

## ANALYSIS OF THE FINANCIAL VIABILITY OF THE AQUAPONICS (FISH FARMING AND HYDROPONICS) SYSTEM USING THE MONTE CARLO METHOD

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**ABSTRACT** – This study aims to evaluate a particular property in Brasília that uses the aquaponics system on a small production scale. The Monte Carlo method was used to estimate its financial feasibility and the probability of the production volume and, consequently, evaluate the risk of this undertaking. The data analyzed included fixed and variable costs, revenues and financial viability indicators, which are net present value (NPV), periodic economic benefit (PEB) and internal rate of return (IRR). It was identified in this research that the cost with the largest participation was the land acquisition, amounting to more than 60%. According to the survey, the venture showed a 56.69% probability to generate a NPV, PEB and IRR rate, respectively, of R\$ 117,784.26, R\$ 16,003.11 and 37%. The probability of occurrence of fish volume and plant production were, respectively, 1179.44 kg and 731.26 kg with 74.43% and 76.16%, presenting a probability greater than 50%, which is considered as more reliable than traditional analysis. Therefore, we can conclude that it is economically viable according to the NPV parameters, which was greater than zero, and the IRR, that was higher than the minimum rate of attractiveness.

**Keywords:** equivalent periodic benefit, financial viability, *Oreochromis niloticus*, *Ocimum basilicum*.

### ***ANÁLISE DA VIABILIDADE FINANCEIRA DO SISTEMA DE AQUAPONIA (PISCICULTURA E HIDROPONIA) USANDO O MÉTODO DE MONTE CARLO***

**RESUMO** – Este estudo tem como objetivo avaliar uma propriedade particular em Brasília que utiliza o sistema aquapônico em pequena escala de produção. O método de Monte Carlo foi utilizado para estimar sua viabilidade financeira e a probabilidade do volume de produção e, conseqüentemente, avaliar o risco deste empreendimento. Os dados analisados incluíram os custos fixos e variáveis, as receitas e os indicadores de viabilidade financeira, que são o valor presente líquido (VPL), o benefício econômico periódico (PEB) e a taxa interna de retorno (TIR). Identificou-se nesta pesquisa que o custo com maior participação foi a aquisição de terras, totalizando mais de 60%. Segundo a pesquisa, o empreendimento apresentou uma probabilidade de 56,69% de gerar uma taxa NPV, PEB e IRR, respectivamente, de R \$ 117.784,26, R \$ 16.003,11 e 37%. As probabilidades de ocorrência de volume de peixe e produção de plantas foram, respectivamente, 1.179,44 kg e 731,26 kg com 74,43% e 76,16%, apresentando probabilidade maior que 50%, considerada mais confiável que a análise tradicional. Portanto, podemos concluir que é economicamente viável de acordo com os parâmetros do VPL, que foi maior que zero, e a TIR, que foi maior que a taxa mínima de atratividade.

**Palavras chave:** benefício periódico equivalente, *Oreochromis niloticus*, *Ocimum basilicum*, viabilidade financeira.

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## INTRODUCTION

Aquaponics is an integrated aquaculture system (cultivation of aquatic organisms) with hydroponics (cultivation of plants without the use of the soil). The plants absorb the dissolved nitrogen compounds from the fish farming effluents and the water returns clean to the fish tank (Hundley & Navarro, 2013; Hundley et al., 2013; Goddek et al., 2014; Love et al., 2014; Hu et al., 2015; Tokunaga et al., 2015; Hundley et al., 2018).

The system is efficient in using water and nutrients dissolved in water. In addition, the system can be deployed in adverse climatic conditions, be it in the cold, the heat, places where there is water shortage and also where there is soil contamination and water that are toxic to aquatic and plant organisms. In other words, the cultivation environment in this system is controllable and can cultivate several species of fish and plants in a relatively small area, and can be installed even within the city (Lucena, 2014).

However, there are few studies that aim to prove financial viability on a commercial scale. Most studies are limited to demonstrating only the technical feasibility and to analyze the productive performance of a certain species of plant and fish in the Aquaponics system. In this context, the objective was to analyze the financial viability of an aquaponics enterprise installed at Pine Tree Farm, located in Brasilia, Distrito Federal, Brazil.

