Journal of Aquatic and Terrestrial Ecosystems
2(2)
Received: May 10, 2023
Accepted: June 28, 2024
Published: July 12, 2024

Economic Viability of Agricultural Carbon Sources on Asian Rice (*Oryza sativa Lejeunia 1753.*) and Nile Tilapia (*Oreochromis niloticus*) Production in a Flocponic System

Rono Kenneth[1]*, Matolla Geraldine[1], Manyala Otieno Julius[2] and Masese Onderi Frank[1]

[1]School of Environmental Sciences, Department of Fisheries and Aquatic Sciences, University of Eldoret, 1125-30100, Eldoret, Kenya

[2]School of Special Planning and Natural Resource Management, Jaramogi Oginga Odinga University of Science and Technology, 210-40601, Bondo, Kenya

Abstract

A flocponic system is a fish and plant-based system that uses carbon sources. However, the economic viability of using carbon sources for production remains unknown. Hence, the study assessed the economic viability of utilizing agricultural carbon sourc es in a flocponic system. A complete randomized design was employed in five treatments (wheat-bran, rhodes-hay, maize-cob, maize-stables, lucerne-hay, agricultural carbon sources, and a control (no carbon), each in triplicate. Each treatment and control had Nile tilapia and rice densities of 98 m^{-3} fry and 250 m^{-2} rice, respectively. The fish yield differed among the treatments and control, with lucerne-hay showing the highest output (2.53±0.02 kgm^{-3}) and control having the lowest. The rice yield component also showed variability. Lucerne-hay had the highest grain yield of 5.70±0.25 kgm^{-3}, followed by wheat-bran, rhodes-hay, maize-cob, and maize-stables treatments. The control yielded the lowest weight of grains and rice straws. The flocponic system's profitability varied between the treatment and control groups. Lucerne-hay, wheat-bran, and rhodes-hay generated positive net income, amounting to 1338.39, 474.69, and 266.1, respectively. The benefit-cost ratios for the lucerne-hay, wheat-bran, and Rhodes-hay treatments were greater than one, with lucerne-hay having the highest value (1.72). There was a slight variation in the expense structure ratio; wheat-bran had the lowest value of 0.88. The gross revenue ratio varied between the treatments and the control group; the control had the highest ratio of 145.39, and lucerne-hay had the lowest. The lucerne-hay, wheat-bran, rhodes-hay, and maize-cob treatments yielded a positive return on investment, while the maize-stable treatment and control had a negative return on investment. The proximate composition and cost

Original Article

ISSN: 2960-1118

of the carbon source may have impacted the profitability of the flocponic production. Wheat-bran, lucerne-hay, and rhodes-hay are suitable for flocponic output because of their high productivity and profitability, resulting in a favorable return on investment. These options are economically viable.

Keywords: Flocponic, yield, Nile tilapia, net income, profitability

Correspondence: kennethrono01@gmail.com

Funding: The author received no financial support for the research, authorship and/or publication of this article.

Data Availability Statement: The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

Competing interests: The authors have declared that no competing interests exist.

Issue DOI: https://doi.org/10.69897/jatems.v2i2

Introduction

The United Nations (2015; FAO, 2023) predicts that aquaculture will be able to support the nutritional needs of more than 9 billion people by 2050. Aquaculture is pivotal in supplying nutritious food to an expanding human population (FAO, 2018; Camilla *et al*., 2022). Intensive aquaculture is essential to meet the increasing global demand for aquaculture (Blanchard et al., 2017; Stevens *et al.,* 2018). However, the growing population and the expansion of intensive aquaculture are causing significant concerns about the limited availability of resources (such as water, space, and feed) as well as environmental issues (such as wastewater and solid waste) that can arise from higher stocking densities and increased feed usage (Bohnes *et al*., 2019; Boyd *et al*., 2020). To achieve sustainable intensification of aquaculture and ensure a consistent supply of fish food without causing further harm to the ecosystem or depleting additional resources, it is necessary to adopt a more efficient, environmentally friendly and economically viable approach to aquaculture (Dauda *et al*., 2019; Turchini *et al*., 2019). Hence, the utilization of efficient aquaculture systems, including recirculating systems, aquaponic systems, and biofloc technology, can significantly enhance sustainable fish production by accommodating large fish stocking densities (Thilsted *et al*., 2016; FAO, 2020). However, the operational costs of recirculating and aquaponic systems are higher (Engle *et al*., 2020; Forster & Slaski, 2010).

Vegetables in aquaponics are subject to low prices, whereas fish, materials, and labor costs experience high prices, which ultimately impact profitability (Ani *et al*., 2021). One of these systems is biofloc technology, which uses the idea of a microbial loop to improve fish production. Nevertheless, its functionality relies significantly on electricity, refined carbon sources, and monocultures, hence hindering its ability to generate higher profits (Badiola *et al*., 2018; Walker *et al*.,

https://doi.org/10.69897/jatems.v2i2.128

2020). To maximize profits and recover costs, a sustainable, resource-efficient fish-based strategy is recommended.

A flocponic system is a zero-water exchange system that integrates and enhances the concepts of biofloc and aquaponic technologies (Pinho *et al.*, 2021). Plants and fish utilize accumulated nutrients, by-products, and carbon sources to support their growth in flocponic systems (Boyd *et al.*, 2020). A flocponic system aims to increase economic diversity by producing value-added products like plants, fish, and microbial proteins. It also aims to protect the environment, prevent outbreaks of aquatic diseases, and increase crop and fish production, thereby increasing the value of water and land (Berg, 2002; Ahmed and Garnett, 2011). In addition, flocponics has the capacity for sustainable intensification by producing a greater amount of food in limited land areas without causing any ecological harm (Ahmed and Garnett, 2011). In order for this system to operate well, external carbon sources are necessary. The nutritional composition and osmotic potential of carbon sources influence the growth and development of organisms, resulting in an acceleration of cell division in plants and facilitating fish growth (Sotiropoulos, 2006).

