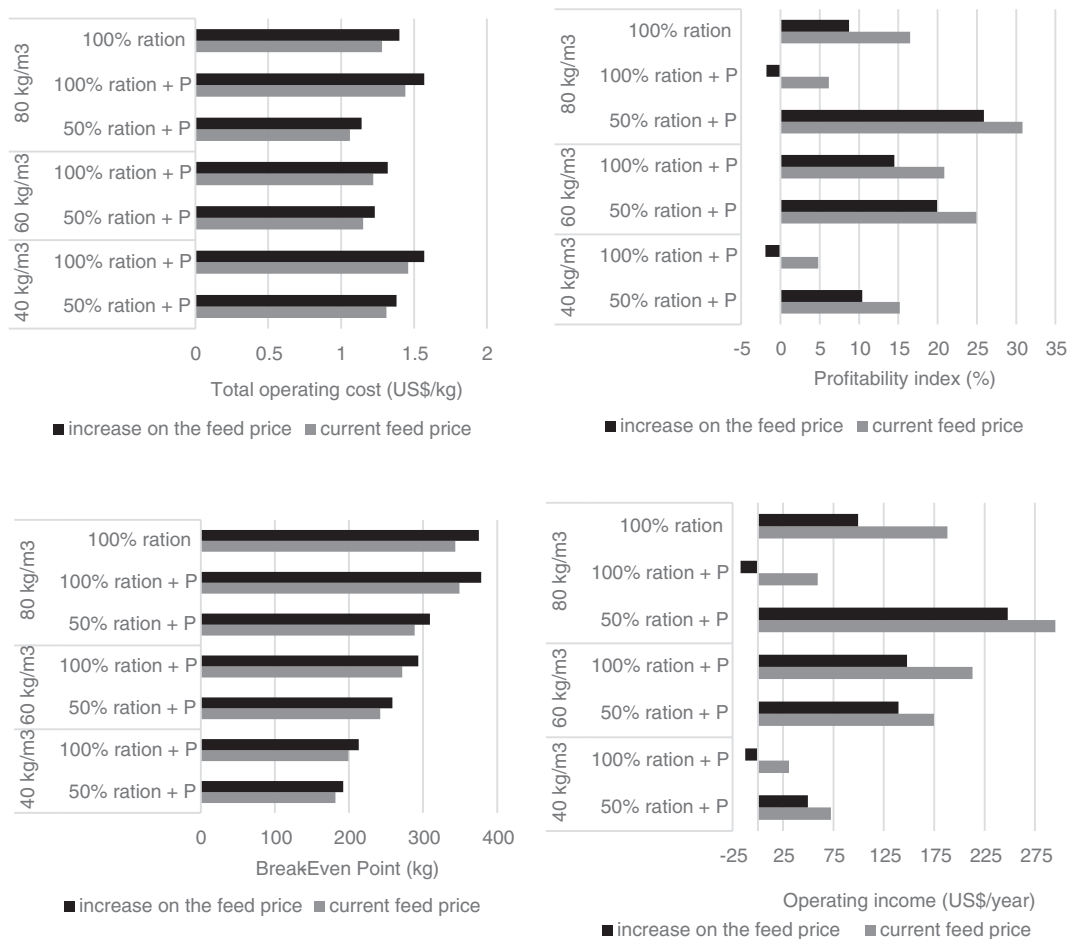


Fig. 1. Economic Indicators (Total operating cost, Profitability index, Break-even point and Operating income) of Nile tilapia in cages in a hydroelectric reservoir, with or without the use of substrates, with or without feed restrictions, in three different stocking densities. Abbreviation P in the legend corresponds to periphyton.

m3 fed 100% and 50% of daily ration, respectively (Table 2).

In the CTRL commercial diet supplies represented approximately 70% of the production costs for both slaughter weights (500 and 800 g). Including substrate reduced the percentage of feed supply on the production cost, and reducing the stocking density there was a lower participation of this item in relation to the labour cost. Feeding the fish two daily meals 100% of ration caused the cost of supplies to be the highest proportion of the total costs, compared with fish fed once a day with 50% of daily ration (Table 3).

The simulated 25% increase in feed costs highlighted the importance of reducing feed costs, which already represented approximately 70% of the total production cost. The treatments with substrate improved the resilience of the system. The group with higher operating income, higher profitability index and that was most cost-effective under the simulated scenario was the same classified in the real situation: with substrate at the highest stocking density fed 50% of daily ration followed by density of 60 kg/m3 fed 100% and 50% of daily ration. Meanwhile, most of the treatments that received 100% of daily ration under this scenario of increased feed costs were not profitable (Table 4).

4. Discussion

This study explored the cost-effectiveness of the production of Nile tilapia in net-cages in hydroelectric reservoirs using substrates to promote the production of periphyton that supplement the fish diet. This production model may be appealing to small-scale producers because it was more efficient and profitable than traditional tilapia farming in cages, allowing the farmers to obtain income using small production

modules and family labour.

