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TECHNICAL AND ECONOMICAL EVALUATION OF THE INTEGRATION AQUACULTURE SYSTEM AND LETTUCE PLANTS PRODUCTION

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Abstract:

This study aimed to carry out a techno-economical study on the integrated aquaponic system for tilapia fish and lettuce plants. Fish and plant production was evaluated technically by determining the yield and economically by estimating the total costs, revenue, payback period, benefit/cost ratio, and internal return rates. The results indicated that the yield of fish is 75 tons and lettuce production is 33750 plants. The total fixed costs of the aquaponic system were 2.28 million Egyptian pounds for the system, while the total variable costs of the aquaponic system were 2.18 million Egyptian pounds. The total revenue for the aquaponic system for ten years was 32.41 million pounds. The benefit/cost ratio for the aquaponic system was 1.25 and the payback period for the system was 2.91 years. The internal return rate (IRR) was 84 %. However, it was 47%, and when the outcome cash flow increased by about 10% was 47%. The internal return rate (IRR) for the aquaponic system when the income cash flow decreased by about 10% was 44%. The internal return rate (IRR) for the aquaponic system when the outcome cash flow increased by about 10% and income cash flow decreased by about 10% was 26%.

More so, a deeper understanding of the economic viability of aquaponics and how an aquaponics system's performance can be optimized is gained. A SWOT analysis was done to point out the various strengths, weaknesses, opportunities, and threats that surround aquaponics. It

emerged from the analysis that whereas highly promising in food production, a raft of challenges is identified, including the high initial investment cost and technical expertise required to operate an aquaponics facility.

Keywords: Tilapia, Lettuce, Aquaponic system, payback period, internal return rate.

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1. Introduction

Aquaponics is the integration between fish culture and hydroponics. It is proper for urban agriculture in that it is good for poor soil and freshwater scarcity. It's a closed-loop system where the risk associated with diseases and contamination is pretty low in an aquaponic system. It enhances urban agriculture and increases global food security[1], this system is an environmentally compatible, recirculating system that employs both hydroponics and aquaculture. It doesn't require the organic effluents to be discarded as pollutants. High-quality protein-enriched fish can be produced together with fresh produce while at the same time limiting the demands for land, water, nutrients, manpower, and other resources[2,3]. This will effectively mineralize the fish effluent/wastage through biochemical conversion into releasing vital nutrients for vegetable growth [4].

Despite the benefits, semi-and large-scale commercial aquaponics system productions remain very limited. For instance, according to the 2018 Census of Agriculture, only 82 farms in the United States were practicing aquaponics. The value of aquaculture products sold by these farms; for example, tilapia, and catfish, include 4 farms with $1,000,000 or more, 9 farms with $ 100, 000 to 999, 000, 13 farms with $ 25, 000 to $99,000 and 56 farms with less than $ 25,000[5].

Between 1974-2013, unsustainable "overfishing" practices increased by 22%. Aquaculture represents a sustainable solution to meeting the growing market demand for protein-enriched food[6]. The most recent study by the United Nations Food and Agriculture Organization (FAO) in 2018 reported that fish production reached 171 million tons in 2016, with aquaculture representing 47% of the total production[7]. Aquaponics production will have aquaculture as a critical component, providing the major protein yield and nutrient source for plant production. Aquaculture is the technology of producing aquatic organisms in controlled environments; it contributes to economic development and stimulates agricultural sectors[8].

This increase in production within fisheries and aquaculture has indeed been phenomenal. The average annual growth in fish consumption is 3.2% from 1961 to the present, surpassing the 1.6%7 increase in the global population. While aquaculture is one of the major sources of fish food because of its popularity, it does pose some serious environmental concerns because it produces a lot of waste[9] that pollutes waterways from residual feed and fish excrement [10]. In traditional aquaculture, the waste produced by fish is disposed of directly without recycling which results in higher water consumption reported by Boyd 2005, also due to its rich labile organic content it pollutes the groundwater and provides nitrification[11-13].

There are numerous advantages to the integration of RAS and hydroponic systems. Hydroponics negates the requirement for filters in RAS as it acts as a biofilter. This saves on the use of fertilizers to sustain plant growth. In an aquaponics system, most of the nutrients required for the growth of plants are obtained from fish wastes [14]. In RAS, water recirculation minimizes the use of fresh water, and less water quality monitoring is required[15]. The shared cost of operation and infrastructure further raises the profit potential. Rupasinghe and Kennedy[16] studied the economic benefit of aquaponics using technical and production information in the case of producing lettuce and barramundi.

