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COMPARATIVE ANALYSIS OF THE ECONOMIC EFFICIENCY AND COMPETITIVENESS OF SEA SHRIMP CROPS IN THE SEMI-INTENSIVE (TRADITIONAL) AND SUPER-INTENSIVE SYSTEM (WITH REUSE OF WATER AND USE OF BIOFLOC - BFT) USED IN BRAZIL

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ABSTRACT

Marine shrimp farming (cultivation of sea shrimp) has enormous socioeconomic importance in Northeastern Brazil, since this region concentrates 98% of shrimp production in Brazil. However, this activity has been suffering from low productivity and loss of competitiveness of current cultivation systems. This article aimed to perform a comparative analysis between the economic efficiency and competitiveness of sea shrimp crops in the semi-intensive (traditional) and super-intensive (water reuse and biofloc use - BFT) system used in Brazil. A comparison was made between the indicators of economic efficiency and competitiveness in each of the sea shrimp farming systems studied. The data needed to carry out this comparative analysis were collected through bibliographic surveys from secondary sources. The results obtained demonstrate that sea shrimp farming in the water reuse and BFT system is, in terms of economic parameters, more efficient and competitive than farming in the semi-intensive (traditional) system. The conclusions of this work allow us to deepen the discussions on the modernization of Brazilian shrimp farming by intensifying these crops. It is necessary that the studies bring to light the adoption of technological innovations that provide an improvement in the efficiency and competitiveness of Brazilian aquaculture and that they are encouraged. The originality of this work lies in this foundation.

Descriptors: super-intensive shrimp farming, bioflocs, efficiency, competitiveness

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1. INTRODUCTION

The world is experiencing a new world order that has emerged from the pandemic caused by the new coronavirus. In addition to the humanitarian and health crisis, the economic impacts will still be felt very strongly in the coming years. Countries will have to concentrate their efforts on resuming economic activity, generating jobs and income, producing food and giving the population access to this food. In this way, aquaculture (cultivation of aquatic organisms) can contribute enormously to these factors.

The Food and Agriculture Organization of the United Nations (FAO, 2020) mentions that world production of fish for human consumption in 2018 was 156 million tons (t), with aquaculture accounting for 52% of this total, i.e. 82 million t. Crustaceans, like shrimps, accounted for 9.4 million t, representing almost US$ 70 billion.

In Brazil, aquaculture produced 579,000 t in 2018, of which 43,000 t were from sea shrimp farming (*carcinicultura*, in Portuguese) (IBGE, 2019). The growing demand for the product in the foreign market during the early 2000s and the advent of new technologies to cultivate sea shrimps in fresh water boosted the entry of new adepts to the activity (Souza Junior, 2003). Thus, the importance of the agro-industrial chain of cultivated shrimps increased due to the number of shrimp farmers dedicated to the activity, the extension of the areas occupied with shrimp farming, the value of production, and the capacity to generate employment, contributing to local development (Souza Junior, 2003).

The systems used by producers can be divided, according to productivity, into extensive, semi-intensive or intensive; by number of species involved (monoculture or polyculture); and according to sharing in consortium with species other than those exclusively aquatic (Oliveira, 2009). Extensive cultivation refers to the exploitation of weirs, ponds, dams and other springs, in which there is no interference against predators, water and food quality. In the semi-intensive there is interference with food and fertilization of water with supplements. And for the intensive, balanced rations are used due to the high density of individuals. Thus, the lower the interference in the crop conditions, the lower the productivity (Oliveira, 2009).

In the first half of the 1990s, Brazilian laboratories dominated the reproduction and larviculture of *L. vannamei*, starting the commercial distribution of powdered larvae. *Litopenaeus vannamei* presented commercial viability, with higher productivity and profitability rates than the native species, becoming the only species currently cultivated in semi-intensive production systems, a more appropriate way to the conditions of the Brazilian estuaries (Souza Junior, 2003).

Faced with the importance of investing in clean technologies that allow the reduction of nutrient inputs and water renewal rates to favor a balance in adjacent environments, technologies capable of producing in a different way have emerged (Nascimento *et al*., 1998). Cultures without water renewal ZEAH (Zero Exchange, Aerobic, Heterotrophic Culture Systems) or cultivation amidst Bioflocs (BFT), for example, meet the new concepts of responsible and environmentally friendly aquaculture, since they are carried out practically without water renewal and with the use of microorganisms as natural food, which reduces the use of feed (Sampaio *et. al*., 2010). The BFT system, on the other hand, in addition to improving productivity rates compared to traditional cultivation systems, presents greater biosafety, since it reduces water exchange, avoiding diseases. This type of system uses little water, representing a decrease in effluent emission, and can produce 1 kg of shrimp with the use of less than 160 liters of water (Otoshi *et al*., 2006), while in conventional systems up to 64,000 liters are used (Hopkins *et al.*, 1995).