Inserting bamboo substrates in the cages to promote periphyton growth increased the weight gain of the fish, shortened the farming cycle, and reduced the feed conversion ratio up to 52 kg/m3 (Garcia et al., 2016), allowing Nile tilapia to be produced with less use of commercial extruded feed and, therefore, lower production cost.

The feed conversion ratio of the fish that received 50% of daily ration was lower than that of the fish that fed 100% of daily ration, particularly for the last phase of cultivation (fish with 800 g). Even though the fish whose feed was restricted needed, on average, 30% more time to reach slaughter weight, they were associated with profitability increases of 3.16 (at a stocking density of 40 kg/m³), 1.2 (stocking density 60 kg/m³), and 5 times (stocking density 80 kg/m³) that of the group that received 100% of daily ration. This result is due to the fact that in this production system, the commercial diet composes 70% of the production cost (Table 3) (Ayroza et al., 2014). The higher proportion of production costs associated with feed is typical of intensive tilapia production systems (Piumsombun et al., 2005; Ofori et al., 2010), and the dependence on extruded feed shows the degree to which the competitiveness of fish farmers is affected by changes in the feed price and by the quality of feed offered.

The simulation of a 25% increase in the feed price demonstrated the higher resilience of productive models that do not rely as heavily on feed (with substrate and fed 50% of daily ration). The insertion of substrate in the cages is a valuable option for small-scale fish farmers that allows them to reduce their dependency on commercial feed.

In the control treatment, feed supplies represented around 70% of the production cost for both sizes evaluated (500 g and 800 g). The inclusion of substrate reduced the proportion of the production cost

Table 3

Contribution of each item to total costs as a percentage from the operating cost of cages of Nile tilapia production in hydroelectric reservoir with or without the use of substrates with or without feed restriction in three different stocking densities.

	With bamboo substrates for periphyton						No bamboo substrates	Fish weight
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	25 kg/m ³		37 kg/m ³		50 kg/m ³			
Labour	42.84	41.48	36.77	34.03	30.97	31.63	24.49	500 g
Inputs	45.43	48.86	52.96	57.60	60.10	60.56	67.01	
Maintenance	4.35	4.52	4.49	4.58	4.55	4.61	4.58	
Depreciation	7.38	5.14	5.78	3.79	4.38	3.20	3.92	

	With bamboo substrates for periphyton						No bamboo substrates	Fish weight
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	40 kg/m ³		60 kg/m ³		80 kg/m ³			
Labour	39.28	34.06	33.13	28.30	29.79	25.31	20.00	800 g
Inputs	48.28	56.13	56.19	63.09	60.75	66.47	71.96	
Maintenance	4.38	4.51	4.47	4.57	4.53	4.59	4.60	
Depreciation	8.06	5.30	6.21	4.04	4.93	3.63	3.44	

devoted to feed for all the treatments. Lower stocking densities as well as feed restriction (50% of the daily recommended feed) were associated with lower feed cost in relation to the labour costs. Considering that the model is designed for use by small-scale producers, it is important to consider that offering one meal per day (containing 50% of daily ration) has many benefits. In addition to reducing the production costs, increasing profitability and reducing dependence on external supplies, it allow farmers to be available during the day to perform different agricultural activities that diversify their production. On family-owned properties, fish farming generally represents only one of

several activities performed by the owners. This diversification builds in resilience to a family's economic prospects, particularly if climatic events or market conditions that impact one activity do not affect each other (Setboonsarng and Edwards, 1998). Integrating cage farm into other daily and seasonal tasks is important, especially for small producers. The time needed to manage the aquaculture activities should not represent an obstacle or prevent other daily management tasks from being carried out on a rural property (Lebel et al., 2009).

A recent study of a fish farmers group of Nile tilapia in net-cage in hydroelectric reservoirs in the State of São Paulo, Brazil, demonstrated

Table 4

Simulation of a 25% increase on the feed price. Productive performance, production cost and profitability indicators of the production of Nile tilapia in cages in hydroelectric reservoir with or without the use of substrates with or without feed restriction in three different stocking densities.

	With bamboo substrates for periphyton						No bamboo substrates	Fish weight
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	25 kg/m ³		37 kg/m ³		50 kg/m ³			
Total production per cage (kg)	150.00	150.00	222.00	222.00	300.00	300.00	300.00	500 g
Daily weight gain (g/fish/day)	2.39	3.74	2.39	3.64	2.40	3.61	2.50	
Feed conversion ratio	1.09	1.05	1.07	1.22	1.27	1.08	1.60	
Total operating cost (US\$/cage)	238.50	222.00	310.80	315.24	414.00	372.00	444.00	
Total operating cost (US\$/kg)	1.59	1.48	1.40	1.42	1.38	1.24	1.48	
Productive cycle (days)	1.92	3.02	1.92	2.92	1.92	2.92	2.03	