## MATERIALS AND METHODS

The present paper consists of a case study with data collection being conducted through an interview with the producer who has the Aquaponics system installed for 3 years in the Pine Tree Farm property, located in the administrative area of the Botanical Garden, in Brasilia, Distrito Federal, Brazil. It is 1023 meters high, at 15°52'31.36" South and 47°48'01.28" West. The experiment was carried out in a randomized block design with 3 x 1 factorial scheme, comprising three different densities of tilapia fingerlings, T1 (72): 72 fish / m<sup>3</sup>, T2 (144): 144 fish / m<sup>3</sup> and T3 (216): 216 fish / m<sup>3</sup> and one crop of basil for each tank, where each treatment continued for 45 days and replicated twice in a recirculating aquaponic system.

The aquaponics system is composed of three cultivation modules with similar production capacity between them, that differ in physical structure and material used in the construction.

Each module is composed of: one fish tank with a capacity of 3,000 liters, one decantation tank with capacity

of 240 liters, one biofiltration tank of 500 liters, one biofiltration tank of 1000 Liters with variable fluid level.

Revenues and expenses were designed to establish a cash flow within a 10-year horizon. It was considered that the minimum wage is R\$ 788.00 (base minimum wage of 2015), minimum attractiveness rate of 6.0% (annual growth target of the enterprise), and average initial weight 35 (g). The initial fish stock was 1096 fish (considering the initial average density of 38.36g / m<sup>3</sup>), fish and plant survival rates were 95% and 100%, respectively, feed conversion rate was 1.73, average ration price was R\$ 2.80, sale price of fish for R\$ 4.50 / kg and feed rate was 99.6g / day / m<sup>2</sup>. The selling price of basil pesto is R\$ 75.00 / kg.

Only the working time that the employee used to manage and feed the fish and the plants was considered. Therefore, it was estimated at 4 hours of work per day to perform activities related to Aquaponics. Considering that the basic remuneration is R\$ 788.00 (40 hours a week), one hour of work is equivalent to R\$ 4,925. Social burden was estimated at 45.59% (CONAB, 2010).

Land remuneration was not included in the production cost, taking into account that the land used for aquaponics is within the owner's area of residence. Therefore, it would not be feasible to lease to third parties and generate income on the land. The water cost was not considered in the present study to fit the reality of the producer of this study.

However, if one considers the water cost in the current study, it is estimated a monthly consumption of at least 16,924 liters of water (taking into account the daily replacement of 1% of the fish tank volume). That, in the current economic scenario, could be converted into an approximate cost of R\$ 103.57 / month (R\$ 6.12 / m<sup>3</sup>). Including the sewage rate, this value will increase to R\$ 207.14 / month (the sewage rate equals to 100% of the water consumption rate). The net present value (NPV), internal rate of return (IRR) and periodic equivalent benefit (PEB) were determined.

According to data obtained on productivity, it was established that the sales volume of fish and plants are uncertain variables. For example, the production of plants and fish as a biological phenomenon is not a deterministic event but rather an event that involves uncertainty and risks to a greater or lesser degree (Coelho Junior et al., 2008). Therefore, in this case, 10,000 pseudo-random numbers of sales volume (plants and fish) were generated by the program Microsoft Excel 2013®, using the random number generator tool, establishing the mean and standard deviation according to the author of the research, based on



the information collected from the producer (Viana et al., 2013).

Afterwards, these data were used to generate the histogram via the histogram tool, which is found in the data analysis tab of the Microsoft Excel® program (Viana et al., 2013).

## RESULTS

Costs ranged from 62.12% to 0.45%, totaling an investment of R\$ 63,985.84. The largest investment was of R\$ 39,750. According to the data collected, it was identified that the land composes about 60% of the total investment cost, followed by the cost of greenhouse, hydroponic trough and fish tank (Table 1).

Table 1. Composition of investment costs by category

Categories	Value sum subtotal	Percentage of total
Ground	R\$ 39.750,00	62,12%
Hydroponics trough	R\$ 6.241,07	9,75%
Fish tank	R\$ 5.029,70	7,86%
Greenhouse	R\$ 4.145,36	6,48%
Pumping system	R\$ 3.330,55	5,21%
Flooded filter	R\$ 2.878,14	4,50%
Pipe system	R\$ 1.558,53	2,44%
Aeration system	R\$ 761,57	1,19%
Variable level filter	R\$ 290,91	0,45%
Total	R\$ 63.985,84	100,00%

The items that displayed the largest shares of the production costs in this study were labor and pesto, respectively, with 46% and 32% (Figure 1). The ration had one of the lowest cost participations because the amount of fish was smaller, focusing only on basil production and not on fish growth.

The composition of costs with the preparation of pesto is described in Table 2.

Initially the values of the mean and standard deviation were established, according to the Table 3, to generate the pseudo-random numbers.

