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Full Length Research

Integrated farming system for sustainable agricultural production

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ABSTRACT: Integration of animal production, aquaculture and crop integration is essential for maximizing water and land productivity. Thus, the increase in global water scarcity and the dual use of water for poultry, crop and fish production has the potential to optimize water use, dispose of aquaculture wastes, provide additional nutrients to crops, and reduce inorganic fertilizer usage, thus maximizing farm productivity. This screen house study was conducted to determine the effects of broilers, and juvenile catfish on the growth, yield parameters, and yield of tomatoes (Solanum lycopersicum L.). The fishes fed on poultry manure while the tomatoes were watered with filtered water from the fishpond. The water changed from the fishpond is irrigated into the screen house; this water serves as fertilizer for the tomatoes as it contains aqueous ammonia. There was a remarkable growth of the tomatoes. The waste from the broilers affected the fish in terms of growth and also had an effect on the pond water properties. The physicochemical properties of the pond water contribute to the performance of tomato properties.

Keywords: Broilers, Juvenile catfish, Tomatoes, Sustainable agriculture.

INTRODUCTION

Integrated agriculture-aquaculture boasts a rich history spanning over 1500 years in Asia, particularly in India. At its core, the principle on which integrated farming operates is that ‘there is no waste’. It means that waste can be repurposed as valuable input for other components. The fundamental tenets of the integrated farming system revolve around harnessing the synergistic effects of interrelated farm activities and conserving resources, emphasizing the comprehensive utilization of farm wastes. It has been observed that fish cum poultry farming enhances the efficiency of marginal and small farms. The integration of different agricultural systems has gained significant attention as a means to enhance sustainability, improve food security, and optimize resource use. Integrated farming systems (IFS) that combine livestock, aquaculture, and crop production have shown promising results in various regions worldwide. Specifically, the integration of poultry, juvenile catfish, and tomatoes represents a multifaceted approach to sustainable agriculture that can address nutritional deficiencies and enhance economic viability (Okeke-Ogbuafor *et al*., 2024; Ullah *et al*., 2020; Huong *et al*., 2018). The concept of integrated farming systems is not new; it has been practised for centuries in various forms. Recent studies have highlighted the advantages of integrating fish farming with poultry and vegetable production as shown in Figure 1. For instance, Okeke-Ogbuafor *et al.* (2024) emphasizes the need for nutrition-sensitive fish farming to combat malnutrition in Africa, suggesting that integrating poultry and fish can yield satisfactory results in terms of productivity and health. Similarly, Ullah *et al*. (2020) report that fish-poultry integration is prevalent in Bangladesh, demonstrating its economic benefits and efficiency.

Moreover, the integration of vegetables, such as tomatoes,

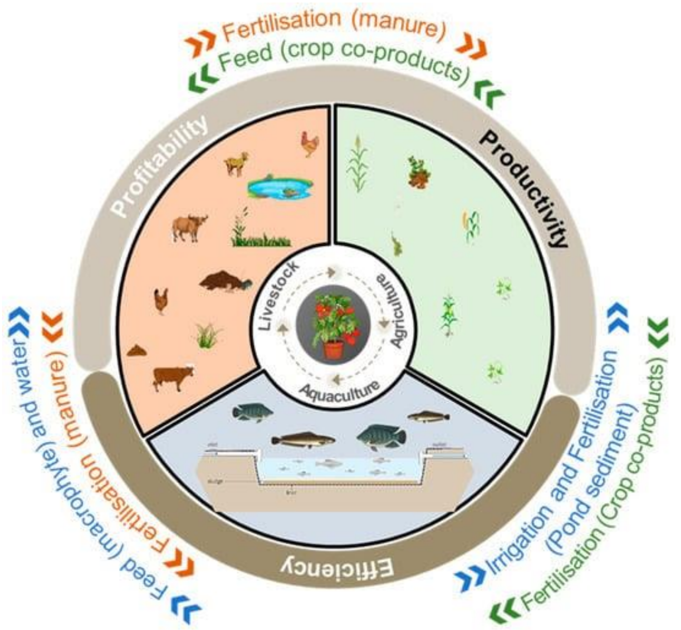

Figure 1. Potential benefits from the integration of aquaculture, livestock, and agriculture (Source: Okeke-Ogbuafor *et al*., 2024).