The flocponic and biofloc systems rely heavily on costly commercial concentrations of carbon sugars, which are in high demand but not readily available locally. The most promising alternative carbon sources are crop residues and agro-products like Rhodes hay, lucerne hay, maize cob flour, maize stumbles, wheat bran, rice bran, maize germ, crude palm oil, oil-rich fiber by-products, palm fruits, and cassava root. These products are widely available, easily accessible, abundant, affordable, or even free, and finally disposed of as waste (Heuzé *et al.,* 2016). These agricultural products provide a beneficial combination of calories, fiber, protein, vitamins, minerals, and bioactive and antioxidant compounds in their dry content. These various organic carbon sources are inexpensive and readily accessible in most regions of Kenya (McDonald *et al.*, 2003). Kowalczuk-Vasilev (2010) and Homolka *et al.* (2008) categorized these as dependable sources of high-quality feed because they originate from plants that adapt to changing rain conditions, thereby boosting feed and carbohydrate production. Nevertheless, this novel strategy will effectively tackle the issues linked to inorganic and refined carbon sources. However, it is crucial to comprehend the economic feasibility of these agricultural products to ensure the long-term profitability and financial sustainability of flocponic or any other production system.

Therefore, an economic analysis of various farm products is required for aquaculture enterprises to make sound operational decisions. Aquaculture firms can improve their production processes and increase earnings by considering various carbon sources' cost implications, market trends, and nutritional value. Hence, it is crucial to do an economic assessment of any carbon source, considering key factors such as expenses for raw materials, processing, transportation, and the possibility of achieving economies of scale. Moreover, examining the sustainability and stoichiometric analysis of the carbon sources could yield valuable insights into their overall cost-effectiveness. These tools aid aquaculture businesses in detecting possible risks and opportunities, allowing them to make well-informed choices that lead to long-term success and profitability. Research on the financial feasibility of using carbon sources in flocponics or other

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

related technologies is scarce. The study aimed to fill a knowledge gap on aquaculture technology's economic viability, the impact of carbon source expenses on revenue from fish and rice sales, and the system's overall profitability. Specifically, the study aimed to determine whether using agricultural carbon sources in flocponic technology is economically feasible. As a result, it was projected that using agricultural carbon sources in the flocponic system would increase crop output, leading to higher profitability.

Materials and methods

Study area

The study was conducted at the University of Eldoret fish (UoE) hatchery for 135 days under greenhouse conditions with temperatures ranging from 26 to 30^{o}C. The campus is 9 Km Northeast of Eldoret Municipality on the Eldoret-Ziwa Road. University of Eldoret is within Rift Valley Province, Uasin Gishu County, and Eldoret Town. The region occupies a global position of 0^{0} 35^{0} North and 35^{0} North 12°East at 2180 meters above sea level. The experimental research used rice seeds from the Ahero rice scheme agro-vet Kisumu County. University of Eldoret (UoE) fish hatchery provided the male sex-reversed *O. niloticus* fingerlings for the research experiment.

Experimental design

The experiment was set up in 18 rectangular indoor plastic fish tanks (1.3m by 1m by 1m in length, width, and depth, respectively) using a flocponic system. In each system, Nile tilapia fry with similar mean weight (0.155±0.01g) and length (2.156±0.03cm) were randomly selected and stocked at the same density (98 fry m^{-3}).

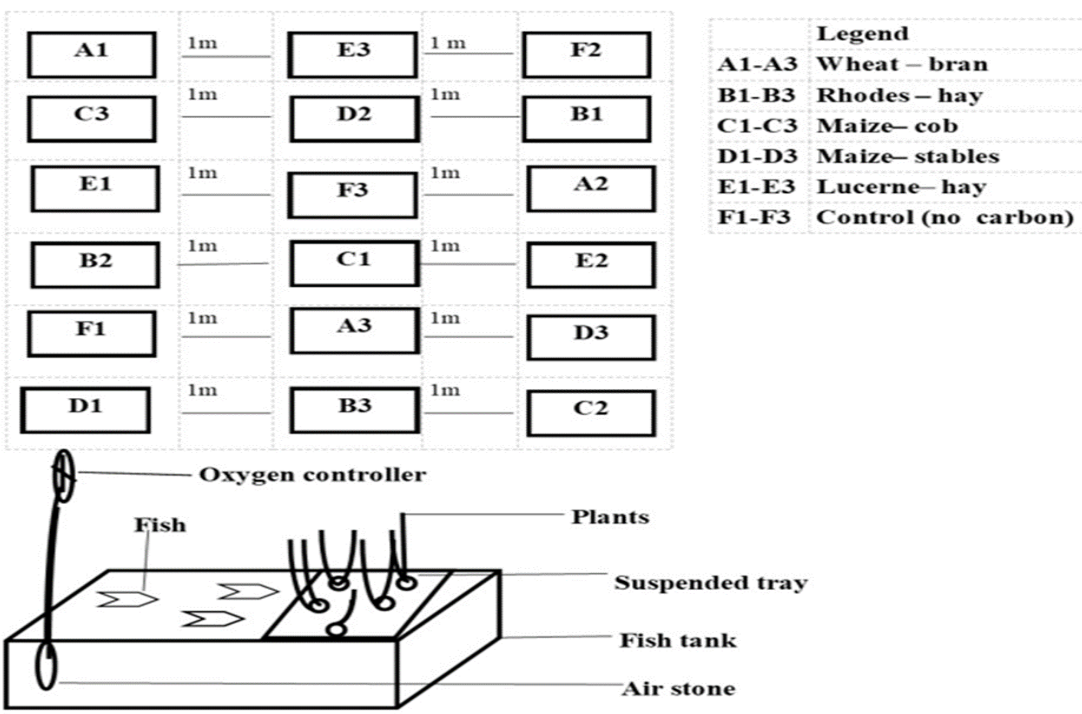

Plate 1: Experimental treatments (wheat-hay, rhodes-hay, maize-cob, maize-stables, and lucerne-hay) and control layout design in a flocponic system

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

Rice seeds with the same density of 250 plants (seeds) per m^{-2} were planted in a suspended plastic egg tray measuring 100 cm by 30 cm in a flocponic fish-holding unit. We added gravel measuring 0.5 inches to the trays to support the germination and growth of the rice seeds. The treatments were done in triplicate in a completely randomized design. The treatments were wheat-bran, rhodes-hay, maize-cobs, maize-stables, lucerne-hay dried ground agricultural carbon sources, and control (no carbon), respectively (plate 1). The stoichiometry analysis helped determine and standardize the daily additions and ratios (C: N of 15:1) of ground agricultural by-products to the system. Continuous aeration was maintained to meet the plant, fish, and microbial oxygen demand by using an air blower mounted with air tubing and air stones in the system. Fish in all treatments received commercial fish diets with the same crude protein (30%) from the Kenya Marine and Fisheries Training Institute in Sangoro. Fish was fed three times daily, at 0930, 1230, and 1630 h.