Separately, they first studied the systems of hydroponic and aquaculture, and then aquaponic to compare the outline. Results indicated that the aquaponic system recorded a higher economic return when compared to other systems. Results also revealed that the other systems. Additionally, the findings indicated that the economic return was strongly influenced by the market prices of both lettuce and barramundi. IRR ranged from 0 to 57%. The breakeven price of aquaponic lettuce and tilapia production was identified by Baker[17] in a hypothetical operation. Lettuce had a break-even price of $3.30/kg and tilapia was $11.01/kg. This research will analyze the economic feasibility of an aquaponics system by looking into initial investment and operational costs, and the revenue generated will be adopted to assess the profitability of the system. A SWOT analysis will identify major factors that affect the economic performance of aquaponics and identify the strengths, weaknesses, opportunities, and threats associated with aquaponics.

The optimization strategies for the economic and environmental performance of aquaponics were developed by taking into consideration the results of the study and creating recommendations that would increase the sustainability and profitability of aquaponic systems.

2. Materials and methods

Experiments were conducted at the center of Fish and Greenhouse, Faculty of Agriculture Moshtohor, Benha University, Egypt, and are positioned at latitude 30° 21` N and 31° 13` E throughout the 2022/2023 season. The Research Committee in the Faculty of Agriculture Moshtohor, Benha University, had already approved the protocols used in this study.

2.1. System description

The experimental system was composed of fish tanks, a screen filter, a biological filter, an oxygen generator and oxygen mixer, hydroponic units, pumps, and pipelines made of polyvinyl chloride installed to connect the components of the system to recirculate the water. Fig. 1.

2.1.1. Fish farm

The experiment used four prepared concrete octagonal fish tanks, each with two openings for settleable and suspended solids. One opening allows 1-15% of total flow, while the second opening permit 85-99% of the total flow. Each tank was provided with a particle trap in the center of water-drain waste solids.

Two stainless steel drum screen filters, measuring 1.2 m in diameter and 2.0 m in length, were sourced from a private company for use in the steel industry's media screening process.

The filter was powered by a 1 kW, 1500 rpm motor. A gearbox was used to slow the motor's rotation speed 500 times to achieve the recommended filter speed of 3 rpm.[18]

The trickling biological filter used in this study was 8.0 m in length, 4.0 m in width, and 4.0 m high in loading bacteria that convert ammonia to nitrate made of concrete with plastic sheets used as media. The aggregate volume of media employed in this research amounted to 96 cubic meters.

