

# SCALE EFFICIENCY IN TAMBAQUI FARMING IN EARTH PONDS IN THE METROPOLITAN REGION OF MANAUS-AM

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## ABSTRACT

This study aimed at determining the scale efficiency in tambaqui production in earth ponds developed in the metropolitan region of Manaus-AM. Eleven fish farms were analyzed and their data were sampled regarding its characteristics, productive data, disbursement, infrastructure value and production value, in order to calculate the total operational cost and profitability indexes. For the DEA (Data Envelopment Analysis) was applied the VRS/BCC (variable return of scale) model with *input* orientation, using three *inputs* (total operational cost, feed value, and depreciation, all in BRL(\$)) per kilo) and one *output* (annual gross revenue, in BRL(\$)) per hectare). The study showed that 80% of the fish farms (DMUs) (decision-making units) had increasing returns to scale, with scale efficiencies lower than 65%, affected by lack of profitability, low technical and marketing knowledge, high production cost (R\$ 4.50 kg<sup>-1</sup>) and low average sales price (lower than R\$ 5.00 kg<sup>-1</sup>).

**Keywords:** *Colossoma macropomum*; data envelopment analysis; production cost; decision making; fish farming.

## EFICIÊNCIA DE ESCALA NA PRODUÇÃO DE TAMBAQUI EM VIVEIROS ESCAVADOS NA REGIÃO METROPOLITANA DE MANAUS-AM

## RESUMO

Este estudo teve por objetivo determinar a eficiência de escala da produção de tambaqui em viveiros escavados desenvolvida na região metropolitana de Manaus-AM. Foram coletados dados de 11 pisciculturas para obtenção de suas características, dados produtivos, desembolsos, valores da infraestrutura e produção, que foram utilizados para calcular os custos operacionais totais e índices de rentabilidade. Para a DEA (Análise Envoltória de Dados) utilizou-se o modelo VRS/BCC (retorno variável de escala) com orientação a *inputs*, utilizando três *inputs* (Custo operacional total, ração e depreciação; todos em reais por quilo) e um *output* (receita bruta anual, em reais por hectare). Houve retorno crescente de escala em mais de 80% das pisciculturas (DMUs - Unidades Tomadora de decisão), com eficiências de escala inferiores a 65%, sendo afetadas pela falta de rentabilidade e baixa eficiência, relacionadas com a falta de infraestrutura adequada, baixos conhecimentos técnico e mercadológico a respeito da atividade, elevado custo de produção (maior que R\$ 4,50 kg<sup>-1</sup>) e baixo preço médio de venda (menor que R\$ 5,00 kg<sup>-1</sup>).

**Palavras chave:** *Colossoma macropomum*, análise envoltória de dados; custo de produção; tomada de decisão; piscicultura.

## INTRODUCTION

Tambaqui (*Colossoma macropomum*) is the most produced native species in Brazil (IBGE, 2014) and its farming is done mainly in earth ponds, due to the high plankton production found in these systems (Costa, 2013). However, the profitability of this production presents great variability owing to the technical and marketing characteristics inherent to the activity (Gomes et al., 2006; Costa et al., 2016; Pedroza Filho et al., 2016). The lack of profitability is caused by the low sale price and the high costs (Gandra, 2010; Pedroza Filho et al., 2016).

The producer is a price taker; therefore, it is up to him to make the right combination of production factors to reduce costs, that is, to be efficient (Sabbag and Costa, 2015). One of the ways to reduce costs is to increase the productive scale aiming to optimize

the use of production factors so that costs are diluted; in this sense, the largest companies present greater scale efficiencies (Gomes et al., 2005). However, in aquaculture, the relationship between efficiency and size of the property is extremely complex and it does not always follow the logic that larger units are more efficient (Yin et al., 2014).