Fish growth performance determination

At the end of the experiment, all fish from each holding were collected to determine their overall length, weight, survival rate, and weight using the Ricker (1979) method. The fish's weight was determined using a precise electronic balance, which provided a reading with an accuracy of 0.01 g. Furthermore, we used a meter caliper with a precision of 0.1 mm to measure the entire length accurately.

i) $$Weight\ gain\ (W) = Final\ weight\ (W_t) - Initial\ weight\ (W_0) \quad \text{(Eq. 1)}$$

ii) $$Percentage\ Survival\ (\%) = \frac{No.of\ fish\ a\ end\ of\ experiment}{No.of\ fish\ at\ beginning\ of\ experiment} \times 100 \quad \text{(Eq. 2)}$$

Wt. is the weight (g) of the fish at the end of the experiment
Wo is the weight (g) of the fish at the beginning of the experiment

Plant growth and biomass measurements

Rice growth characteristics (number of tillers, number of leaves, and height) were randomly measured weekly (Abbadi *et al.,* 2014). The height of the rice was measured using a ruler to estimate the overall distance from the substrate to the apical meristem in each treatment. The count of leaves and tillers for each treatment was randomly determined using the methodology described by Abbadi *et al*. (2014). At the end of the experiment, a precise electronic balance (WJEUIP, Model WA50002Y, W&J Instrument Co. Ltd., China) with an accuracy of 0.01 mg was used to measure rice yield components (the weight of the rice grains and straws) and determine their total weight (Yoshida, 1981).

Simple and complex sugars analysis of agricultural carbon sources (wheat-bran, rhodes-hay, maize-cob, maize-stables, and lucerne-hay)

The dried ground agricultural by-products (treatments) were extracted for six hours using 80% ethanol to eliminate any free sugars present. The mean fructose concentration in the extracted samples of all the treatments was determined using the standard curve equation, sample absorbance, extract volume, and the actual mass of each tissue sample following the Ashwell (1957) standard procedure. The glucose concentrations were measured using the glucose oxidase method, following the procedures outlined by Ashwell (1957) and Krishnaveni *et al.* (1984). We determined the cellulose using

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

the Updegroff (1969) standard approach. The starch concentration was determined by multiplying the glucose concentration in the tissue remnant by 0.9, which accounts for water loss when glucose units combine to generate starch, following the standard approach described by Hodge & Hofreiter (1962).

Table 1: Mean± SE levels of simple and complex sugars of agricultural by-products (wheat-bran, rhodes-hay, maize-cob, maize-stables, and lucerne-hay)

Carbohydrate (Mg/100ml)	Wheat-bran	Rhodes-hay	Maize-cob	Maize-stables	Lucerne-hay
Starch	51.78±0.62[a]	70.26±0.70[b]	74.18±0.47[c]	20.86±0.74[d]	21.31±0.42[d]
Cellulose	1466.60±16.30[a]	1586.70±27.30[b]	1596.90±20.80[b]	1720.00±16.90[c]	765.00±20.20[d]
Fructose	46.24±0.55[a]	51.33±5.11[a]	32.61±1.76[b]	21.99±0.74[b]	68.77±1.80[c]
Glucose	16.97±0.536[a]	10.94±0.357[b]	9.23±0.279[b]	10.39±0.413[b]	22.16±1.31[c]

Note: *Values with different superscripts (a, b, c, d, e) within the same row are significantly (p<0.05) different.*

Economic analysis

Gross Margin

Gross margin aids in determining profitability when fixed expenses account for a small part of overall production costs. The gross margin is the difference between total revenue and total variable costs, as shown in the equation below (Abah et al., 2013).

GM=TR-TVC..(Eq. 3)

Net income

Net farm revenue was used to evaluate overall profitability after accounting for fixed and variable costs (Engle, 2012). Britton (1970) defines net farm income as an important part of the income, profit, and loss statement. Positive net farm income implies a profit, whereas negative net farm income indicates a loss (Hottel & Gardner, 1983). It was computed by subtracting the total cost from the entire revenue, as stated in the following equation:

NFI=TR-TC..(Eq. 4)

where NFI represents net farm income, TR represents total revenue, and TC represents total cost.

Profitability ration

Profitability ratios were used to evaluate the financial viability of carbon sources in flocponic fish and rice production. According to John *et al*. (2017), profitability ratios are financial computations that determine whether a business can turn a profit by contrasting expenses with revenues over a given time frame. Lesakova (2007) claims that profitability ratios measure a company's capacity to turn a profit, return on investment, and asset management proficiency. Consequently, a profitability ratio is a tool for determining whether a business is generating a healthy enough profit. According to Husain *et al*. (2020), companies that have a strong profitability ratio tend to attract investors, as they are the ones who make long-term investments and consider profitability. Expense structure, gross revenue, benefit-cost ratio (BCR), and return on investment were the

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

profitability ratios used in the current study.