	With bamboo substrates for periphyton						No bamboo substrates	Fish weight
	50% ration	100% ration	50% ration	100% ration	50% ration	100% ration	100% ration	
	40 kg/m ³		60 kg/m ³		80 kg/m ³			
Total production per cage (kg)	214.54	209.45	323.03	343.87	417.84	372.38	411.79	800 g
Daily weight gain (g/fish/day)	3.07	3.91	2.68	3.53	2.66	3.62	3.56	
Feed conversion ratio	1.06	1.59	1.22	1.61	1.29	1.79	1.84	
Gross revenue (US\$/cage)	330.06	322.23	496.97	529.03	642.83	572.90	633.53	
Total operating cost (US\$/cage)	295.74	328.40	397.96	452.32	476.42	583.07	578.22	
Total operating cost (US\$/kg)	1.38	1.57	1.23	1.32	1.14	1.57	1.40	
Operating income (US\$/cage)	34.32	- 6.17	99.01	76.71	166.41	- 10.17	55.31	
Profitability index (%)	10.40	- 1.92	19.92	14.50	25.89	- 1.78	8.73	
Break-even point (kg)	192.04	213.25	258.42	293.71	309.36	378.62	375.47	
Productive cycle (days)	1.45	2.01	1.41	1.93	1.49	1.68	1.80	
Operating income (US\$/year)	49.70	- 12.38	139.53	148.15	247.92	- 17.11	99.44	

Sale price of fish (800 g) = US\$1.54/kg. US\$1.00 = R\$3.25 (May 2017).

that the most efficient farmers produce more with a smaller amount of feed during each farming cycle, considering the cost of initial investments and production costs (Sabbag and Costa, 2015). The present study demonstrated that the most efficient production model in relation to the control (production system adopted by Brazilian farmers) for 800 g Nile tilapia were the treatments that included a substrate. Using the highest stocking density and feed restriction of 50%, the annual operating income was 57% higher than the CTRL and the profitability index was 87% higher than the CTRL. The next most efficient approach used a stocking density of 60 kg/m³ with inclusion of substrates (either with or without feed restriction). At this stocking density, the treatment in which fish were fed 100% of daily ration presented annual operating income 13% higher than the CTRL and the profitability index 26% higher than the CTRL. With feed restriction of 50%, the annual operating income was 7% higher than the CTRL and the profitability index was 51% higher than the CTRL.

These production models required a smaller total operating expense and resulted in increased profitability index. To select the best treatment, is important to consider that using a lower stocking density reduces the mortality risk due to diseases, poor-quality water inside the cages and reduces the environmental loading ratio and increases the system renewability, this is the proportion of renewable resources of the total inputs (Garcia et al., 2014; Garcia et al., 2013), making it safer and more sustainable. In the same way, feed restriction should be encouraged to reduce dependence of external resource, to reduce the nutrient input in the system and to allow workers to be available to perform different activities that diversify their production.

Chaibu et al. (2004) observed that the profitability index of hybrid red tilapia is highly sensitive to feed costs, market prices, income, and survival rates. Similarly, the stocking density affects the survival rate and feed conversion, which directly affects the profitability. Thus, large aquaculture businesses with intensive systems obtain higher incomes than small fish farmers, but the profitability of the small-scale fish farmers is higher when they use a less intensive system (Lebel et al., 2013).

It is important to consider that for market niches for 500 g-tilapia, this production may become viable because allows a higher number of cycles per year. Producing up to a weight of 500 g, the higher stocking density fed 100% of daily ration with substrates provided the best outcome, with a higher mean daily weight gain, lower feed conversion ratio, production cost per kg of fish produced 15% lower than the CTRL and three farming cycles per year. When fish reached 800 g, the performance and economical results of this treatment were inferior to the CTRL group, indicating that there was a limit on the net cage's support capacity (Garcia et al., 2016).

The economic analysis for the present study used the average sales price paid by fish processing units, the most common buyers of Nile tilapia produced in net cages. However, in Brazil, smaller producers prefer to send their final product to specific markets that pay superior values over those paid by major processing units. Such sales may take place directly at big fairs like CEAGESP (São Paulo General Warehousing and Centers Company), fee fishing facilities and fish markets. Thus, the results we present reflect the worst-case market situation, and higher revenues are possible depending on the destination of the fish produced.

Considering the productivity of periphyton in substrates is regulated by resource availability (Azim et al., 2005) we encourage studies to evaluate productivity of periphyton in Brazilian reservoirs (Siqueira and Rodrigues, 2009). Moreover, we recommend studies to assess the effect of the net cage farming on periphyton productivity, since Mallasen et al. (2012) recorded high influence of the cage culture in the ecosystem over time with higher levels of nitrate and suspended material near net cages in the same reservoir of the present experiment (Nova Avanhandava, Tietê river).

5. Conclusions

The present study demonstrates the economical profitability of the insertion of bamboo substrates into net-cages for production of Nile tilapia. This production model offers a way for small-scale producers to increase the efficiency of the system with annual operating income up to 57% higher and the profitability index up to 87% higher than the usual system adopted by Brazilian farmers. It also enables them to devote more time to diversifying their economic activities and gives them access to the fish produced for consumption.

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