In this context, efficiency is defined as the best possible combination of *inputs* to generate the maximum *output*, in other words, the ratio between the production observed and the maximum possible production (Banker, 1984; Coelli, 1996; Gomes et al., 2005). The Data Envelopment Analysis (DEA) is a tool that has been used successfully to determine the efficiency of productive units, allowing to generate a single indicator (efficiency measure), which facilitates the decision-making process regarding the performance of *decision-making units* analyzed (DMUs) (Charnes et al., 1979; Banker, 1984; Gomes et al., 2005; Alam et al., 2012; Benicio et al., 2015; Sabbag and Costa, 2015). The determination of efficiency through the DEA allows managers to compare productive units among themselves, to evaluate the allocation of available resources for production and to determine the possible production to be reached (Gomes et al., 2005). It also seeks to identify the ideal technology that presents the greatest rationalization in the use of production factors and an increase of returns (Charnes et al., 1979; Coelli, 1996). Thus, this work aimed to determine the scale efficiency in the tambaqui farming in earth ponds, using the DEA tool.

## MATERIAL AND METHODS

Eleven fish farms were selected which represented the production systems in earth ponds in the metropolitan region of Manaus, considered the region of highest fish consumption per capita in Brazil (Gandra, 2010). The selected fish farms produce tambaqui roelo (>0.900 kg) and/or curumim (450 to 700 g); using several marketing channels and having several production scales based on Resolution CEMAAM/N° 01/08 – of July 03 2008 (Amazonas, 2008), which established the following categories: micro - ME (<2 hectares of water, one fish farm), small - EPP (2 to 10 hectares of water, six fish farms), medium - EMP (10 to 50 hectares of water, four fish farms).

A semi-structured questionnaire was applied to the producers, in which were identified the creation phases, production cycles, management adopted, the infrastructure used, the production data, disbursement and production value. With the results, it was possible to characterize the production systems as to the infrastructure used, the handling, the environmental monitoring and the enterprise management.

The microenterprise (MP; n = 1) was represented by a family farmer who also owns vegetable and fruit crops and poultry farms. The fish farm of this property is characterized by earth ponds smaller to 2,000 m<sup>2</sup>, without water supply and drainage systems, where the supply is made through pipelines with a semi-artesian well only for the replacement of the lost water. In these earthen ponds are produced *Arapaima gigas*, *Brycon amazonicus*,

*Piaractus mesopotamicus* and *C. macropomum* roelo without the use of aeration.

Small-scale fish farms (EPP; n = 6) were characterized by family farmers who have fish farming as the main income source of the property. These have an average of 2.76 hectares (ha) for tambaqui production, wherein 50% of the cases (P1, P5, and P6) was observed the use of aerators. The exclusive production of curumim occurred only in fish farming P1; 33.3% of the DMU's (P2 and P4) produce only roelo and 50% (P3, P4, and P6) have a concomitant production, generating curumim and roelo. In all properties, the supply of earth ponds is done by pumping with the aim of restoring lost water (P1, P3, P4, and P5) or total renovation at the end of the production cycle (P2 and P6). The water used in this process comes from large dams (P2, P4, P5, and P6), rivers (P3) or own springs (P1).

The four medium-sized enterprises (EMP; n = 4) have an average of 10.75 hectares destined to tambaqui production, all of which use aeration and have their own supply and drainage system. These enterprises are made up of commercial producers, who have in fish farming the sole source of income for the property. Among them: M3 and M4 produce only tambaqui roelo; the M1 produces only tambaqui curumim and M2 performs a concomitant production.

The production cost and the gross revenue were calculated with the data of zootechnical performance and the respective prices of the factors and products. The costs were determined based on the Total Operating Cost (TOC) structure, adding the Effective Operating Cost (EOC) with the other costs that do not represent effective monetary disbursement (depreciation and value for family labor). The EOC was obtained by adding the expenses with fingerlings, feed, labor, maintenance of fixed capital, energy, fuel, liming, fertilization and operating license. The depreciation of the infrastructure, equipment, and utensils was calculated by the linear method (Matsunaga et al., 1976).