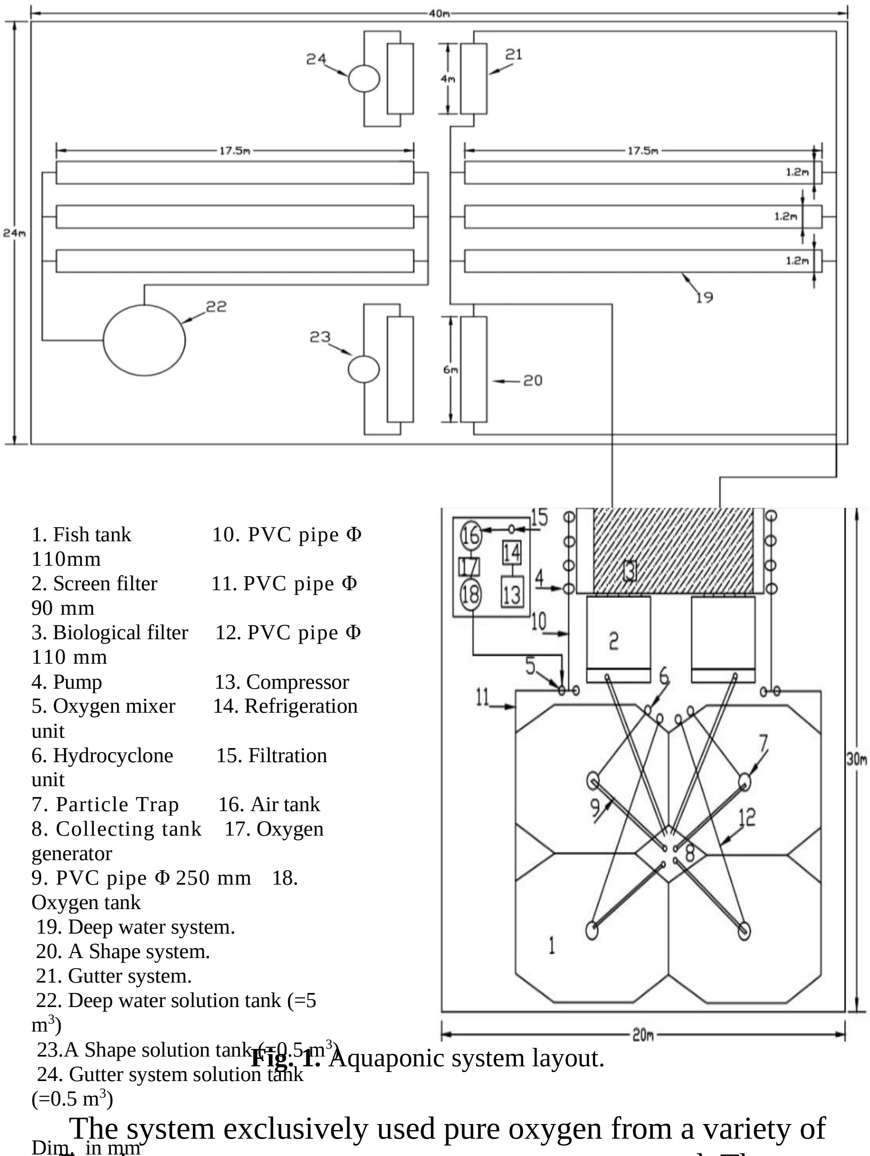

Fig. 1. Aquaponic system layout.

The system exclusively used pure oxygen from a variety of gases. For the oxygen gas, an oxygen generator was used. The pure oxygen gas was added to the water by using the oxygen mixer. Water and oxygen enter from the top of the oxygen mixer. During this, the water and oxygen move downward. An oxygen generator is used to provide the oxygenation system with its requirements of pure oxygen. Composed of an air compressor (Model BOGE – Flow rate 15 m3 h-1 – Head 10 bar – Power 25 kW, Germany), refrigeration unit, filtration unit, 1 m3 stainless steel tank for storage air, oxygen generator (Model BOGE – Flow rate 10.75 m3 h-1 – Head 6.25 bar – power 1 kW, Germany), and a 1 m3 stainless steel tank for storage oxygen pure.

2.1.2. Hydroponic systems

The hydroponic systems have three types of systems which are: deep water, A shape, and gutter systems according to Amin *et al*[3]. The Deep-water system consists of six rectangular concrete tanks covered by polyethylene sheets with 1 mm thickness used for lettuce plants' culture. The dimensions of each tank are 17.5 m in length, 1.2 m in width, and 0.3 m high. The ground slope of the tank was 2 %. The foam boards were wrapped around the tanks to support the plants. The A shape system consists of ten units; each one consists of three stands made of iron. The dimensions of each stand are 1.2 m wide and 1.7 m high. Each A shape consists of nine polyvinyl chloride (PVC) pipes, the dimensions of the pipe are 110 mm in diameter and 6.0 m in length. The slope of the pipes was 2 %. Small tubes (φ16 mm) were used to provide a solution for tanks in the closed system. The gutter system consists of ten units, each comprising three stands made of iron. Each stand measures 1.2 m wide and 1.0 m high. Each gutter system consists of three gutters made of PVC. Each gutter is 4.0 m long, 0.15 m wide and 0.10 m high. The gutter slope was 2 %. Small tubes of 16 mm diameter were used for supplying the tanks with solution in a closed system. The solution nutrient system employed a circular polyethylene tank to collect by gravity the drained solution from the end of each of the three systems. The pH and Electrical Conductivity (EC) were further brought to 6.5–7.0 and 800 – 840 ppm, respectively[19]. Ambient air temperature averaged 25.97 ± 4.37 °C, while the average water temperature was 24.03 ± 3.92 °C. The average relative humidity was 65.4% and the light intensity was 338.55 ± 40.06 W m−2.

2.2. Plant and fish species

2.2.1. Lettuce plants

The lettuce seedlings used in the present study were originally procured from the Protected Houses Center, Faculty of Agriculture Moshtohor, Benha University. The lettuce seedlings grew in the plastic cups (7 cm diameter and 7 cm height) filled with peat moss. The cups are irrigated daily using water with nutrient solution. Two weeks lettuce seedlings were planted at 25.0 plant m-2 in the experimental tanks[20].

2.2.2. Nile Tilapia fish

Tilapia nilotica fingerlings were used at the beginning of the experiment. Fish were brought from the General Authority for Fish Resources Development of A.R.E. in ElKnater El-Khiria, Kalubia, Egypt. The fish were weighed every ten days, and the flow rate according to the growth rate was regulated Following Rakocy's research, daily feed rates were adjusted based on the size of the fish.[21, 22]

2.3. Cost analysis

2.3.1. Total cost

2.3.1.1. Fixed costs

Fixed costs include expenses like equipment depreciation, interest, insurance, taxes, management, and general overhead. Overhead and management account for 15% of all pre-harvest variable costs, covering non-specific expenses such as utilities, transportation, facility maintenance, equipment, and fees. Depreciation and salvage values were calculated using specific equations.