Benefit-Cost Ratio (BCR)

A profitability indicator, the benefit-cost ratio, summarizes a project's or a proposed project's value for money. According to Olaoye *et al.* (2013), a BCR of less than one denotes loss, a BCR of one indicates break-even, and a BCR of greater than one indicates profit. BCR is calculated by weighing total revenue (TR) from fish, rice grains, and rice straw sales against the total cost (TC) of fish production for the production cycle, as shown in the equation below:

BCR=TR/TC ....(Eq. 5)

Expense Structure Ratio (ESR)

The ESR was employed to assess the profitability of a flocponic system that employs carbon sources by determining the proportion of the total fixed expenses. The value is determined by dividing the fixed cost by the total variable cost, as shown in the following equation:

ESR=FC/TVC..(Eq. 6)

Gross Revenue Ratio (GRR)

The gross revenue ratio (GRR) measures the amount spent on returns. The calculation entails dividing the total cost (TC) by the total revenue (TR), as demonstrated by the following equation:

GRR=TC/TR ....(Eq. 7)

Return on Investment (RoI)

The return on investment (RoI) is a profitability measure that aids in evaluating a firm or corporation's profitability (Magni, 2013). The data displays the earnings generated by each flocponic unit, encompassing the profits derived from every KSH invested. The calculation involves dividing the flocponic's total cost (TC) by the profit (P), as illustrated in the following equation:

ROI=P/TC ....(Eq. 8)

Data analysis

Descriptive statistics were employed to evaluate the mean yields of Nile tilapia and rice. The study employed a one-way analysis of variance (ANOVA) in Minitab 19 software to assess significant variations in Nile tilapia yield, rice yield, and Nile tilapia survival between the treatments and control group. The economic feasibility of flocponics was assessed using the following indicators: net income, gross margin, break-even price, benefits-cost ratio, expense structure ratio, gross revenue ratio, and return on investment (Obiero *et al*., 2022).

Results

Table 2 shows the yields of Nile tilapia, rice grains, and rice straw in the flocponic system for treatment and control groups. The rice and fish yields varied ($p = 0.0001$) among the treatments and controls, with lucerne-hay having the highest production volume (15.16 Kgm^{-3}) and the control group achieving the lowest (5.54 Kgm^{-3}). The carbon-based treatments resulted in higher fish production than the control group. Nevertheless, there were variations ($F_{0.05,5}$=1280.13, $p = 0.0001$) in fish yield across the different treatments. The lucerne-hay treatment produced the highest yield (2.53 Kgm^{-3}), followed by wheat-bran, Rhodes-hay, maize-cob, maize-stables, and the control. The yields of rice grains also differed ($F_{0.05,5}$=105.98, $p = 0.0001$) between the treatments and the control; the Lucerne-hay treatment showed the highest grain yields (5.70 Kgm^{-3}), while the control recorded the lowest.

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

Table 2. Yields of Nile tilapia and rice at different agricultural carbon sources wheat-bran, Rhodes-hay, maize-cob, maize-stables and lucerne-hay) and control in flocponic systems

Parameters	CARBON SOURCES							
	Wheat-bran	Rhodes-hay	Maize-cob	Maize-stables	Lucerne-hay	control	F-value	p-value
Fish yield (Kgm^{-3})	2.11±0.01^{a}	1.83±0.01^{b}	1.62±0.02^{c}	1.35±0.01^{d}	2.53±0.02^{e}	1.36±0.01^{d}	1280.13	0.0001
Rice grain Yield (Kgm^{-3})	3.41±0.12^{a}	3.31±0.14^{a}	2.56±0.13^{b}	2.36±0.07^{c}	5.70±0.25^{d}	2.09±0.04^{e}	105.98	0.0001
Rice straw yield (Kgm^{-3})	5.58±0.14^{a}	4.84±0.08^{a}	3.18±0.01^{b}	2.41±0.02^{c}	6.93±0.03^{d}	2.09±0.04^{e}	798.42	0.0001
Total yield (Kgm^{-3})	11.02	9.98	7.36	6.12	15.16	5.54		

Furthermore, similar results were observed for rice straw yield, with lucerne-hay being the best-performing treatment with the highest rice straw yield of 6.93 Kgm^{-3}.

Table 3 presents an evaluation of gross revenue, total variable, total fixed cost, total cost, gross margin, net income, and price breakeven. The Lucerne-hay treatment generated the highest gross revenue from yields (3192.41 Kshs), while the control had the lowest (1274.20 Kshs). The total variable cost differed slightly, with the wheat-bran treatment having the highest TVC. The total fixed cost was comparable between the treatments and the control group. The gross margin exhibited variation, with the lucerne-hay treatment yielding the highest value (2223.39 Kshs), while the control group yielded the lowest value (306.60 Kshs). The net income exhibited variability between the different treatment and control groups. Lucerne-hay, wheat-bran, and Rhodes-hay treatments showed a favorable net income, whereas maize-cob and maize-stables treatment and control showed a negative income. The Lucerne-hay, wheat-bran, and Rhodes-hay treatments had a lower price break-even point compared to the sale cost per production volume. This means that the revenue generated was sufficient to cover the variable costs and generate profits. In contrast, the control, maize-cob, and maize-stable treatments had a higher price break-even point than the sale cost per production volume. Table 4 shows the profitability ratio results (BCR, ESR, GRR, and RoI). BCR differed between the control and treatment groups. The Lucerne-hay treatment had the highest benefit-cost ratio (BCR) value of 1.72, followed by the wheat-bran, Rhodes-hay, maize-cob, and maize-stable treatments. The control treatment had the lowest BCR, 0.69. The expense structure ratio (ESR) also differed slightly, with wheat-bran having the lowest ESR value of 0.88. The gross revenue ratio (GRR) also varied between treatments and controls, with control having the highest GRR value of 145.39 and lucerne-hay having the lowest GRR value of 58.08. The return on investment (RoI) displayed both negative and positive percentages. Treatments with wheat-bran, Rhodes-hay, and lucerne-hay showed a positive return on investment, whereas maize-cob, maize-stables carbon sources, and control had a negative percentage RoI.