The following indicators were used: Average Total Operating Cost - TOC (R\$ kg<sup>-1</sup>), feed cost, depreciation cost, and gross revenue - GR (R\$ ha<sup>-1</sup> year<sup>-1</sup>). The proportion of each type of fish destined for each marketing channel was considered to determine gross revenue. All values used in this work refer to January 2015, with 1US\$ = R\$ 2,638.

The 11 fish farms (DMUs) are tambaqui producers in the system of earth ponds and are in the same region of production; therefore, they are considered homogeneous and satisfied one of the presuppositions of the model. These fish farms have varied products, three produce only tambaqui curumim four of them produce only the tambaqui roelo and the other four produce both tambaqui curumim and roelo. To perform the DEA, the sample number obeyed the assumption of it should be at least twice as large as the sum between the inputs X and the outputs Y, that is, 2(X+Y) (Ali and Seiford, 1993).

The Variable Returns to Scale (VRS) model was used to determine the efficiency of fish farms (Banker, 1984). This model assumes the condition of convexity, where the unobserved production plans result from convex combinations of the observed ones and are not restricted to passing through the origin, thus admitting variable returns of scale (Banker, 1984; Gomes et al., 2005).

As the DMUs of the present work have different scales, this is the most indicated model. The efficiency of each DMU ( $h_0$ ) that uses  $n$  inputs to produce  $s$  outputs is then determined by the following envelope model:

$$h_0(x^j, y^j) = \text{Min } h_0$$

$$\text{s.a. } h_0 x_{io} \sum_{k=1}^n x_{ik} \lambda_k \geq 0, \forall i$$

$$-y_{jo} \sum_{k=1}^n y_{jk} \lambda_k \geq 0, \forall j$$

$$\sum_{k=1}^n \lambda_k = 1$$

$$\lambda_k \geq 0, \forall k$$

Where:  $h_0$  is the efficiency of the DMU;  $x_{io}$  is the DMU's inputs under analysis;  $y_{jo}$  are the DMU's outputs under analysis;  $\lambda_k$  is the contribution of DMU  $k$  in target formation of the DMU<sub>0</sub>.

Subject to resolution of the multiplier problems by the following model:

$$\text{Max } h_0 = \sum_{j=1}^s u_j y_{j0} - u_*$$

$$\text{s.a. } \sum_{i=1}^m v_i x_{ik} = 1$$

$$-\sum_{i=1}^m v_i x_{ik} + \sum_{j=1}^s u_j y_{jk} - u_* \leq 0, \forall k$$

$$u_j, v_i \geq 0; \forall j, i$$

$$u_* \in \mathbb{R}$$

Where:  $h_0$  is the efficiency of the DMU;  $x_{io}$  is the DMU's inputs under analysis;  $y_{jo}$  are the DMU's outputs under analysis;  $v_i$  are the weights calculated by the model for the inputs;  $u_j$  are the weights calculated by the model for the outputs;  $u_*$  is a dual variable that represents the scale factor, associated with the condition  $\sum_{k=1}^n \lambda_k = 1$ .

The value of  $u_*$  denominated as scale factor shows the behavior of the DMUs according to the scale of production and can present three situations:

- $u_* > 0$  indicates that the DMU is operating with decreasing returns to scale (DRS), where the increase in inputs will cause a less than proportional increase in outputs;
- $u_* < 0$  indicates that the DMU is operating with increasing returns to scale (IRS), where the increase in inputs will cause a more than proportional increase in outputs;
- $u_* = 0$  indicates that the DMU is operating with constant return to scale, where the increase in inputs will cause an increase in equal magnitude in the outputs;

Scale efficiency is obtained by the ratio between the efficiency of the constant return scale (CRS/CCR) and Variable return scale (VRS/BCC) models (Charnes et al., 1979; Banker, 1984). Being that, the existence of a difference between the efficiency of the two models is an indication of scale inefficiency. In this way, the efficiency of a DMU varies from 0 to 1 and the higher the value obtained, the more efficient the DMU.