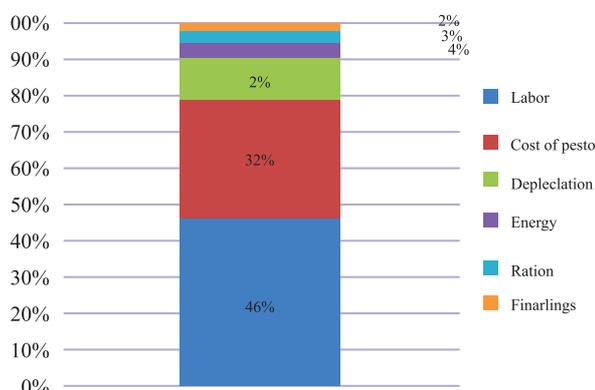


Figure 1 - Composition of the operational costs of the aquaponics system.

Table 2 - Composition of pesto cost

Item	Cost per kilo
Olive oil	R\$ 5,00
Garlic	R\$ 0,06
Chestnuts	R\$ 1,35
Honey	R\$ 0,15
Salt	R\$ 0,10
Packaging	R\$ 2,04
Transport	R\$ 3,00
Labor	R\$ 8,00
Total	R\$ 19,70

Table 3 - Fish and plant production data

	Average	Máximo (+20%)	Mínimo (-50%)	Standard deviation
Fish	950,1	1140,2	475,1	342,6
Plant (kg)	580,6	696,7	290,3	209,3

According to the fish volume histogram, the probability of a yield of 1179.44 kg is 74.43% (Figure 2). According to Coelho Junior et al. (2008), if a decision made by Monte Carlo method present a probability of occurrence greater than 50%, it will be a better decision than the ones taken traditionally. The probability of higher occurrence can be determined from the graph and by identifying the crossover point of the frequency line of the histogram and the accumulated frequency line.

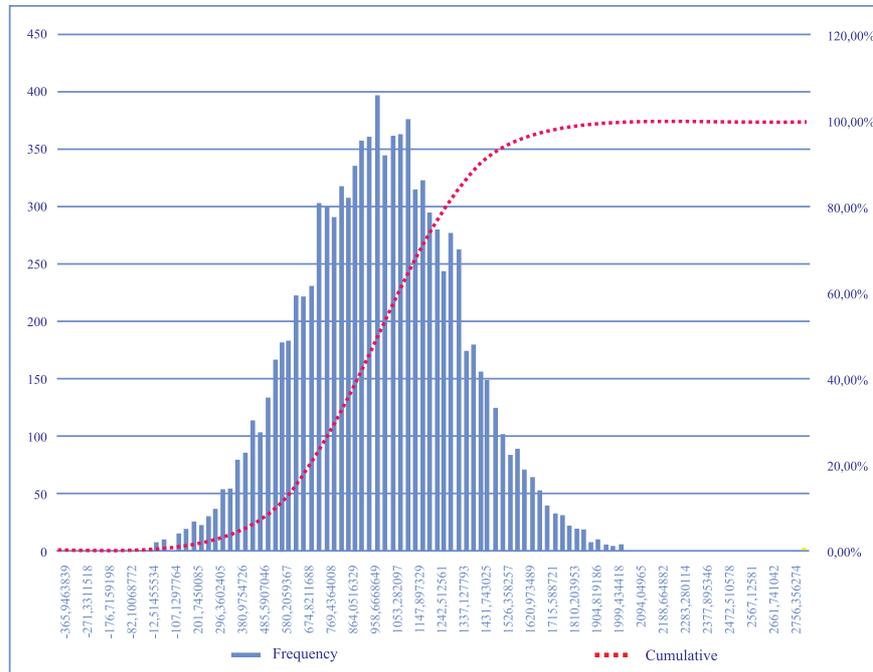


Figure 2 - Histogram and cumulative frequency of fish production.

The probability of obtaining a productivity of 731.26 kg of pesto volume is 76.16% (Figure 3). Considering that there is a probability greater than 50%, we

can consider that the decision taken by this measure is still considered better than the traditional method.