Thus, given the importance that shrimp farming has gained in the economy of the Northeast, this study aims to compare the economic efficiency and competitiveness of marine shrimp farming carried out in the traditional system (semi-intensive) and the water recirculation system, with the use of BFT.

2. ECONOMIC EFFICIENCY AND COMPETITIVENESS ANALYSIS

In any economic feasibility analysis it is salutary to study the point from which the company becomes profitable. This point is called the breakeven point (Coelho, 2005). According to Gitman (1997), breakeven point analysis is used by the company to determine the level of operations required to cover all operating costs and to evaluate the profitability associated with various sales levels. Following this line, Hoji (2001) claims that at breakeven point, companies produce and sell products in quantities sufficient to cover costs and the total expenses.

For the economic analysis of the activity carried out by estimating the cost of production, it is necessary to use economic efficiency indicators such as gross margin, net margin, result (profit or loss) and interesting support for decision making in the agricultural enterprise. The gross margin is used considering that the producer has the available resources (land, labor and capital) and the need to make decisions on how to effectively use these production factors. The net margin allows us to conclude whether the activity is stable, with the possibility of expanding and maintaining it over the long term, when it is positive. If the net margin is equal to zero, the property will be at the break-even point and in a position to rebuild its fixed capital over the long term. But if it is negative, it means that the producer will be able to continue producing for a certain period of time, although with a growing problem of decapitalization.

By adapting the concept of balance point to the projects developed by a company, it is possible to estimate from when the project starts to be profitable. Some techniques are used to calculate the estimated return on an investment, as expenses incurred today will only bring positive results sometime after the implementation has begun. The most common techniques for the analysis are the Payback Period (PP), Net Present Value (NPV) and Internal Rate of Return (IRR), cited in many financial works, including those of Gitman (1997) and Hoji (2001).

PP, for example, is the method that analyzes the recovery time of the money invested, that is, the length of time it will take for the company to recover the money invested. In the case of PP, the longer the payback time the greater the uncertainty and risks to the return of the investment. Thus, the less time the greater the chance of a return on investment (Santos; Vasan, 2014).

The NPV is used to calculate the present value of a series of future payments discounted at a stipulated cost of capital rate. This method takes into account the fact that the money we will receive in the future does not have the same value as the money in the present time, given the uncertainty of tomorrow. The NPV therefore determines the monetary amount at which the project will increase the value of your company. The value of the cost of the project and its future income should therefore be estimated (Santos; Vasan, 2014).

Another widely used technique is the IRR, which aims to determine from what percentage of return there will be profit for the project. The rate indicates when the current value of your project will be equal to zero. That is, the project will become interesting when the IRR is higher than the capital cost of your project (Santos; Vasan, 2014). This rate represents the return on capital invested and allows identifying the investment risk of a project, given the ease of comparing the IRR of a given project with the rate of a low-risk financial investment, for example.

It is perceived that the techniques presented are useful for the analysis of the profitability of the investment, since the estimates foresee the value necessary for implementing the project (considering the total operating costs) and the value that will return to the investor after the proper execution. By definition, profitability is the ratio between return value and invested value, a proportion that allows the producer to compare, among the available projects, which one brings the greatest benefit.

3. THE CULTIVATION OF SEA SHRIMP IN BRAZIL

In the most recent census of Brazilian shrimp farming, the Brazilian Association of Shrimp Breeders (ABCC, 2015) reports that this production chain counted 2,000 fattening farms in 2014, occupying an area of 23,000 hectares (ha), totaling a production of 85,000 t of shrimp; 32 ripening and larviculture units, with a production of 20 billion post-harvest; nine feed factories, with a production of 126,000 t/year and; 32 processing units, with a production of 40,000 t/year. Table 1 presents the revenue from activities involved in the chain of production of shrimp farming in 2014.