into these systems can further enhance sustainability. Research by Huong *et al*. (2018) indicates that integrated aquaculture systems contribute significantly to food security and economic development. The TAC (Tomatoes, Aquaculture, and Livestock) model exemplifies how such integration can improve household nutrition and income (Huong *et al*., 2018). The rational use of water in agriculture is of paramount importance as the world's freshwater resources are under increasing threat. It is estimated that 70% and 80% of the world's freshwater is used for crop irrigation, while water use conflicts are expected to increase in arid and semi-arid regions due to recurrent droughts, severe water scarcity, and acute food insecurity (De Wrachien *et al*., 2021). Fish and poultry farming is a comprehensive system that amalgamates fish farming and poultry farming. In this arrangement, fish rely on poultry droppings or deep litter materials as their primary feed. The underlying concept of integrated poultry and fish farming aims to establish a symbiotic system that maximizes productivity through optimal resource utilization This paper explores the potential benefits and challenges of such an integrated system, drawing on empirical data and existing research.

MATERIALS AND METHODS

Experimental site

The experiment was carried out in the backyard of the Department of Fisheries Technology of Oyo State College of Agriculture and Technology Igboora, Nigeria.

Experimental birds and management

A total of 100 poultry birds, 1000 juvenile catfish, and a designated area for tomato cultivation were integrated into a pilot farm setup. The broiler chickens were housed in a one-unit battery cage. The birds were placed on both sides of the cage with equal numbers on both sides. Experimental diets were introduced from 4-8 weeks and fed for the duration of the experiment. The birds ate the same diets.

480 juvenile African catfish with an average weight of 6.2±0.2g were obtained from a local catfish producer and used for the study. The juveniles were raised in two (2) experimental earthen ponds (4 m x 6 m x 1 m each) and identified as ponds A and B. No treatment was applied to Pond A, while Pond B was fertilized using broiler droppings at the rate of 100 g/m^2 (Ndome *et al.,* 2011). Both ponds were stocked with 240 juvenile Catfish each, according to FAO stocking recommendation of Catfish seeds. The fish in both ponds were fed with supplementary commercial fish feed at the rate of 5% body weight for 12 weeks.

The seedlings were raised under shades made from palm fronds for four weeks. A screen house was constructed where the seedlings were transferred. The soil was bagged using seed pots and the seedlings were transferred to the seed pots placed inside the screen house. A drip tape was passed from the fishpond to the screen house, well placed on each of the seed pots. The water from the fishpond was filtered before passing it to the drip tape.

This research integrated crop, poultry and fish farming at a time by using a technique in order to manage the poultry farm, fish farm and produce crops. The fish were fed on poultry manure and the remaining manure of poultry birds and waste were used as fertilizer to raise tomatoes. When the water of the fishpond is changed, the water is passed through tape drip to the crops. Broiler waste produces ammonia and when these wastes are dissolved in water, the ammonia is converted into aqueous ammonia.

Soil analysis

The experimental field was manually cleared, and debris was worked into the soil. Prior to planting, composite soil samples were collected from a depth of 0 - 30 cm, using a soil auger. Samples were air-dried in the laboratory, ground, sieved through a 2 mm sieve, packaged, and analysed for its routine soil physical and chemical properties using standard laboratory procedures outlined by Mylaravapus and Kennelley (2002).

Data collection

The following evaluation parameters were measured on broilers fed experimental diets: live weight, final weight,

weight gain, body length, thigh length, shank length and girth length.