In fish farming, producers seek alternatives to rationalize the factors used in production, therefore, the input orientation is considered as the most appropriate way for this analysis. To determine efficiency was used the program DEAP 2.1 (Coelli, 1996), considering the input direction, seeking to show the rationalization of costs but without altering the revenue of the enterprise. Three inputs were used (Mean Total Operating Cost [R\$ kg<sup>-1</sup>] - X1, Feed [R\$ kg<sup>-1</sup>] - X2, Depreciation [R\$ kg<sup>-1</sup>] - X3); and an output (Annual Gross Revenue [R\$ ha<sup>-1</sup>] - Y). By the model used was also verified what should be the reduction in costs (inputs) in order to the enterprise becomes efficient, keeping the same revenue through the model VRS (variable return to scale). The efficiency values of each fish farming were obtained for the VRS and CRS models, as well as the scale efficiency, given by the ratio between the efficiency of both models.

Scale inefficiencies - for values less than one - will occur when fish farmers operate in the bands of increasing or decreasing returns, that is, outside of the correct production scale.

It is important to highlight that the VRS model must be evaluated concomitantly with the CRS (constant returns to scale) model. The last obtained by the linear relation between inputs and outputs so that an increase or decrease of input results in a proportional increase or decrease of outputs.

## RESULTS AND DISCUSSION

Initially, the production and commercialization of tambaqui were observed in two size patterns: curumim and roelo (Table 1). In four fish farms, the production of curumim and roelo is carried out concomitantly, that is, the animals start with 0.5 g and after a mean cycle of  $218 \pm 57$  days, two-thirds of the animals are ready for sale in the curumim standard. The remainder (one-third) of the animals are kept in the earth ponds and fattened for another 180 days, to reach a roelo pattern.

**Table 1.** Mean productive indicators of tambaqui curumim and roelo, farming in earthen ponds in the metropolitan region of Manaus, in January 2015.

Indicator	Curumim (450 a 700g)	Roelo (>0.9 kg)
Average density (fish ha <sup>-1</sup> )	10,200	4800
Final average weight (g)	557.14	2,090.00
Total production cycle (days)	218.57	348.38
Apparent feed conversion	2.32	2.03
Productivity (g m <sup>-2</sup> year)	757	668

Concurrent production practice is an attempt by fish farmers to reduce costs and increase profitability through infrastructure optimization, since some fixed disbursements are diluted when production is increased (Benicio et al., 2015), as well as to supply the market of the industrial center of Manaus which was previously served by fishing. However, with the reduction of fish stocks and the supply of small fish, the demand was met by tambaqui curumim (Gandra, 2010).

That the production of tambaqui curumim is concomitant or individual, was an aspect that directly influenced the profitability and efficiency of the DMUs, since its production was viable only in a medium-sized company (M1), which has a staggered production, used a quality feed and aerators efficiently. The companies that presented losses are characterized by using low quality or inadequate feed for species which increase the AFC (apparent feed conversion), enhancing production costs. This lack of economic viability found in the fish farms classified as ME and EPP (Table 2) is a worrying factor that can de-structure the tambaqui market in the state of Amazonas, already verified by Lima et al. (2015), who after assessing 413 properties, they observed that the production of tambaqui in this State is mainly carried out on family farms with less than 5 hectares of water. Therefore, if no measures are taken regarding production in the state, the productive chain of that species may be compromised and collapse.

The lack of management tools and the generation of several products observed mainly in micro and small properties do management difficult as a whole since the producer must have a greater range of technical and marketing information to become his property profitable and efficient (Iliyasu et al., 2014). However, the diversification of production is a way for the producer to minimize the risk of the activity because its income does not depend on a single product (Gomes et al., 2005). Even with technical assistance and search for knowledge in lectures and participation in associations, it was observed that the management

of these properties is precarious, being one of the factors of the low efficiency found (Table 3).