Depreciation = (initial investment-salvage value)/total expected life in years (1)

$$Salvage\ \text{value} = 10\%\ \text{cost new} \quad (2)$$

Salvage values of the greenhouse and system are considered as 40% of the initial investment[23].

2.3.1.2. Operational cost

The operating cost in the budget is further broken down into pre-harvest operating and harvest and marketing costs. Pre-harvest costs commonly include fingerlings, seeds, feed, chemicals, media, fertilizers, energy, fuel, and labor.

2.3.2. Techno-economic analysis:

The techno-economic analysis of the system is done based on factors such as initial investment for construction of the system, initial cost of the environmental systems of the equipment, operating cost of equipment, pumping cost, feed and chemicals, maintenance, energy, fuel cost, the life of the system, and the salvage value after the expiration of the project.

2.3.2.1. Analysis of economic viability

The following parameters have been used for performing the economic analysis of the system for an individual plant and 1 kg of fish:

1. Total life of the project.
2. The discount rate is set at 10% as compared to the bank-lending rate.
3. Salvage values of the building and system are considered as 40% of the initial investment.
4. Total revenue generated has been calculated as per the yield obtained in each month.
5. Information obtained from the agricultural scientists.
6. Comparative economic analysis of the equipment with others.

2.3.2.2. Economic indicators

Total costs and revenue equations are as follows:

Growth revenue = total marketable yield x average price/kg fish (3)

Total production costs= operating costs + fixed costs (4)

Return over operating costs = Growth revenue – operating cost (5)

Return to management = Growth revenue – Total production costs (6)

2.3.2.3. Benefit/cost (B/C) ratio

The benefit/cost (B/C) ratio was determined using the following equation:

$$B/C\ \text{ratio} = \frac{benfit\ \text{cost}}{\text{production cost}} \quad (7)$$

2.3.2.4. Payback period (P.B.P)

The payback period is the time it takes for a project to generate enough revenue to recover its initial investment cost. The following equation is applicable to calculate this period:

$$\text{P.B.P} = \frac{total\ \text{invistment cost}}{\text{average annual profit}} \tag{8}$$

$$\text{a}verage\ \text{annual profit} = \frac{profit}{\text{operating life}} \tag{9}$$

$$\text{profit} = total\ \text{return - total cost}\left(fixed\ \text{cost} + \text{o}perating\ \text{cost}\right) \tag{10}$$

2.3.2.5. Internal return rate (IRR)

The internal return rate is the present value of total outcome cash flow to the present value of total income cash flow, and it is the most important financial evaluation criteria for a project. The internal return rate can be worked out with the following equation:

$$\text{IRR} = r_a + \frac{NPV_a}{\text{NPV}_\text{a} - NPV_b}\left(\text{r}_\text{b} - r_a\right) \tag{9}$$

Where:-

r_a is the lower discount rate chosen

r_b is the higher discount rate chosen

NPV_a is the net present value calculated using the lower discount rate

NPV_b is the net present value calculated using the higher discount rate

All research methods were conducted in compliance with Benha University guidelines, including adhering to relevant institutional, national, and international regulations for plant-based experiments.

3. Results and discussions

3.1. Techno-economic analysis

3.1.1. As to techno-economic study in this regard, it is based on factors like initial investment for construction of the system; the initial cost of equipment; operating cost of such equipment; cost for pumping, feed, chemicals, maintenance, energy, and fuel; life of the building system; and salvage value after the expiration of the project.

3.1.2. Fixed costs of fish farm

Fixed costs include building costs, equipment costs, fittings cost, and hydroponic units cost. Most of these costs are incurred even if a little production takes place and should consider these costs when planning production costs as shown in Table 1. It could be seen that the total fixed costs of the fish production were L.E 2,280,075 for the system. These results showed that the cost percentages of building, equipment, fittings, hydroponic units, and others were 23, 50, 2, 20, and 5%, respectively.

Table 1 Fixed cost of the aquaponic system.