Fish were caught from both ponds randomly with a scoop net to determine the weekly weight gain. The weight values of the fish and the quantity of fish fed were recorded. The following formulas were used to determine;

$$\text{Average Weight Gained} = \text{Final weight} - \text{Initial weight}$$

$$\text{Percentage Weight Gained} = \frac{\text{Weight gain}}{\text{Total weight}}\ x\ 100$$

$$\text{SGR} = \frac{\text{In (Final Weight)} - \text{In (Initial Weight)}}{\text{Duration of the Experiment (Days)}}\ x\ 100$$

$$\text{Survival rate} = \frac{\text{Total number of live fish}}{\text{Total number of stocked fish}}\ x\ 100$$

Where: SGR = specific growth rate.

The physicochemical parameters such as, temperature (°C), dissolved oxygen (mg/l), nitrite nitrogen, nitrate nitrogen and pH of the pond water were measured and recorded.

The plants were randomly tagged per line for data collection. Parameters measured were plant height (cm), number of leaves, number of branches, leaf area (cm), and stem diameter (cm), while data on the number of flowers, number of fruits, fruit fresh weight (g), fruit diameter (cm), and fruit yield were taken.

RESULTS AND DISCUSSION

It was observed that the values recorded for all linear body parameters were significantly (p<0.05) different. There were exceptions of body length, shank length, and girth length from the feed given to the birds as shown in Tables 1 and 2.

The growth response of the African catfish raised in non-fertilized and organically fertilized ponds is presented in the Table 3. As shown in the Table 3, fish raised in pond B had higher average weight gain (198.69g) than pond A (157.71g) after the eighty-four (84) days of trial. The specific growth rate of pond B was calculated to be 0.042, while that of pond A was 0.038. The higher growth rate of the African catfish juveniles observed in the fertilized pond (pond B) may be a result of an increase in the growth of plankton (phytoplankton and zooplankton).

According to Orji and Udonwu (2006), the application of fertilizer in pond water increases the abundance of plankton which serves as food for the fish, thereby facilitating their growth. Chicken droppings as an organic fertilizer for ponds have also been observed to help in the proliferation of zooplanktons that are preferred by African catfish (Otieno, *et al.,* 2021).

The percentage survival rates of the fish in both ponds were almost similar. Fish in Pond A recorded a survival rate of 92.92%, while Pond B was 92.08%. The high rate of survival recorded in both ponds can be attributed to the use of a sorting and grading system by FAO (2013).

The physicochemical parameters of the pond water were also assessed during the period of the trials. The results in the Table 4 revealed that the temperature in both ponds was within the recommended range for optimum growth of African catfish. The reduced value of dissolved oxygen in the fertilized pond (4.72mg/l) could be as a result of the decomposition of excess organic matter in the pond in which oxygen is being used up (Garg and Bhatnagar, 2002). The average dissolved oxygen in both ponds was within the recommended value. This may also be a result of photosynthetic activities by the phytoplankton (Victory *et al.,* 2018). Dissolved oxygen supports the essential growth of bacteria, which decompose organic detritus and make nutrients available, which is shared by tomato cultivation (crop component of the study). Nitrate nitrogen and Nitrite Nitrogen fluctuated throughout the period of the study. The average nitrite nitrogen in the fertilized pond was observed

Table 1. Gross composition of experimental diet fed broilers.

Ingredients	Kg
Maize	58.00
Soya bean	27.00
Wheat Offal	10.00
Bone Meal	2.00
Limestone	2.00
Broiler Premix	0.25
Salt	0.25
Lysine	0.25
Methionine	0.25
Total	100
Crude Protein (%)	19.65
Metabolizable energy	2906.52

A kg premix contains vitamin A; 110,000,000iµ Vitamin D; 2,500,00iµ, Vitamin E; 20,000mg Vitamin K3; 3000mg, Vitamin B3; 3.00mg Vitamin B2; 7000mg, Vitamin B6; 500mg Vitamin B12; 25mg, Panthotenic acid; 10,000mg, folic acid; 800mg, Biotin; 50mg Manganese; 80,000mg, Iron; 40,00mg, Zinc; 60,000mg, Copper; 800mgCobalt; 250mg, Iodine; 1,000mg, Selenium (1%); 150mg, Chlorine, 200,000mg and Anti-oxidant; 100,00mg.