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

Table 3: Cost and returns (Kshs) and in flocponic systems at different agricultural carbon sources (wheat-bran, Rhodes-hay, maize-cob, maize-stables, and lucerne-hay) and control

	CARBON SOURCES					
Parameter (Kshs)	Wheat-bran	Rhodes-hay	Maize-cob	Maize-stables	Lucerne-hay	Control
Revenue from fish yield (Kshs)	845.21	731.95	645.84	539.14	1013.69	543.82
Revenue from rice seeds yield	681.78	661.56	512.22	471.24	1138.92	417.42
revenue from rice straw (stables) yield	836.70	725.70	477.12	360.99	1039.80	312.96
Gross revenue (Total revenue)	2363.69	2119.21	1635.18	1371.37	3192.41	1274.20
variable costs						
fish feeds	120.85	120.00	120.00	119.00	121.2	120.00
Carbon source	50.00	20.00	15.00	10.00	20.00	0.00
water	130.00	130.00	135.00	140.00	130.00	150.00
Electricity	350.00	350.00	350.00	350.00	350.00	350.00
miscellaneous	200.00	200.00	200.00	200.00	200.00	200.00
Sub-total variable costs	850.85	820.00	820.00	819.00	821.20	820.00
Interest on operating cost	153.153	147.60	147.60	147.42	147.816	147.60
Total variable cost (TVC)	1004.003	967.60	967.60	966.42	969.016	967.60
Fixed Costs						
Fish holding unit	450.00	450.00	450.00	450.00	450.00	450.00
air pump	200.00	200.00	200.00	200.00	200.00	200.00
amortization	100.00	100.00	100.00	100.00	100.00	100.00
sub-total fixed cost	750.00	750.00	750.00	750.00	750.00	750.00
Interest on the fixed cost	135.00	135.00	135.00	135.00	135.00	135.00
Total fixed cost	885.00	885.00	885.00	885.00	885.00	885.00
Total cost (TC)	1889.00	1852.60	1852.60	1851.42	1854.02	1852.60
Net return TVC (Gross margin)	1359.69	1151.61	667.58	404.95	2223.39	306.60
Net return TC (Net income)	474.69	266.61	-217.42	-480.05	1338.39	-578.40
Cost Per Unit (CPU)	212.95	212.44	222.28	224.42	210.57	230.29
Break-even price (BEP)	170.18	185.71	251.83	302.98	122.29	334.83
margin (CPU and BEP)	122.50	115.44	90.75	66.27	146.65	55.41

Note: *1 USD =120 average exchange rate during the 2023 production cycle.*

ISSN: 2960-1118

Table 4: Profitability ratio (Kshs) in flocponic system at different treatments (wheat-bran, Rhodes-hay, maize-cob, maize-stables, and lucerne-hay carbon sources) and control

Parameter	CARBON SOURCES (TREATMENTS)					
Profitability ratios	Wheat-bran	Rhodes-hay	Maize-cob	Maize-stables	Lucerne-hay	Control
BCR (Benefit-cost ratio)	1.25	1.14	0.88	0.74	1.72	0.69
ESR (Expense Structure ratio)	0.88	0.92	0.92	0.92	0.91	0.92
GRR (Gross revenue ratio)	79.92	87.42	113.29	135.01	58.08	145.39
RoI (Return on investment) %	25.13	14.39	-11.74	-25.93	72.19	-31.22

Note: 1 *USD =120 average exchange rate during the 2023 production cycle.*

Discussion

A feasibility assessment was conducted to explore the potential of incorporating agricultural carbon sources into the flocponic system. This assessment involved analyzing profitability ratios, net income, break-even price, variable and fixed costs, and revenue generated. The findings indicate that the costs associated with inputs such as fish feeds, carbon sources, and energy can have an impact on the revenue generated from fish, rice grains (seeds), and rice straw production. This reveals that an increase in feed, carbon, and electricity costs might lead to a substantial decline in revenue for the flocponic system. According to Obiero *et al*. (2022), the price of fish feeds and other inputs, such as fish seeds, are some of the variables influencing aquaculture's total cost of production. Similarly, Musa *et al.* (2021) proposed that factors such as seeds and fish feeds have a significant role in determining farm revenue within the tilapia business. The present investigation, however, specifically examined flocponic production and discovered that carbon sources and electricity played a substantial role in influencing income. According to current findings, electricity accounted for approximately 41% of the total variable cost. The total variable cost differed slightly between the treatments and the control group. In terms of total variable cost, wheat-bran was the most expensive treatment, followed by lucerne-hay. Nevertheless, the lucerne-hay treatment had the highest gross income, followed by wheat-bran, while the control had the lowest. This suggests that the lucerne-hay and wheat-bran treatments directly enhanced the growth yield of fish and rice in the flocponic system. The stoichiometry and sugar proximate analysis of wheat-bran and lucerne-hay revealed a higher ratio of simple sugars to complex sugars. This could potentially contribute to enhanced rice and fish yields. According to Luciana *et al.* (2021), the inclusion of glucose or sucrose in banana tissue culture results in a rise in fresh weight. According to Li *et al*. (2020) and Chu and Brown (2021), the addition of carbon sources to an integrated system enhances the conditions for plant growth by promoting nutrient absorption, leading to increased crop yield and reduced phytotoxicity. In addition, Manan *et al*. (2020) found that bacteria had a greater ability to break

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

down simple carbohydrates than complex carbohydrates. This leads to an increase in microorganisms, as well as improved water quality and fish nutrition. The gross margin and net return/income results differed between carbon-based flocponics and control. All treatments exhibit a favorable gross margin, indicating substantial profitability.

The lucerne-hay treatment yielded the best gross margin, followed by the wheat-bran, Rhodes-hay, maize-cob, and maize-stable, while the control had the lowest gross margin. These findings indicate that lucerne-hay and wheat-bran are more economically advantageous carbon sources when utilized in flocponic systems. Nevertheless, the net return or income differed among the treatment and control groups. Both the maize-cob and maize-stable treatments, as well as the control group, showed negative values. This shows a shortfall in these carbon sources in flocponic production. The lucerne-hay, wheat-bran, and Rhodes-hay led to a positive net income, indicating that these carbon sources improve the economic viability of the flocponic system. The profitability ratio is a set of financial metrics that allow investors to assess a company's ability to generate profits and sustainability by considering its operational costs and other relevant expenses over a specific period (Subedi *et al.*, 2019).