Item	Fixed Cost, L.E	%
Building	522,000	23
Equipment	1,132,500	50
fittings	52,000	2
Hydroponic units	465,000	20
Others	108,575	5
Total	2,280,075	100

Source: Calculated from experimental work

3.1.3. Operating costs of the fish production

Operating costs consist of two main parts: those related to activities before harvesting and those related to activities after harvesting. Pre-harvest costs commonly include fingerlings, feed, seedlings, media, fertilizer, energy, and labor. Table 2: Total variable costs of the aquaponic system It could be seen that the total variable cost of the aquaponic system was 2,183,425 L.E. In addition, the obtained results of this study revealed that the cost of fingerlings, feed, lettuce seedlings, media, labor, energy, fertilizers, maintenance, and harvest were 60,000, 1,913,000, 17,000, 14,175, 84,000, 63,750, 25,500, 3,000 and 3,000 L.E, respectively.

Table 2 The total operating costs of the aquaponic system.

Item	Operating Cost, LE
Fingerlings	60,000
Feed	1,913,000
Lettuce seedlings	17,000
Media	14,175
Labors	84,000
Energy	63,750
Fertilizers	25,500
Maintenance	3,000
Harvest	3,000
Total	2,183,425

Source: Calculated from experimental work

3.1.4. Economic indicators

3.1.4.1. Total costs and total renovation

Table 3 presents the total operation costs and total renovation. It could be seen that the total costs started at LE 4,463,500 in the first year.

In the fifth year, the total costs were LE 2,411,433, where a cost of renovation of LE 228,008 was added. At the end of the ten years, there is an additional renovation cost of LE 228,008 that is added to maintain the same total cost. The results also showed that the total costs of the aquaponic system were LE 24,570,340 (10 years).

Table 3 The total costs.

Year	Fixed Costs, LE	Renovation	Variable Costs, LE	Total Costs, LE
1	2,280,075	0	2,183,425	4,463,500
2			2,183,425	2,183,425
3			2,183,425	2,183,425
4			2,183,425	2,183,425
5		228,008	2,183,425	2,411,433
6			2,183,425	2,183,425
7			2,183,425	2,183,425
8			2,183,425	2,183,425
9			2,183,425	2,183,425
10		228,008	2,183,425	2,411,433

Source: Calculated from experimental work

3.1.4.2. Total revenue:

Table 4. presents aggregate revenue accrued from the aquaponic system during a ten-year period. It can be seen from the table that the total revenue of fish and lettuce production started at LE 3,236,250 in the first year. In the case of adding cost revenue of LE 22,801, the total revenue was LE 2,411,433 in the fifth year. In the ten years, a cost revenue of LE 22,801 was added on top so that the total cost can remain constant. The results also indicated that the fish and lettuce production have a total revenue of 32,408,102 LE within the 10 years.

Table 4 The total revenue for the fish production (10 years).

Year	Revenue	End Value	Total
1	3,236,250		3,236,250
2	3,236,250		3,236,250
3	3,236,250		3,236,250
4	3,236,250		3,236,250
5	3,236,250	22,801	3,259,051
6	3,236,250		3,236,250
7	3,236,250		3,236,250
8	3,236,250		3,236,250
9	3,236,250		3,236,250
10	3,236,250	22,801	3,259,051

Source: Calculated from experimental work

3.1.4.3. Benefit-cost ratio (B/C):

Table 5 shows that the result, which started with LE 4,463,500 in the first year and ended with LE 2,411,433, started with LE 3,236,250 and concluded with LE 3,259,051 in year ten. Thus, it may be concluded that the benefit-cost ratio for the aquaponic system was 1.25. According to Sethi and Sharama,[23] the benefit-cost ratio measures the worth of the project and is acceptable when the B/C ratio is higher than 1.

Table 5 The benefit-cost ratio for the aquaponic system.

Year	Outcome Cash Flow	Income Cash Flow	Net Present Value (NPV) at 10%	
			Income	Outcome
1	4,463,500	3,236,250	3,967,556	2,876,667
2	2,183,425	3,236,250	1,725,175	2,557,037
3	2,183,425	3,236,250	1,533,489	2,272,922
4	2,183,425	3,236,250	1,363,101	2,020,375
5	2,411,433	3,259,051	1,338,174	1,808,542
6	2,183,425	3,236,250	1,077,018	1,596,346
7	2,183,425	3,236,250	957,350	1,418,974
8	2,183,425	3,236,250	850,978	1,261,310
9	2,183,425	3,236,250	756,424	1,121,165
10	2,411,433	3,259,051	742,591	1,003,612
			14,311,857	17,936,948
Outcome/Income			**1.25**	

Source: Calculated from experimental work

3.1.4.4. Internal return rate (IRR) and payback period

Table 6 represents the internal rate of return for the aquaponic system. It is observable that the net cash flow in the first year was (-1,227,250) declined to (+ 847,618) in year 5 and ended with + 847,618 in year 10, where the recorded internal rates of return for the aquaponic system were 84 %. The payback period for the aquaponic system was 2.91 years.