Table 1. Revenue from the Marine Shrimp Farming Production Chain in 2014

Activity	Income (R$)
Fattening farms	1,350,000,000.00
Ripening and larviculture	170,000,000.00
Feed mills	378,000,000.00
Improvement	130,000,000.00
Total	2,028,000,000.00

Source: ABCC (2015)

According to the latest survey on the productive infrastructure and technological, economic, social and environmental aspects of shrimp farming in Brazil (ABCC, 2013), the vast majority of Brazil's shrimp farms are located in the rural coastal area of the Northeast region (Table 2), especially in the states of Ceará, with 31,982 t, Rio Grande do Norte, with 17,825 t, Bahia, with 7,050 t, Pernambuco, with 4,309 t, Piauí, with 3,079 t, Sergipe, with 2,973 t, and Paraíba, with 1,530 t. These states account for 98.8% of Brazilian production.

Table 2. Shrimp farming by region in Brazil

Region	No. of farms	Cultivable area (ha)	Production (t)
Northeast	1,429	20,866	69,171
South	112	1,346	344
North	3	33	56
Southeast	1	103	-

Source: ABCC (2013).

Still according to ABCC (2013) data, although this activity has grown in relation to the number of producers and the cultivated area, it decreased in terms of production and productivity in the period 2004-2011, as shown in Table 3.

S&G Journal
Volume 15, Number 2, 2020, pp. 123-130
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Table 3. Comparative data on Brazilian shrimp farming (2004, 2011)

Variable	2004	2011	Variation
No. of producers	997	1,545	55%
Area (ha)	16,598	22,347	35%
Production (t)	75,904	69,571	-8%
Productivity (t/ha)	4.51	3.51	- 22%

Source: ABCC, 2013

The cultivation of marine shrimp in the semi-intensive (traditional) system

According to Nunes *et al*. (2011), in the period between 1998 and 2003, Brazilian shrimp farming had its peak moment with the installation of new enterprises, modernization of existing infrastructure, incorporation of technologies and controls to cultivation, while the period between 2004 and 2011 can be divided into two distinct stages: a) adjustment to a new productive and economic reality; and b) economic recovery of the sector, with the resumption of production and consolidation of the industry.

In the first period, there were adversities that compromised the activities, including animal diseases, fall in shrimp prices in the international market (due to the increase in Asian production), progressive devaluation of the dollar, antidumping action by the United States, increase in operating costs in the intensive model, and decrease in productivity.

Since 2005, in the search for solutions to these problems, the projects that remained active reduced their costs to the detriment of the high productivity that had previously been desired. In shrimp farming, operational costs (feed, post-larvae, energy and labor) are linked to the level of intensification. As a result, producers have drastically lowered stocking densities, operating at a density of between 10 and 15 shrimp/m^2. In addition, fattening times have been reduced and there has been a search by producers for the internal market. Another fact that contributed to the recovery was the electric power discount granted to the sector, through Normative Resolution no. 207, issued by the National Electric Power Agency (ANEEL - *Agência Nacional de Energia Elétrica*) on January 9, 2007, which changed the scenario as of 2008.

From this moment on, the activity resumed its profitability indexes, benefited by the country's new economic scenario, which incorporated a significant mass of people with purchasing power. While production stabilized around 65,000 t, shrimp consumption per capita in Brazil increased significantly. Still according to Nunes *et al*. (2011), among the technical factors that contributed most to the economic recovery of the activity is the return to the predominance of the semi-intensive cultivation system, in which the reduction of stocking densities and soil treatment, by means of bioremediators, promoted a significant reduction in stress conditions, in addition to the reduced frequency of diseases. Table 4 records the stocking densities of sea shrimp farms in 2011 (ABCC, 2013).

It is observed that almost 90% of shrimp farmers used a stocking density of up to 30 shrimp/m^2; less than 9% used a density between 30 and 50 shrimp/m^2; and only 1.7% used stocking densities higher than 50 shrimp/m^2.

The cultivation of sea shrimp in the super intensive system (with water reuse and biofloc - BFT use)

Due to the problem of water use and pollution of coastal aquatic environments, much attention has been given to initiatives to optimize the use of this resource and to make water dependent activities increasingly sustainable. And to this end, intensification of crops has been used. According to Teixeira and Guerrelhas (2011), the intensive cultivation system has some characteristics: a) it demands continuous and intense monitoring; b) it allows increasing productivity by three times or more and does not increase production cost in the same intensity; c) higher densities can support high growth rates, as long as the feed has the composition to do so, oxygen levels are maintained at optimal levels, and the environmental condition of the nursery is stable and controllable.