The lack of supply and drainage systems observed, may be directly affecting the quality of the water and, consequently, the production and profitability of the activity. The fact that tambaqui is a plankton filtering fish throughout its life (Araujo-Lima and Goulding, 1997) indicates that its creation must be developed in a highly eutrophic system (Cavero et al., 2009). Based on this information, some farmers, at the time of construction of the earth ponds did not invest in a drainage system, because as the years go by the system becomes more eutrophic and decreases the need for disbursements with fertilization. In the literature, we can find reports about the production of species that feed on plankton in which the eutrophication of earth pond has led to a greater technical efficiency of fish farms (Kareem et al., 2009; Iliyasu et al., 2014). Nevertheless, the accumulation of waste from previous cycles creates an environment conducive to the emergence of sanitary problems, which will invariably jeopardize production as a whole (Asche and Roll, 2013; Iliyasu et al., 2014). This fact is worrying, considering that the sanitary management adopted by the most of fish farmers was restricted to the sanitary emptiness (in 54.55% of the fish farms), and being done the exposition of dry earth ponds for a short period (less than seven days) to the sun rays; and the application of lime (in 45.45% of fish farms) for disinfection. Even so, the presence of sanitary barriers or biosecurity practices was not observed, which increases the risk of disease involvement for the activity. Also, the producers reported an increase in the incidence of parasites, mainly *Acantocephalus*.

The producers received technical assistance and knowledge about the activity, but this knowledge did not generate an adequate combination of the factors of production which resulted in high production costs, lower profitability and low efficiency, especially in micro and small farms (Table 2 and 3). This fact is contrary to studies by Iliyasu and Mohamed (2015) and Iliyasu et al. (2014),

**Table 2.** Production and economic indicators of tambaqui production in earthen ponds in the metropolitan region of Manaus AM, in January 2015, 1US \$ = R\$ 2,638.

Fish Farm (DMU's)	Fish farming area (ha)	Tambaqui Area (ha)	Annual production (t year <sup>-1</sup> )	Average Selling Price (R\$ kg <sup>-1</sup> )	Average Operating Cost (R\$ kg <sup>-1</sup> )	Feed (R\$ kg <sup>-1</sup> )	Depreciation (R\$ kg <sup>-1</sup> )	Gross Revenue (R\$ ha <sup>-1</sup> year)	Operating Profit (R\$ year <sup>-1</sup> )
Micro	1.73	0.71	2.25	4	6.03	3.34	0.74	26,718.75	-4,571.32
P1	2.28	2.28	15.75	3.8	5.25	2.68	0.76	26,250.00	-22,794.45
P2	2.82	2.16	8.4	8.5	5.9	3.07	0.96	28,888.89	12,848.32
P3	2.1	2.1	15.18	4.12	7.01	5.02	0.43	29,760.00	-44,719.21
P4	4.5	4.5	33.98	5.56	5.03	3.65	0.33	40,800.00	12,843.89
P5	8.1	2	16	5	5.6	4.11	0.28	40,000.00	-9,557.17
P6	8.64	3.49	12	4.17	4.5	3.9	0.1	14,326.65	-3,994.07
Mean	4.74	2.76	16.88	5.19	5.55	3.74	0.48	30,004.26	-9,228.78
M1	16	6	280	3.8	3.66	2.88	0.33	66,500.00	38,877.63
M2	10.9	6	57.43	5.56	4.69	2.97	0.32	49,364.00	26,750.95
M3	11	11	220	6.2	5.4	3.76	0.55	124,000.00	176,427.97
M4	25	10	75	5.5	4.6	3.54	0.09	41,250.00	80,848.24
Mean	15.73	10.75	158.11	5.26	4.59	3.29	0.32	70,278.50	80,726.20

Micro: micro-fish farms, <2 hectares of water; P1 to P6: small fish farms, from 2 to 10 hectares of water; M1 to M4: medium-sized fish farms, from 10 to 50 hectares of water.



**Table 3.** Production, economic and efficiency indicators of tambaqui production in earthen ponds in the metropolitan region of Manaus-AM, in January 2015, 1US \$ = R \$ 2,638.