The profitability ratios, including the Benefit-Cost Ratio (BCR), Economic Sustainability Ratio (ESR), Gross Revenue Ratio (GRR), and Return on Investment (RoI), exhibited differences among the various treatments and the control group. The lucerne-hay, wheat-bran, and Rhode-hay treatments had more than one BCR, indicating that they were more profitable than the maize-cob, maize-stable, and control treatments, which had less than one BCR. As per Investopedia (2019), a business is considered profitable when its costs are lower than its benefits, which is shown by a cost-benefit ratio over one. The expenditure structure ratio for each treatment revealed that in the flocponic system, fixed costs constitute a minor proportion of the total cost involved in producing Nile tilapia and rice. Using lucerne hay and wheat bran as carbon sources reduces the cost of managing flocponic production compared to using Rhodes hay, maize cob, and maize stables. Investors can afford to invest in a flocponic system powered by lucerne-hay and wheat-bran carbon sources because their ESR values are lower.

The GRRs exhibited variation among the treatment groups and the control group. Lucerne-hay, wheat-bran, and Rhodes-hay carbon sources spend 58, 80, and 87 cents for every KSH return on the flocponic production, respectively; in contrast, maize-cob, maize-stable carbon sources, and the control group spend 100 cents (1 KSHs) for every Kenyan Shilling (KSH) return. As a result, 42%, 20%, and 13% of the returns from lucerne-hay, wheat-bran and Rhodes-hay carbon sources, respectively, are retained as gross profits, indicating the profitability of these carbon sources in comparison to maize-cob, maize-stable carbon sources, and control, which yield a negative return.

Similarly, employing Lucerne hay, wheat bran, and Rhodes hay carbon sources in a flocponic system results in a good return on investment. This means that when utilizing lucerne-hay, wheat-bran, and Rhodes-hay, the farmer earns 72%, 25%, and 14%, respectively, of the profit for each KSH spent, demonstrating that these carbon sources are the most profitable in a flocponic system. In addition, the break-even prices for flocponic production were 170, 186, 252, 303, 122 and 335 for wheat-bran, Rhodes-

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

hay, maize-cob, maize-stables, lucerne-hay carbon sources, and control, respectively. The break-even prices for maize-cob, maize-stables carbon sources, and control were higher than the actual production volume price when compared to wheat-bran, Rhodes-hay, and lucerne-hay. This suggests that wheat-bran, Rhodes-hay, and lucerne-hay are more lucrative carbon sources in flocponic production. According to Ani *et al*. (2021), Tokunaga *et al.* (2015), Engle (2015), and Shoko *et al.* (2016), the break-even price is an important economic aspect in any agribusiness because it serves as a measure of profitability by measuring production costs. The increased gross margins, net income, and improved profitability ratios observed in lucerne-hay, wheat-bran and Rhodes-hay can be attributed to the presence of bioactive compounds (nutrient profiles, sugars, and minerals) in this carbon source. These compounds enhance the availability of nutrients, water, and bacterial biomass, potentially leading to higher volumes of rice and Nile tilapia production and consequently improving revenue profitability indicators. Despite limited research and publication on the topic, it is now recognized that the choice of a carbon source in a flocponic system has a substantial influence on the system's potential profitability.

Conclusion and Recommendation

Agricultural carbon sources have had a considerable impact on flocponic yields and profitability. The use of agricultural carbon sources in flocponics greatly increased the productivity of Nile tilapia and rice. Overall, the results suggest that lucerne-hay, wheat-bran, and rhodes-hay performed better than other treatments and controls. The economic feasibility of using different agricultural carbon sources in flocponics and control methods varied. The study revealed a significant influence of carbon expenses on the profitability of flocponic systems. Lucerne-hay, wheat-bran, and Rhodes-hay were found to be highly profitable and valued, resulting in a good gross margin, net income, and return on investment. The composition of these carbon sources may have resulted in increased fish and rice yields in a flocponic system, boosting profitability. Therefore, it is advisable to use wheat-bran, rhodes-hay, and lucerne-hay in flocponic production since they improve profitability. Nevertheless, lucerne-hay was proven to be the most beneficial option in generating more profit. Hence, farmers should consider the cost and availability of these recommended goods if they intend to use them.

References

Abah, D., Zaknayiba, D.B. & Simon, E. (2013) Economic analysis of fish marketing in Lafia local government area of Nasarawa State, Nigeria. Production Agriculture and Technology Journal*, 9(2), 54–62. http:// patnsukjournal.net/Vol9No2/P5.pdf*

Abbadi, J., Joska, G., & Burkhard, S. (2014). Effects of nitrogen supply on growth, yield, and yield components of safflower and sunflower. Plant soil. http://dx.doi.org/10.1007/s11104-008-9569-5.

Ahmed, N., Garnett, S.T. (2011) Integrated rice-fish farming in Bangladesh: meeting the challenges of food security. Food Security 3:81–92. https://doi.org/10.1007/s12571-011-0113-8.

Ani, J. S., Manyala, J. O., Fitzsimmons, K. M., and Masese, F. O. (2021). Effects of stocking density on growth, water quality, and economic performance of monosex Nile tilapia (*Oreochromis niloticus*) reared in the aquaponics system. Aquaculture and Fisheries, https://doi.org/10.1016/J.AAF.2021.03.002.

Ani, J. S., Masese, F. O., Manyala, J. O., and Fitzsimmons, K. (2021). Assessment of the Performance of Aquaponics and its Uptake for Integrated Fish and Plant Farming in

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128
Sub-Saharan Africa. Vol 4, pp123-138, Africa Environmental Review-Journal. http://www.aer-journal.info/.

Ashwell, G. (1957). In Methods in Enzymol 3 (*Eds* Colowick, S J and Kaplan, N O) Academic Press New York p 75.

Badiola, M., Basurko, O. C., Piedrahita, R., Hundley, P., and Mendiola, D. (2018). Energy use in Recirculating Aquaculture Systems (RAS): A review. Aquaculture Engineering 2018; 81:57-70. https://doi.org/10.1016/j.aquaeng.2018.03.003.