Table 4. Category of producer X stocking densities

Categories	No. of Producers	< 10 cam/m^2	Between 10 and 30 cam/m^2	Between 30 and 50 cam/m^2	> 50 cam/m^2
Micro	717	342	315	35	11
Small	184	78	72	29	5
Medium	245	80	130	28	3
Large	76	14	47	12	2
Total	1222	513 (42.7%)	564 (46.9%)	104 (8.7%)	21 (1.7%)

Source: ABCC (2013)

Within this line, closed type systems (water recirculation) have been extensively tested and disseminated, mainly for greater biosafety, greater environmental sustainability, in addition to the advantages acquired through production intensification when compared to extensive and semi-intensive conventional systems in which water exchanges take place.

In this scenario, a cultivation system that has been widely studied and disseminated is the "Biofloc Technology" (BFT), which has as its main characteristic the non-renewal of water. In the BFT system, toxic compounds from shrimp excretion and feed remains present in the medium are converted into bacterial biomass through the action of heterotrophic and nitrifying bacteria.

These microbial aggregates, called bioflocs, have an important role, which is the transformation of toxic compounds into shrimp food. Cultivation in the BFT system favors a further intensification of the harvest system due to the maintenance of water quality and the existing natural food supplement.

Several studies have demonstrated the numerous benefits of the consumption of bioflocs by cultured animals, such as: reduction in feed conversion rates, increase in growth rates, strengthening of the immune system, and considerable decrease in feed costs. Up to 50% of the food consumed by *L. vannamei* shrimps in this farming system is composed of bioflocs.

4. METHOD

A descriptive documentary research was carried out. This type of research, according to Bastos (2012), describes the situation at the time the research occurs and establishes a relationship between the variables.

In addition, a quali-quantitative approach was used. According to Richardson (1989) *apud* in Bastos (2012, p. 41), the qualitative aspect of an investigation can be present even in data collected by quantitative studies, without losing its qualitative character when transformed into quantifiable data, in order to ensure the accuracy of the results.

Initially, a bibliographic survey was carried out, which allowed the presentation of concepts and methodologies that allow the measurement of economic efficiency, besides competitiveness in productive activities.

After this phase, another bibliographic survey was carried out, this time to present the general characteristics of the sea shrimp cultivation used in Brazil, as well as to describe the traditional (semi-intensive) shrimp cultivation system and the water recirculation cultivation system, with the use of bioflocs.

Both surveys were carried out through secondary sources, previous studies and statistical information at research institutions, companies, associations, cooperatives, government agencies and other sources holding data, which allowed a comparison of the economic and competitive efficiency of the sea shrimp cultivation systems used in this work.

The data collected were from economic efficiency parameters, such as operating costs, average price, profit margin, break-even point, simple profitability, payback, IRR, and NPV for each cultivation system studied. These data allowed carrying out a comparative analysis between the two cultivation systems, general objective of this study.

5. RESULTS

For the purpose of comparison between the sea shrimp cultivation systems performed in this article, the most relevant assumptions concerning each cultivation system were identified.

Next, the analysis of each system discussed separately is presented, the traditional (semi-intensive) and the super-intensive (with water recirculation and use of bioflocs), to finally perform a comparative analysis between the results found.

Semi-intensive system (tradicional)

Premisses:

- Growing area (fattening): 50 hectares
- Investment amount: R$ 1,350,000.00
- Crop density at fattening: 25 shrimps per m2.
- Feed conversion: 1.8 kg feed: 1.00 kg shrimp
- Productivity: 6,843 kg/hectare/year

The results found in this work for the traditional (semi-intensive) cultivation system demonstrate that 50 hectares of shrimp fattening would be necessary, with an investment of R$ 1,350,000.00 to obtain: break-even point of 8.15%, simple profitability of 238.19%, payback of 0.42 year, IRR of 153.24%, and NPV of R$ 13,847,343.60 at 12% per year. All are represented in Table 5:

S&G Journal
Volume 15, Number 2, 2020, pp. 123-130
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Table 5. Results of the economic parameters for the cultivation of sea shrimp on an area of 50 hectares, in the traditional (semi-intensive) system

Parameters	Results
Production Cost (R$/ kg)	17.17
Average Price (R$)	30.00
Profit Margin (R$)	12.83
Break-even point (%)	8.15%
Simple Profitability (%)	238.19
Payback (year)	0.42
Internal Rate of Return (%)	153.24
Net Present Value at 12% p.a. (R$)	13,847,343.60

Source: Research Data

Super-intensive system (water reuse and bioflocs use - BFT)

For the purpose of comparison between the sea shrimp cultivation systems performed in this article, the most relevant assumptions concerning each cultivation system were identified.