Variables	Fish Farm (DMU's)												
	Micro	P1	P2	P3	P4	P5	P6	Mean	M1	M2	M3	M4	Mean
Efficiency of the CCR model (CRS)	0.24	0.30	0.29	0.27	0.48	0.51	0.34	0.36	0.87	0.64	1.00	1.00	0.88
Efficiency of the BCC model (VRS)	0.82	1.00	0.88	0.61	0.83	0.78	1.00	0.85	1.00	0.98	1.00	1.00	1.00
Scale Efficiency	0.30	0.30	0.32	0.44	0.58	0.65	0.34	0.44	0.87	0.65	1.00	1.00	0.88
Scale Type	irs	irs	irs	irs	irs	irs	irs		irs	irs	crs	crs	
Output (x1000)	13.64	-	-	29.65	19.83	14.64	-	10.69	-	15.54	-	-	3.88
Benchmarking pairs	M1 P1	P1	M1 P1	M1 M4 M1	e M4 M1 M4	M1 M4	P3	-	M1	M1 M4	M3	M4	-
	<b>Target</b>												
Total Operating Cost (R\$ kg <sup>-1</sup> )	4.69	5.25	5.15	3.92	3.88	4.10	4.50	4.47	3.66	3.72	5.40	4.60	4.35
Feed (R\$ kg <sup>-1</sup> )	2.75	2.68	2.69	3.07	3.03	3.19	3.90	3.09	2.88	2.92	3.76	3.54	3.28
Depreciation (R\$ kg <sup>-1</sup> )	0.61	0.76	0.73	0.26	0.27	0.22	0.10	0.39	0.33	0.32	0.55	0.09	0.32
Gross Revenue (R\$ ha <sup>-1</sup> year x1000)	40.36	26.25	28.89	59.41	60.63	54.64	14.33	66.50	64.90	124.00	41.25	40.36	26.25
	<b>Variation (%)</b>												
Average Total Operating Cost	-22.17	-	-12.78	-44.02	-22.90	-26.77	-	-17.75	-	-20.68	-	-	-5.17
Feed	-17.66	-	-12.28	-38.94	-16.90	-22.38	-	-15.09	-	-1.62	-	-	-0.40
Depreciation	-17.70	-	-23.75	-38.84	-16.97	-22.50	-	-17.01	-	-1.56	-	-	-0.39
Gross Revenue	51.04	-	0.00	99.62	48.61	36.61	-	30.81	-	31.48	-	-	7.87

irs: increasing returns to scale; crs: constant return to scale; Micro: micro-fish farms, <2 hectares of water ; P1 to P6: small fish farms, from 2 to 10 hectares of water; M1 to M4: medium-sized fish farms, from 10 to 50 hectares of water; CCR (CRS): efficiency model by Charnes, Cooper and Rhodes (Constant Return Scale); BCC (VRS): efficiency model by Banker, Charnes and Cooper (Variable Return Scale).

which showed a positive correlation between the level of information that producers have about the activity and the technical efficiency of these DMU's. However, Cinemre et al. (2006) and Iliyasu et al. (2014) have shown that the relationship between efficiency and contact with extension service is not clear, because the fact of the producer having a technical follow-up does not mean that the transmitted instructions refer to the best technologies for the type of enterprise and that these will be accepted.

In the production cost, the feed presented an increase of participation as the scale of production increased, with mean values of 55.39% of TOC in ME; 67.89% of TOC in EPP and 72.15% of TOC in EMP. On the contrary, depreciation decreased its participation in TOC by increasing the production scale, with values of 22.16% in ME; 14.44% in EPP, and 9.85% in EMP. Feed share in TOC higher than 55%, as well as in this work, have been reported in the production of tambaqui in several regions of Brazil; and in cases where the feed has a lower participation in TOC, the profitability was also lower (Pedroza Filho et al., 2016). The increase of the share of the feed and decrease of the depreciation with the production scale evidences the optimization in the use of the production factors, because as the production scale increases, it is expected that the fixed costs and the depreciation are diluted and thus, the DMU efficiency enhances (Irz and McKenzie, 2003; Gomes et al., 2005).