Table 7 shows the internal return rate (IRR) for the fish and lettuce production when the outcome cash flow increased by about 10%. It could be seen that the internal rate of returns for the two above-mentioned systems was 47 % for the aquaponic system.

Table 6 The internal return rate (IRR) for the aquaponic system.

Year	Outcome Cash Flow	Income Cash Flow	Net Cash Flow
1	4,463,500	3,236,250	-1,227,250
2	2,183,425	3,236,250	1,052,825
3	2,183,425	3,236,250	1,052,825
4	2,183,425	3,236,250	1,052,825
5	2,411,433	3,259,051	847,618
6	2,183,425	3,236,250	1,052,825
7	2,183,425	3,236,250	1,052,825
8	2,183,425	3,236,250	1,052,825
9	2,183,425	3,236,250	1,052,825
10	2,411,433	3,259,051	847,618
	IRR	84%	

Source: Calculated from experimental work

Table 7 The internal return rate (IRR) for the aquaponic system when the outcome cash flow increased by about 10%.

Year	Outcome Cash Flow+10%	Income Cash Flow	Net Cash Flow
1	4,909,850	3,236,250	-1,673,600
2	2,401,768	3,236,250	834,483
3	2,401,768	3,236,250	834,483
4	2,401,768	3,236,250	834,483
5	2,652,576	3,259,051	606,475
6	2,401,768	3,236,250	834,483
7	2,401,768	3,236,250	834,483
8	2,401,768	3,236,250	834,483
9	2,401,768	3,236,250	834,483
10	2,652,576	3,259,051	606,475
	IRR	47%	

Source: Calculated from experimental work

Table 8 presents the internal return rate for fish and lettuce production in case of income cash flow decreasing by about 10% in value. One could observe that the IRR for an aquaponic system was 44 %.

Table 9 presents the internal rate of return for fish and lettuce production when the outcome cash flow increased by about 10% and income cash flow decreased by about 10%. It could be seen that the internal rates of return for the aquaponic system were 26 % for the system.

Table 8 The internal return rate (IRR) for the aquaponic system when the income cash flow decreased by about 10%.

Year	Outcome Cash Flow	Income Cash Flow-10%	Net Cash Flow
1	4,463,500	2,912,625	-1,550,875
2	2,183,425	2,912,625	729,200
3	2,183,425	2,912,625	729,200
4	2,183,425	2,912,625	729,200
5	2,411,433	2,933,146	521,713
6	2,183,425	2,912,625	729,200
7	2,183,425	2,912,625	729,200
8	2,183,425	2,912,625	729,200
9	2,183,425	2,912,625	729,200
10	2,411,433	2,933,146	521,713
IRR		44%	

Source: Calculated from experimental work

Table 9 The internal return rate (IRR) for the aquaponic system when the outcome cash flow increased by about 10% and income cash flow decreased by about 10%.

Year	Outcome Cash Flow+10%	Income Cash Flow-10%	Net Cash Flow
1	4,909,850	2,912,625	-1,997,225
2	2,401,768	2,912,625	510,858
3	2,401,768	2,912,625	510,858
4	2,401,768	2,912,625	510,858
5	2,652,576	2,933,146	280,570
6	2,401,768	2,912,625	510,858
7	2,401,768	2,912,625	510,858
8	2,401,768	2,912,625	510,858
9	2,401,768	2,912,625	510,858
10	2,652,576	2,933,146	280,570
IRR		26%	

Source: Calculated from experimental work

Economic Indicators for Aquaponic System The results, as illustrated in Table 10, indicated that the fixed cost, variable cost, and total revenue were 2,280,075, 2,183,425, and 32,408,102 LE, respectively. Benefit/Cost ratio, payback period, and internal return rate accounted for 1.25, 2.91 years, and 84%, respectively.

Table 10 Economic indicators

Fixed cost, LE	Variable cost, LE	Total revenue, LE	Benefit/cost ratio	Payback period, year	Internal return rate,%
2,280,075	2,183,425	32,408,102	1.25	2.91	84

Source: Calculated from experimental work

Optimizing Aquaponics to be Economically Viable:

According to the data presented and analyzed in this paper, a few strategies to consider in optimizing aquaponic systems for higher economic viability include:

1. Maximize Production-Minimize Costs

Intensification of Production: The Stocking density of fish as well as plant density in hydroponic systems has to be increased, keeping in view the optimum water quality and optimum nutrient levels.