Berg, H. (2002). Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam-economic and ecological considerations, Vol 41, 95-107, Ecological economics. https://doi.org/10.1016/S0921-8009(02)00027-7.

Blanchard, J. L., Watson, R. A., Fulton, E. A., Cottrell, R. S., Nash, K. L., Bryndum-Buchholz, A., B€uchner, M., Carozza, D. A., Cheung, W. W. L., and Elliott, J. (2017). Linked sustainability challenges and trade-offs among fisheries, aquaculture, and agriculture. Nature Ecology Evolution, 1(9):1240–1249. doi: 10.1038/s41559-017-0258-8

Bohnes, F. A., Hauschild, M. Z., Schlundt, J., and Laurent, A. 2019. Life cycle assessments of aquaculture systems: a critical review of reported findings with recommendations for policy and system development. Review in Aquaculture 11(4): 1061–1079. https://doi.org/10.1111/raq.12280.

Boyd, C. E., Abramo, L. R. D., and Glencross B. D. (2020). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. Journal of World Aquaculture Society, 51 (3):578-633. https://doi.org/10.1111/jwas.12714.

Britton, D.K. (1970) The analysis of net farm income: an examination of farm management survey data. *Journal of* Agricultural Economics, 21(3), 351–389. https://doi.org/10.1111/j.1477-9552.1970.tb01390.x

Camilla, C., David, W., Jasmin, S., and David, C. A. (2022). Sustainable Intensification of Aquaculture through Nutrient Recycling and Circular Economies: More Fish, Less Waste, Blue Growth, Reviews in Fisheries Science & Aquaculture, 30:2, 143-169, https://doi.org/10.1080/23308249.2021.1897520.

Chu, Y. T., & Brown, P. B. (2021). Sustainable Marine Aquaponics: Effects of Shrimp to Plant Ratios and C/N Ratios. Frontier in Marine Science. 8:771630. DOI:10.3389/fmars.2021.771630

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A. S., and Akinwole, A. O. (2019). Waste production in aquaculture: Sources, components, and management in different culture systems. Aquaculture and Fisheries 4(3):81–88. https://doi.org/10.1016/j.aaf.2018.10.002.

Engle, C. R. (2015). Economics of Aquaponics. SRAC publication - Southern Regional Aquaculture Centre, No. 5006(5006), 4.

Engle, C. R., Kumar, G., and van Senten, J. (2020). Cost drivers and profitability of U.S pond, raceway, and RAS aquaculture. Journal of the World Aquaculture Society 1–27. http://dx.doi.org/10.1111/jwas.12706.

Engle, C.R. (2012) Determining the profitability of an aquaculture business: using income statements and enterprise budgets. Southern Regional Aquaculture Center *(SRAC)*, 4402, 1-6.

FAO. (2018). The State of World Fisheries and Aquaculture-Meeting the sustainable development goals. Rome: Fao. https://www.fao.org/3/i9540en/I9540EN.pdf.

FAO. (2020). The State of World Fisheries and Aquaculture. Food and Agriculture Organization of The United Nations (FAO); https://doi.org/10.4060/ca9229en.

FAO. (2023). The Global Sustainable Aquaculture Roadmap: Pathways for Systemic Change White Paper

Forster, J., and Slaski, R., (2010). Lessons from unsuccessful farms. In: Chadwick, E.M.P., Parsons, G.J., Sayavong, B. (Eds.), Evaluation of Closed-Containment Technologies for Saltwater Salmon Aquaculture. NRC Research Press, Ottawa, p. 21.

Heuzé, V., Tran, G. and Lebas, F. (2016). Maize Cobs. Feedipedia, a Programme by INRA, CIRAD AFZ, and FAO. https://www.feedipedia.org/node/718.

Hodge, J. E., & Hofreiter, B. T. (1962). In: Methods in Carbohydrate Chemistry (eds Whistler, R L and Be Miller, J N) Academic Press New York

Homolka, P., Koukolova, V., Němec, Z., Mudřik, Z., Hučko, B., and Sales, J. (2008). Amino acid contents and intestinal digestibility of lucerne in ruminants as influenced by growth stage. Czech Journal Animal

ISSN: 2960-1118

Science, 53, 2008 (12): 499–505. https://doi.org/10.17221/367-CJAS.

Hottel, J.B. & Gardner, B.L. (1983) The rate of return to investment in agriculture and measuring net farm income. American Journal of Agricultural Economics, 65(3), 553–557.

Husain, T., Sarwani, Sunardi, N. & Lisdawati. (2020) Firm's value prediction based on profitability ratios and dividend policy. Finance & Economics Review, 2(2), 13–26. https://doi.org/10.38157/financeeconomics-review. v2i2.102

Investopedia. (2019). Benefit-Cost Ratio. Corporate Finance & Accounting: Financial Ratios. https://www.investopedia.com/terms/b/bcr.asp.

John, A.O., Emmanuel, A.O., Ogbonna, C.G., Chidinma, N.L., Bolatito, S., Ayodeji, A.T., et al. (2017) Profit analysis of fish farming enterprises in ikenne local government area of Ogun State, Nigeria. *Asian Journal of* Agricultural Extension, Economics & Sociology, 18(1), 1–8. https://doi.org/10.9734/AJAEES/2017/28219

Kowalczuk-Vasilev, E. (2010). Skład chemiczny, wartość pokarmowa i przydatność produktów z lucerny w żywieniu ludzi i zwierząt [Chemical composition, nutritive value and usefulness of alfalfa products in human and animal nut]. In: Alfalfa in human and animals' nutrition. T. 6. Monographic E.R. Grela. Stow. Rozw. Reg. Lokaln. "Progress" Dzierdziówka – Lublin, 13-25 [in Polish].

Krishnaveni, S., Theymoli, B., & Sadasivam, S. (1984). Sugar Distribution in Sweet Stalk Sorghum. *Food Chemistry* 15, 229-232. http://dx.doi.org/10.1016/0308-8146(84)90007-4

Lesakova, L. (2007) Uses and limitations of profitability ratio analysis in managerial practice. In: *International conference on management*. pp. 259–264. http://kgk.uni-obuda.hu/system/files/24_Lesakova.pdf.