Conversely, the high share of depreciation (> 10%) and low share of the feed (<60%) in the TOC, as observed in the Micro,

P1, P2 and P6 DMUs, resulted in lower technical and scale efficiency. Behavior also observed by Asche et al. (2008), which found an increase of up to 25% in the importance of feed, with a better performance of capital.

In 81.81% of the properties, there was an increasing return to scale (irs), with efficiencies lower than 65%. Showing that any reduction in inputs (TOC in R\$ kg<sup>-1</sup>; Feed in R\$ kg<sup>-1</sup>; Depreciation in R\$ kg<sup>-1</sup>) would result in a more than proportional increase in gross revenue (R\$ ha<sup>-1</sup> year) and, consequently, in operating profit. It can be observed, mainly in micro and small enterprises, that to reach the efficiency curve must be reduced the rationing, depreciation and TOC costs by at least 15% (ME) and 22% (EPP) and to increase revenues by at least 51% (ME) and 30% (PPE) (Table 2 and 3). It is also evidenced the high discard (observed by the difference between the value obtained and what should be achieved) that exists during the production process cannot be efficiently used, generating a high average TOC.

The increasing scale returns found in more than 80% of DMUs are indicative that DMUs are constrained in their production by market, technical or political limitations. As observed in this study and corroborated by Benicio et al. (2015), one of the reasons for an increasing return is the inability of DMUs to rationalize fixed costs with the scale of production, which refers to the optimization of the use of fixed capital. Another factor that contributes to an increasing scale returns and evidenced by Benicio et al. (2015)

is the lack of specialization of DMUs, which generate more than one product and cannot optimize the production factors.

There was an increase in technical and scale (CRS and VRS) efficiency, as the production scale increased, but only two fish farms (M3 and M4) were efficient due to the lower costs and higher profits, showing that majority do not use the most appropriate technology for the activity and that micro- and small-scale development is also not recommended in the situation in which the activity is being developed (Table 2 and 3).

The lowest operational costs (average of R \$ 4.59 kg<sup>-1</sup>) and higher operating profits (average of R \$ 80,726.20 year<sup>-1</sup>) were obtained in the EMPs (Table 2), which reflected an efficiency of 88% (Table 3). These values are at least twice as large as those found in micro- and small-scale projects. The M1 and M4 projects were the benchmarking pairs, ie, those DMUs considered as models for the others. This fact can be understood to the better relationship between the inputs and outputs obtained by these units, where M1 despite not obtaining the highest operating profit, it had the lowest TOC. In another hand, the M4 presented only the third lowest TOC and the fourth highest revenue, obtaining the second highest profit.

## CONCLUSIONS

More than 80% of the fish farms presented an increasing scale return, with efficiencies below 65% and with strong indications of the relationship between the size of the property, the product generated (roelo or curumim) and the profitability of the activity.

The profitability and high efficiencies observed in MEs's are related to the use of aerators, even if in insufficient quantities; less idle infrastructure; greater bargaining power and market and technical knowledge; specialization of production, developing only fish farming; and greater production control. But it is also possible to observe that, even with the existence of a drainage and supply system, the DMU's M1 and M2 do not change the water at the end of the production cycle, which coincides with the achievement of technical efficiencies and a scale of less than 100%.

The lack of profitability and low efficiency found in MEs and EPPs is directly related to the lack of adequate infrastructure, low technical and marketing knowledge regarding the activity, and with the fact of mean production cost (R\$ kg<sup>-1</sup>) is higher than the average of selling price (R\$ kg<sup>-1</sup>). Thus, the increase in efficiency can be improved by professionalizing the activity through training and participatory courses, to increase technical and marketing knowledge; organization of fish farmers into groups that reduce input costs and increase bargaining power; use of aerators to increase productivity; adequate nutritional and water management; and use of management tools such as spreadsheets and software that allow short, medium and long term decision making.

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