Water Quality Optimization: Economic efficiency in filtration and aeration of the water-keeping the levels of dissolved oxygen optimal and at the same time ensuring minimal nutrient losses.

Growing High-Value Crops: Emphasize high-value crops, which are much in demand in the market. It can range from herbs and exotic vegetables to ornamental fishes.

Energy Consumption: Minimize the use of electrical equipment by using energy-saving devices, such as LED lights and low-energy pumps.

Precision Farming Techniques: Exploit the use of sensors and automation for environmental parameter monitoring and control, thus optimizing resource utilization and reducing labor costs.

2. Value Addition Products and Diversification

Value Addition Products Processing and Selling: Add value to the products by smoking the fish, filleting, or processing vegetables to increase the sale value.

Diversify Production: Incorporate new crops or aquatic species to distribute risk and maximize income.

The selling of educational and experiential services incorporates tours, workshops, and training programs since the latter represents a secondary source of revenue.

3. Market and Distribution Strategies

Target Market Niche: High-value products that are in demand by restaurants, gourmet food stores, and online retailers.

Sales can be directly to the consumer through farmers' markets, community-supported agriculture, or sales through the Internet.

Develop relationships with buyers over time to ensure steady demand for the produce and to drive up prices.

Export Markets: Exploit the export markets for value-added crops, such as specialty fish or organic vegetables.

4. Sustainable Practices and Environmental Impact

Minimal Environmental Impact: Impart training on environmental sustainability by reusing water, reducing waste, and using organic fertilizers in their stead.

Certification: Get certification, such as organic or sustainable farming, that gives them an edge to differentiate products for better prices.

Community Participation: Engage local communities in the establishment of aquaponics projects for social and environmental benefits accruing to food security and job creation.

By implementing such strategies, an aquaponic system becomes viable and sustainable economically; hence it contributes to food security and environmental sustainability.

To evaluate the feasibility and sustainability of aquaponics systems, a SWOT analysis was conducted to identify critical factors that could impact their success

Table 11 SWOT analysis

Strengths	Weaknesses
Controlled Environment: The aquaponics system is in a controlled environment. This will allow for optimal growth conditions. **Year-Round Production:** The system allows for year-round production, thus minimizing dependency upon seasonal fluctuations. **Water Conservation:** The water consumption in a recirculating system is minimal. **Sustainable Agriculture:** Accomplished by minimizing chemical usage and waste products.	**Initial Investment:** The initial outlay cost can be very high. **Specialized Knowledge:** It involves some expertise to keep the system running efficiently **Disease and Pest Control:** Constant vigilance to avoid any outbreak **Energy Requirements:** This system needs energy to drive the pumps and lighting requirements of the systems.
Opportunities	**Threats**
Organic Food-Growing Demand: There is an increased demand by consumers for organic and locally sourced produce. **Government Incentives:** Some governments give incentives for sustainable agriculture practices. Diversification The system can easily be expanded to include a wide variety of fish and plant species. **Educational Opportunities**: The system can be used to teach sustainable agriculture	**Climate Change:** Severe weather conditions disrupt the operation of the system. Disease Outbreaks: Diseases in the fish can wipe out the system. **Market Fluctuations:** Fluctuations in the prices of fish and plants affect profitability. **Competition:** More competition from traditional farming and other aquaponic systems.

Source: Extracted based on experimental work's results

Developing Strategies to Optimize Aquaponics

The following strategies, based on SWOT analysis, are put forward for considering methods of optimizing the economic and environmental performance of aquaponics:

Leveraging Strengths

- Controlled Environment: Adopt precise environmental control to maximize production and reduce losses.
- Year-Round Production: Adopt strategies for consistent production, including lighting and temperature conditions.

- Nutrient Recycling: Monitoring of nutrient levels should be done continuously and corrected accordingly for optimization in plant growth and fish health.
- Save on Water: Employ water conservation techniques such as efficient filtration and recycling of the water.

Mitigating Weaknesses

- High Initial Investments: Seek loans or grants to cushion the farmer/entrepreneur from high initial capital investments
- Technical Expertise: Provide adequate training and education amongst farmers and entrepreneurs for capacity building
- Disease and Pest Control: Stringent bio-security measures and early diagnosis of disease
- Wastage of Energy: Energy-efficient equipment and renewable sources of energy

Seizing Opportunities

- Market Niche: Concentrate on niche target markets that are in demand, such as high-class restaurants and organic food stores.
- Government Subsidy: Avail itself of subsidies by the government to assist in aquaponic farming.
- Diversification: Diversify into raising different fish and plant species.
- School and University Tie-ups: Tie up with schools and universities for better promotion of aquaponics with more entrants.