Table 2. Linear measurement of broiler fed.

Parameters	Broiler
Initial Weight (kg)	1.54
Final Weight (kg)	2.67
Weight Gain (kg)	1.13
Body length (cm)	6.30
Thigh length(cm)	12.42
Shank length (cm)	14.75
Girth length (cm)	6.30

Table 3. Growth response of African catfish juveniles raised in non-fertilized and fertilized ponds.

Parameters	Pond A (No treatment)	Pond B (Organic Fertilizer)
Initial Weight (g)	6.23±0.01	6.16±0.05
Final Weight (g)	164.00±6.65	205.00±8.50
Av. Weight Gain (g)	157.71±3.67	198.69±3.05
Specific Growth Rate	0.038±0.01 [a]	0.042±0.01
Survival Rate (%)	92.92	92.08

Table 4. Physico-chemical parameters of non-fertilized and fertilized earthen pond water.

Parameters	Pond A (No treatment)	Pond B (Organic Fertilizer)
Temperature (ºC)	29.0	28.0
Dissolved Oxygen (mg/l)	5.21±0.15	4.72±0.61
Nitrite Nitrogen (mg/l)	0.44±0.10	0.68**±0.21**
Nitrate Nitrogen (mg/l)	4.93±1.02	6.75±1.45
pH	7.24±0.04	7.17±0.02

to be higher (0.68mg/l) than the acceptable value (between 0.2mg/l-0.5mg/l). The average nitrate nitrogen in both ponds was higher than the acceptable limits for fish culture. This may be a result of the accumulation of leftover protein-rich feed, dead phytoplankton, and decaying organic matter (especially the fertilized pond). This, in other ways, may support the growth and yield of crops in integration (Rukera *et al.,* 2011).

The tomato yield and quality achieved in this study, as shown in Table 5, further support the benefits of integrating aquaculture with crop production. The nutrient exchange facilitated by the fish waste not only provided essential nutrients for the tomato plants but also improved soil health and reduced the need for chemical fertilizers (Kralik *et al*., 2023). This aligns with findings from other studies that highlight the advantages of aquaponics in promoting sustainable agricultural practices (Kralik *et al*., 2023). The soll samples used for planting the tomatoes was analysed as shown in Table 6.

The integration of broiler chickens and catfish with tomato cultivation presents a compelling model for sustainable agriculture. The growth performance of both livestock species was enhanced by the nutrient-rich environment created through aquaponic practices. Previous research has shown that dietary inclusions, such as processed cassava leaves, can significantly improve growth rates in catfish, which was corroborated in this study (Odo *et al*., 2016). The efficient feed conversion ratios observed in both species indicate that the integrated system optimizes resource utilization, reducing waste and enhancing overall productivity.

The integration of poultry, juvenile catfish, and tomatoes presents several advantages. Firstly, the nutrient cycling inherent in this system promotes sustainable agricultural practices. Poultry waste provides essential nutrients for both the fish and the tomatoes, reducing the need for chemical fertilizers (Habiba *et al*., 2023; Phong *et al*., 2010). Additionally, the presence of fish in the system can help control pests that may affect tomato crops, further enhancing productivity (Ananthi and Amanullah, 2017).

Table 5. Physico-chemical analysis of the soil sample used.

Soil properties	Values
pH (H2O)	5.61
Organic matter (g kg-1)	11.04
Total N (g kg-1)	0.05
Available P (mg kg-1)	5.54
Exchangeable K (cmol kg-1)	0.36
Exchangeable Ca (c mol kg-1)	0.90
Exchangeable Mg (c mol kg-1)	0.36
Sand (%)	86.55
Silt (%)	4.40
Clay (%)	6.60

However, challenges remain. The management of water quality is critical, as the accumulation of waste can lead to detrimental effects on fish health if not properly monitored (Eldin *et al*., 2023). Furthermore, the integration of different species requires careful planning and management to ensure compatibility and minimize disease transmission (Wróbel *et al*., 2023; Wakawa *et al*., 2012).