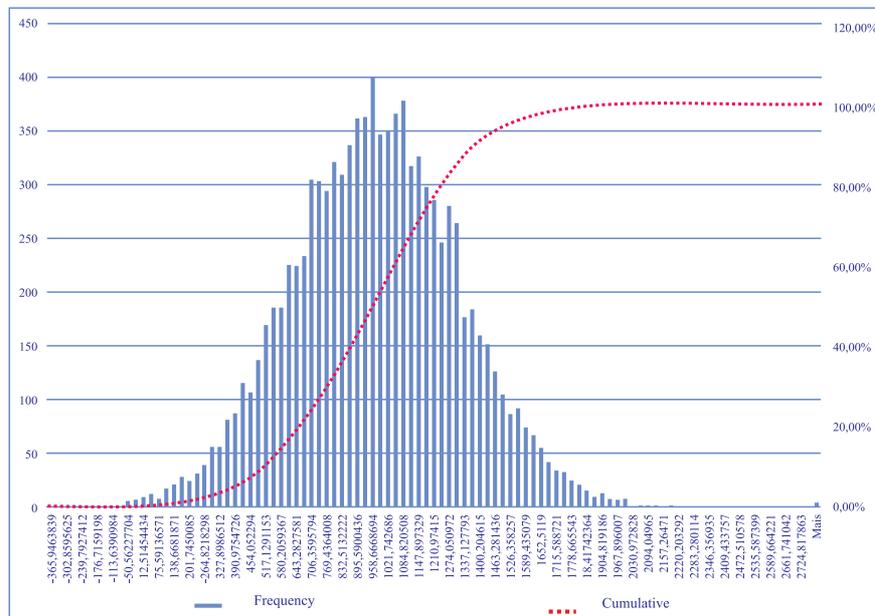


Figure 3 - Histogram and the cumulative frequency of pesto production.



The annual revenue from this system was estimated at a gross annual total of R\$ 63,200.40, with most of the revenue generated by the sale of pesto, which was 91.3% of the total (Table 4).

Table 4 - Gross annual revenue

Product	Annual recipe	%
Tilápia	R\$ 5.307,48	8,8%
Pesto	R\$ 54.844,50	91,2%
Sum	R\$ 60.151,98	100%

According to the survey, the NPV was R\$ 117,784.26, considering a minimum attractiveness rate of 6% per year and the horizon of the 10-year venture. Or, better, the producer has a financial return of R\$ 16,003.11 per year on average, not counting the labor received by the enterprise, which is a minimum wage per month (Table 5).

The IRR being this 37%. This high rate can be explained by the fact that the cost of manufacturing the pesto is not included in the initial investment.

Table 5 - Financial indicators

Minimum attractiveness rate	6%
Net present value (10 years)	R\$ 117.784,26
Internal rate of return (IRR)	37%
Benefit of the economic period (10 years)	R\$ 16.003,11

## DISCUSSION

The highest cost of Aquaponics production was labor with 46%, obtaining a similar value to that of Tokunaga et al. (2015), which was 48%, followed by electricity and feed costs, respectively, of 23% and 11%.

The fish production was 58.30% higher than the production of plants. In the study by Tokunaga et al. (2015), lettuce production was 853% higher than tilapia production. This can be explained by the fact that the crop structure is larger than the current study. The culture tank used by Tokunaga et al. (2015) was 75.71m<sup>3</sup> and a hydroponic area of 1142 m<sup>2</sup>, in a ratio of approximately 1:15 unlike the current study, which it has a ratio of 1: 1.32. However, other studies had a similar proportion to the current study, which remained in a 1:0.64 to 1: 2.4 range (Cani et al.,

2013; Dunwoody, 2013; Petrea et al., 2014; Salam et al., 2014, Trang & Brix, 2014).

The producer outsources the pesto production and thus does not use an industrial kitchen that requires more initial investment. In the future, with the increase of production, it will be necessary to establish an industrial kitchen for food safety reasons and sanitary requirements for the commercialization of the product. Thus, this cost can be allocated after the operation.

For the production of basil and okra, Rakocy et al. (2004) used the ratio of approximately 1:5. In this study, the hydroponic Floating Raft System (FRS) was employed, similar to the system used by Tokunaga et al. (2015), which used the largest proportion of the hydroponic area. However, Dunwoody (2013) employed the same type of system but used the ratio of 1: 1,18, corroborating that even in this type of system a smaller proportion, similar to the current study, could be used, demonstrating the technical feasibility of Channel Catfish (*Ictalurus punctatus*) and basil (*Ocimum basilicum* L. Nufar FI).

The internal rate of return (IRR) presented a high value in comparison to the other studies, but they were within the range of 1.70% to 45.51% (Furlaneto & Esperancini, 2009; Almeida, 2013) In this paper, we present the results obtained in this study. This can be explained by the fact that the initial investment is low compared to other ventures that obtained these low IRRs. Therefore, we must not only evaluate the IRR, but also other methods that allow a complete analysis of financial viability. If one evaluates the venture only by the IRR, we can find investments that have a very high IRR but also a very high risk of not obtaining the desired results, such as bets, high risk stocks and stock market options.