Addressing Threats

- **Climate Change:** Find adaptation strategies to the change in climate, for example - growing weather-resilient varieties of crops besides adopting water-saving methods.
- **Biosecurity and Disease Outbreak:** Practice strict biosecurity; monitor against disease outbreaks.
- **Market Volatility:** Product diversification and move towards value-added products.
- **Competitive Pressure:** Brand your products, add value with packaging, and offer unique products.

Specific Strategies

1- Adoption of Technologies:

- Adopting advanced technologies to reduce labor costs through automated feeding systems, monitoring water quality, and energy-efficient lighting for better production efficiency.

2- Market Research:

- Carry out market research to understand consumer preferences and emerging trends.
- Develop marketing strategies that will help in selling your products and creating brand awareness.

3- Partnerships:

- Engage in local businesses, researchers, and sharing of government agencies.
- Partnering with Distributors/ Retailers: This will help reach more markets.

4- Sustainable Practices:

- Reducing feed inputs in the Aquaculture and avoiding environmental degradation.
- Organic farming practices should be employed in the production of quality organic products.

With these in place, aquaponics would again play a helpful role in food security and sustainable development regarding economic growth and conservation of the environment.

4. Conclusion

An evaluation study was carried out successively for the technical and economic integration between the fish and plant systems. The most important results were as follows: The total costs of the aquaponic system were L.E 4,463,500 for the system. The total revenue for the aquaponic system was 32,408,102 L.E for 10 years. The benefit/cost ratio for the aquaponic system was 1.25 for this study. This study's payback period was 2.91 years. For the aquaponic system, the internal return rate was 84 % for the system. If the outcome cash flow of the system increases by about 10%, the IRR of the system is 47%. If the income cash flow of the system decreases by about 10%, then the IRR for this system is 44%. A system with an increased outcome cash flow of about 10% and decreased income cash flow of about 10% shows an IRR of 26%. To assess the economic viability of aquaponics systems and identify strategies for their optimization.

The SWOT analysis was done to identify the strengths, weaknesses, opportunities, and threats linked with aquaponics. The various analyses pointed out that though aquaponics has great potential for food production in sustainable ways, its major barriers are huge initial investment costs and technical expertise requirements. Further studies are recommended to study more variables affecting the performance of the aquaponic system such as environmental factors.

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التقييم الفني والاقتصادي لنظام الزراعة المائية المتكامل وإنتاج نباتات الخس

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الملخص

استهدف البحث إجراء دراسة فنية واقتصادية لنظام الزراعة المائية المتكامل لإنتاج سمك البلطي ونباتات الخس. حيث تم تقييم إنتاج الأسماك والنباتات من الجانب الفني من خلال تحديد الإنتاجية واقتصاديًا من خلال تقدير التكاليف الإجمالية والإيرادات وفترة الاسترداد ونسبة العائد للتكلفة ومعدلات العائد الداخلي. أظهرت النتائج ان التكاليف الإجمالية لنظام الزراعة المائية 4,463,500 جنيه مصري للنظام. بلغ إجمالي الإيرادات لنظام الزراعة المائية 32,408,102 جنيه مصري (10 سنوات). بلغت نسبة العائد إلى التكلفة لنظام الزراعة المائية 1.25 لهذه الدراسة. بلغت فترة الاسترداد لهذه الدراسة 2.91 سنة. بلغ معدل العائد الداخلي (IRR) لنظام الزراعة المائية 84٪ للنظام. بلغ معدل العائد الداخلي للنظام عندما زاد التدفق النقدي الناتج بنحو 10٪ 47٪. بلغ معدل العائد الداخلي للنظام عندما انخفض التدفق النقدي للدخل 10٪ بلغ نحو 44٪. وقد بلغ معدل العائد الداخلي للنظام عندما زاد التدفق النقدي الناتج بنحو 10٪ وانخفض التدفق النقدي للدخل 10٪ بلغ نحو 26٪.

كما تم إجراء تحليل SWOT لتحديد نقاط القوة والضعف والفرص والتهديدات المرتبطة بالزراعة المائية. وكشف التحليل أنه في حين توفر الزراعة المائية إمكانات كبيرة لإنتاج الغذاء المستدام، إلا أنها تواجه تحديات مثل تكاليف الاستثمار الأولية المرتفعة ومتطلبات الخبرة الفنية.

الكلمات المفتاحية: البلطي، الخس، نظام الزراعة المائية، فترة الاسترداد، معدل العائد الداخلي.