Li, S., Zhao, X., Ye, X., Zhang, L., Shi, L., & Xu, F. (2020). The effects of condensed molasses soluble on the growth and development of rapeseed through seed germination, hydroponics, and field trials. Agriculture 10, 1–20. https://doi.org/10.3390/agriculture10070260

Luciana, A. D., Paula S. A. F., Bruno, M. M. D., Ana, L. M. A., Fabiano, G. S., Roniel, G. A., Paulo, S. P., & Aurélio, R. N. (2021). The impact of carbon source on cell growth and the production of bioactive compounds in cell suspensions of *Hancornia speciosa* Gomes. Scientific Reports 11:24315 https://doi.org/10.1038/s41598-021-03845-0

Magni, C.A. (2013) Average internal rate of return and investment decisions: a new perspective. *The Engineering Economist*, 1(April), 37–41. https://www.tandfonline.com/doi/abs/10.1080/00137911003791856

Manan, H., Amin-Safwan, A., Kasan, N. A., and Ikhwanuddin, M. (2020). Effects of biofloc application on survival rate, growth performance and specific growth rate of pacific white leg shrimp, Penaeus vannamei culture in closed hatchery system. Pakistan Journal of Biological Sciences, 23: 1563-1571. http://dx.doi.org/10.3923/pjbs.2020.1563.1571.

McDonald, W., Nikandrow A., Bishop A., Lattimore, M., Gardner, P., and Williams, R. (2003). Effect of Plant Growth Stimulants on Alfalfa Response to Salt Stress. Lucerne for pasture and fodder. Vol. (8) 4, Agriculture Science.

Musa, S., Aura, C. M. and Okechi, J. K. (2021) Economic analysis of tilapia cage culture in Lake Victoria using different cage volumes. Journal of Applied Aquaculture, 34(3), 674–692. https://doi.org/10.1080/10454438.2021.1884632.

Obiero, K., Brian Mboya, J., Okoth Ouko, K. and Okech, K. (2022) Economic feasibility of fish cage culture in Lake Victoria, Kenya. Aquaculture, Fish and Fisheries, 2, 484–492. https://doi.org/10.1002/aff2.7.

Olaoye, O.J., Ashley-Dejo, S.S., Fakoya, E.O., Ikeweinwe, N.B., Alegbeleye, W.O., Ashaolu, F.O., et al. (2013) Assessment of socio-economic analysis of fish farming in Oyo State, Nigeria. Global Journal of Science Frontier Research Agriculture and Veterinary, 13(9), 197–208.

Pinho, S. M., Jessica, P. L., Luiz, H. D., Mauricio, G. C. E., Samon, G., Marc, C. J. V., Karel, J. K., and Maria, C. P. (2021). Flocponics: The integration of biofloc technology with production. Review in aquaculture, 00:1-29, http://dx.doi.org/10.1111/raq.12617.

Ricker, W. E. (1979). 11-Growth rates and models. Fish physiology, Vol. 8, pp 677-743. https://doi.org/10.1016/S1546-5098(08)60034-5.

ISSN: 2960-1118

https://doi.org/10.69897/jatems.v2i2.128

Shoko, A. P., Limbu, S. M., and Mgaya, Y. D. (2016). Effect of stocking density on growth performance, survival, production, and financial benefits of African sharp tooth catfish (*Clarias gariepinus*) monoculture in earthen ponds. Journal of Applied Aquaculture, 28(3), 220-234. https://doi.org/10.1080/10454438.2016.1188338.

Sotiropoulos, T. (2006). Sucrose and Sorbitol effects on shoot growth and proliferation in vitro, nutritional status, and peroxidase and catalase isoenzymes of M 9 and MM 106 apple (Malus domestica Borkh.) rootstocks. European Journal of Horticulture Science 71(3):114–119.

Stevens, J. R., Newton, R. W., Tlusty, M., Little, D. C. (2018). The rise of aquaculture by-products_ Increasing food production, value, and sustainability through strategic utilisation. Mar Policy. 90:115–124. https://doi.org/10.1016/j.marpol.2017.12.027.

Subedi, P., Pandit, N. P., Mahato, N. K., Karki, M., and Uprety, A. (2019). Economic analysis of fish production using different feed types practiced in Dhanusha district, Nepal. Journal of Agriculture and Natural Resources, 2(1), 252-264. DOI: https://doi.org/10.3126/janr.v2i1.26084.

Thilsted, S. H., Thorne-Lyman, A., Webb, P. (2016). Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. *Food Policy*. 61:126-131. https://doi.org/10.1016/j.foodpol.2016.02.005.

Tokunaga, K., Tamaru, C., Ako, H., and Leung, P. (2015). Economics of Small-scale Commercial Aquaponics in Hawaii. Journal of the World Aquaculture Society, 46(1), 20-32. https://doi.org/10.1111/jwas.12173.

Turchini, G. M., Trushenski, J. T., and Glencross, B. D. (2019). Thoughts for the future of aquaculture nutrition: realigning perspectives to reflect contemporary issues related to judicious use of marine resources in aquafeeds. North Am J Aquaculture. 81(1):13–39. https://doi.org/10.1002/naaq.10067.

United Nations, (2015). World Population Prospects: The 2015 Revision, Key Findings, and Advance Tables. New York (USA): United Nations. Working Paper No.: ESA/P/WP.241.

Updegroff, D. M. (1969). Semimicro-determination of cellulose in biological materials *Analytical Biochemistry* 32 420. https://doi.org/10.1016/s0003-2697(69)80009-6

Walker, D. A. U., Morales-Suazo, M. C., and Emerenciano, M. G. C. (2020). Biofloc technology: principles focused on potential species and the case study of Chilean river shrimp *Cryphiops caementarius*. Reviews in Aquaculture. 12(3):1759-1782. https://doi.org/10.1111/raq.12408.

Yoshida, S. (1981). Fundamental of Rice Crop Science. Los Baños, Laguna, the Philippines: International Rice Research Institute: 269.

ISSN: 2960-1118