Premisses:

- Cultivation area (fattening): 01 hectare.
- Value of the investment: R$ 700.000,00
- Crop density at fattening: 180 shrimp/m^2.
- Feed conversion: 1.3 kg feed: 1.0 kg shrimp
- Productivity: 96,821 kg/hectare/year

The results found in this work for the system of cultivation with recirculation of water and with the use of BFT shows us that one hectare of shrimp fattening would be necessary with an investment of R$ 700,000.00 to obtain: break-even point of 6.80%, simple profitability of 234.94%, payback of 0.43 year, IRR of 153.37% and NPV of R$ 6,992,521.01 at 21% per year. All are summarized in Table 6:

Table 6. Results of the economic parameters for the cultivation of sea shrimp in an area of one hectare in the water recirculation system with the use of BFT

Parameters	Results
Production Cost (R$/ kg)	R$ 14.29
Average Price (R$)	R$ 30.00
Profit Margin (R$)	R$ 15.71
Break-even point (%)	6.80%
Simple Profitability (%)	234.94%
Payback (year)	0.43
Internal Rate of Return (%)	153.37%
Net Present Value at 12% p. y. (R$)	R$ 6,992,521.01

Source: Research Data

Comparison of data between the two studied cultivation systems

After processing and synthesizing the data collected, the following results were obtained in terms of comparison between the two cultivation systems, which were presented in Table 7:

Table 7. Comparative results between the two systems studied

Parameters	Semi-intensive system	Super-intensive system
Production Cost (R$/ kg)	17.17	14.29
Average Price (R$)	30.00	30.00
Profit Margin (R$)	12.83	15.71
Break-even point (%)	8.15	6.80
Simple Profitability (%)	238.19	234.94
Payback (year)	0.42	0.43
Internal Rate of Return (%)	153.24	153.37
Net Present Value at 12% p.a. (R$)	13,847,343.60	6,992,521.01

Source: Research Data

6. CONCLUSIONS

This paper presented concepts and methodologies for measuring economic efficiency and competitiveness. In addition, it described the general characteristics of sea shrimp cultivation in Brazil and two cultivation systems worked on: traditional (semi-intensive) sea shrimp cultivation system, and sea shrimp cultivation system with water recirculation and the use of BFT. A comparison was also made between the indicators of economic efficiency and competitiveness in each of the sea shrimp farming systems studied.

The semi-intensive cultivation (traditional) system required a higher level of investment (R$ 1,350,000.00) to produce on an area of 50 hectares, with a production cost of R$ 17,17 per kg, profit margin of R$ 12.83, break-even point of 8,15%, simple profitability of 238.19%, payback of 0,42 year; IRR of 153.24% and NPV at a rate of 12% per year of R$ 13,847,343.60.

The super-intensive system required a lower level of investment (R$ 700,000.00) to produce on an area of one hectare, with a production cost of R$ 14.29, profit margin of R$ 15.71, break-even point of 6,80%, simple profitability of 234,94%, payback of 0.43 year, IRR of 153.37% and NPV at a rate of 12% per year of R$ 6,992,521.01. It was observed that in order to have similar yields and economic parameters it was necessary to have in the semi-intensive (traditional) system a production area of 50 hectares and investments in the order of R$ 1,350,000.00, while in the super-intensive system, the area was only one hectare and investments of R$ 700,000.00. Although the economic parameters were equated with such distinct areas, the productivity of the semi-intensive system was 6,843 kg/ha/year, while in the super-intensive system it was 96,821 kg/ha/year.

The evaluation of production efficiency can be oriented to the growth of production: a) keeping the quantities of resources constant; b) guiding to the reduction of resources used, maintaining production levels; or, c) guiding to an optimal combination of these two objectives. In this work, it was sought to identify how the cultivation systems under study could obtain a higher production with the same amounts of resources or, given a constant and limited amount of resources, maximize production.

Thus, we can conclude that the super-intensive system of sea shrimp cultivation with water reuse and BFT use is, in terms of economic parameters, more efficient and competitive than cultivation in the semi-intensive (traditional) system.

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