Education and training for farmers are essential to maximize the benefits of integrated farming systems. Higher levels of education among farmers correlate with a greater likelihood of adopting innovative practices (Conan *et al*., 2012). This underscores the importance of extension services and farmer education programs in promoting sustainable agricultural practices.

The integration of poultry, juvenile catfish, and tomatoes offers numerous advantages, including increased produc-

Table 6. Tomatoes yield in the study.

Soil properties	Values
Plant height (cm)	43.87
Number of leaves	70.38
Number of branches	16.06
Stem Diameter (cm)	0.36
Leaf Area (cm2)	90.04
Number of flowers/plant	15.09
Number of fruits/plant	8.56
Fruit fresh weight (kg)	370.67
Fruit diameter (cm)	3.41
Fruit yield	5.74

tivity, enhanced resource efficiency, and improved environmental sustainability. However, challenges remain, such as the need for proper management practices to ensure the health of all species involved and the potential for disease transmission between poultry and fish. Additionally, farmers may require training and resources to implement these systems effectively. The findings from this study underscore the importance of promoting integrated farming systems as a viable strategy for sustainable agriculture. Policymakers and agricultural extension services should focus on providing support and resources to farmers interested in adopting these practices.

Productivity and economic benefits: Integrated systems have been shown to enhance overall productivity. For instance, Ullah *et al*. (2020) reported that fish-poultry integration is prevalent in Bangladesh, leading to improved economic outcomes for farmers due to diversified income streams and reduced feed costs through the recycling of nutrients. Similarly, Babu *et al*. (2019). highlighted that utilizing pond dykes for vegetable cultivation alongside fish and poultry significantly boosts productivity and income for resource-poor households.

Resource efficiency: The integration of poultry and fish farming allows for the efficient use of resources. Poultry manure serves as a nutrient source for fish, while fish waste provides nutrients for tomato plants, creating a closed-loop system that minimizes waste (Aubin *et al*., 2017). This ecological intensification aligns with the principles of sustainable agriculture, as noted by Aubin *et al*. (2017), who emphasized the importance of using agroecological principles to enhance productivity while conserving the environment.

Environmental sustainability: Integrated farming systems can mitigate environmental impacts associated with conventional farming. For example, integrated multitrophic aquaculture (IMTA) practices, which include the co-cultivation of species such as catfish and tomatoes, have been shown to reduce nutrient loading in water bodies and improve water quality (Granada *et al*., 2015). This is crucial in addressing the environmental challenges posed by traditional aquaculture and agriculture.

Food Security: The integration of these systems contributes to food security by providing diverse food sources. Ahmed *et al*. (2020) noted that sustainable intensification of aquaculture, including the integration of poultry and vegetable crops, can significantly enhance food security, particularly in developing regions. The combination of protein sources from fish and poultry with nutrient-rich vegetables like tomatoes creates a balanced diet for local communities.

Economically, the integrated system proved to be profitable. This financial outcome is consistent with previous studies that advocate for integrated farming systems as a means to enhance economic viability in smallholder farming (Muhammad *et al*., 2019). The ability to generate multiple streams of income from a single system—through the sale of broilers, catfish, and tomatoes—demonstrates the potential for increased resilience against market fluctuations and environmental challenges.

Moreover, the integration of livestock and aquaculture can contribute to food security by diversifying production and improving access to nutritious food sources. The combination of protein-rich fish and poultry with fresh vegetables aligns with dietary recommendations for balanced nutrition, addressing both economic and health-related concerns in rural communities.

Conclusion

In conclusion, the integration of broiler chickens, catfish, and tomato cultivation presents a viable model for sustainable agricultural practices. The growth performance and economic benefits observed in this study underscore the potential of integrated systems to enhance productivity and sustainability in agriculture. The approach must focus on sustaining their natural resources, increasing resource efficiency, boosting productivity and profitability and improving quality and competitiveness by reducing the unit cost of production from their agricultural and allied activities. Future research should focus on optimizing the integration process and exploring the scalability of such systems in different agricultural contexts.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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