With the application of the Monte Carlo method, Simões & Gouvea (2015) obtained an internal rate of return of 54.2% working with Nile tilapia (*Oreochromis niloticus*) in the system of 10 net tanks in the central west of State of São Paulo. The sale price was US\$ 1.70, which is equivalent to R\$ 3.38. This same study indicated that the production per cycle and the expected sales value are the variables that most exert an impact on the financial indicator. Therefore, it can be said that the high IRR rate is due to the high sales value established and the production volume. The IRR calculated in this study was considerably higher than the simulated SELIC rate used in the same study, which was 10.5% (Simões & Gouvea, 2015).

In a case study of tilapia fish in a tank within the same state, the IRR ranged from 22% to 74.72%, showing that there is economy of scale in tank fish farming, as

evidenced by the decreasing yield curve. That is, as the scale of production increases, the total average cost of production decreases. The total cost of the projects with 100, 64 and 40 net tankers were R\$ 1.54 / kg, R\$ 1.67 / kg and R\$ 1.70 / kg, respectively (Vera-Calderón et al., 2004).

In a hydroponic crop with NFT type system, Weymar Junior et al. (2010) showed that producing lettuce (*Lactuca sativa* L.) had a high IRR of 47%, when selling the lettuce foot for the price of R\$ 0,80, with the initial investment of R\$ 68,428.28, being that the minimum rate of attractiveness used in this study was 11% per years. It is interesting to note that even the product sold in the “in natura” form obtained a high profitability. This can be explained by the fact that this hydroponic system has a better productivity. According to this study, hydroponic cultivation can achieve a 30% higher productivity than the traditional one, due to the separation of the cultivation phases that go from the formation of the seedlings and growth phases until the final harvest (Weymar Junior et al., 2010).

According to Love et al. (2014), currently many producers have opted to grow tilapia (69% of respondents) half of the respondents grew two species. And the other cultivated species are ornamental fish (43%), catfish (25%) and other aquatic animals (18%).

Increasing the area of plant cultivation may be a viable short-term option to improve income due to higher conversion rate of plant biomass compared to fish. While the lettuce can generate nine kg of biomass from fish waste fed with 1 kg of feed, the fish has conversion in the range of 1:1 (Love et al., 2014). But in this case, one should consider the cost of the land to be purchased. Another option would be to add vertical hydroponics systems that optimize the use of space. According to Lucena (2014), one of the vertical cultivation systems can reach a productivity of up to 10 times more than a conventional agriculture. For example, the Canadian vertical cropping system consists of towers of hydroponic plantation at a 3.3 m height and with 1,6m width that occupies an area of 1.6 m<sup>2</sup>. In turn, each tower is composed of 24 trays with a length of 1 m and a width of 0.6 m. This tower is equivalent to a horizontal area of length of 4.8 m and width of 3.0 m, totaling 14.4 m<sup>2</sup>. That is, in an area of 1.6 m<sup>2</sup>, 1056 units of a variety of plants can be produced, such as basil, cabbage, arugula, chinese cabbage, spinach, endiva, radichio, mizuna and komatsuna (Lucena, 2014). This shows that a very large variety of plants can be produced and marketed using this type of system.

In relation to the value of the BPE obtained, it allows us to interpret that the producer will have, on average and annually, a financial return of approximately

R\$ 16 thousand, not counting that he will receive the *pro labore* every month.

## CONCLUSIONS

It was concluded that the Aquaponics system in the Distrito Federal, in the presented model, is economically feasible. The total initial cost was R\$ 63,985.84, and more than 60% of the cost was for the land acquisition. Other components, such as fish tank, hydroponic gutters and water pump separately accounted for less than 10% each. Using the Monte Carlo method, we obtained pseudo-random numerical data which, when analyzed, obtained a probability of 74.43% of producing 1179.44 kg of fish and 76.16% of producing 731.26 kg of pesto.

According to the estimated production data, it was shown, financially, that the project has the probability of 56.69% in generating the NPV of R\$ 117,784.26, PEB of R\$ 16,003.11 and IRR of 37%. Because it presents a probability greater than 50%, it is concluded that the enterprise is economically feasible and that the internal rate of return of the enterprise exceeds by 600% the growth expectation stipulated by the study, which is 6% per year.

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