Comparative analysis of African catfish growth performance and water quality in traditional pond system with water hyacinth and aquaponic system with pepper plants

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Abstract

The sustainability of aquaculture depends on maintaining optimal water quality and ensuring favorable conditions for fish growth. This study compared the growth performance of African catfish (Clarias gariepinus) and water quality in two distinct systems: a traditional pond incorporating water hyacinth (Eichhornia crassipes) and a media-based aquaponic system with pepper plants (Capsicum spp.). The study aimed to assess fish growth rates and health, evaluate key water quality parameters (pH, temperature, dissolved oxygen, ammonia, and nitrate), and determine their impact on nutrient cycling and overall aquaculture sustainability. Two experimental setups were created using 1m x 1m x 0.8m plastic IBC tanks, designated as Pond A (water hyacinth) and Pond B (pepper-based aquaponic system). Each tank was stocked with 20 post-juvenile African catfish of similar size, averaging 0.035 kg. Regular measurements were conducted to monitor fish growth and water quality. Statistical analyses, including t-tests and ANOVA, were employed to compare results. The study was conducted at a fish farm in Nike Layout, Enugu State, Nigeria. Preliminary findings indicate that the aquaponic system offered more stable nutrient conditions, promoting slightly higher growth rates. Fish in Tank B (aquaponic system) achieved an average weight of 0.83 kg, compared to 0.69 kg in Tank A (water hyacinth) over four weeks. The aquaponic system demonstrated superior water quality, with lower ammonia (3.8–25 mg/L) and nitrate levels (0.01–2.95 mg/L), likely due to nutrient uptake by the pepper plants. In comparison, the traditional pond system with water hyacinth also improved water quality but showed higher ammonia (5.4–33 mg/L) and nitrite levels (0.01–0.56 mg/L). ANOVA results revealed no statistically significant difference ($p = 0.05$) in fish growth or water quality parameters between the two systems, despite the aquaponic system's higher fish growth performance. These findings highlight the potential of both systems for sustainable aquaculture, offering valuable insights for practitioners to select appropriate technologies based on specific goals and resources. This research contributes to advancing sustainable and efficient aquaculture practices.

Keywords: Aquaculture sustainability, Water quality management, African catfish (Clarias gariepinus), Traditional pond system, Media-based aquaponic system, water hyacinth

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Introduction

Aquaculture has emerged as a vital component of global food production (Little et al., 2016; Lal et al. 2024), addressing the increasing demand for protein-rich foods while alleviating pressure on wild fish populations (Gómez et al., 2019; Muringai et al., 2021). Among the diverse species cultivated, African catfish (Clarias gariepinus) stands out due to its rapid growth rate, hardiness, and adaptability to various environmental conditions (Isa, 2019; Barasa, J.E. and Ouma; 2024; Ojelade et al., 2022). However, one of the primary challenges in aquaculture is maintaining optimal water quality, which directly influences fish health and growth performance (Boyd, 2017; Yavuzcan Yildiz et al., 2017). Effective water quality management is essential to mitigate the accumulation of waste products, prevent disease outbreaks, and enhance overall productivity (Bosma and Verdegem, 2011; Boyd, 2017; Singh, 2024). Traditional pond systems have long been a staple in aquaculture due to their simplicity and low operational costs (Beveridge and Little, 2002; Edwards, 2015; Rui, 2024). In these systems, aquatic plants like water hyacinth (Eichhornia crassipes) are often introduced to improve water quality (Villamagna and Murphy, 2010; Yan et al., 2017). Water hyacinth is known for its remarkable ability to absorb nutrients and contaminants from water, thereby reducing levels of ammonia, nitrates, and other pollutants (Rezania et al., 2015; Ting et al., 2018; Moyo et al., 2013). This natural filtration process can create a more favorable environment for fish growth (Scott and Sloman, 2004; Crab et al., 2007). However, uncontrolled proliferation of water hyacinth can lead to oxygen depletion and other ecological issues, necessitating careful management (Cho, M. E. and Tifuh, J., 2012; Jha et al., 2024). In recent years, aquaponics has gained popularity as an innovative and sustainable aquaculture method (Chauhan and Mishra, 2022; Okomoda et al., 2023). Aquaponic systems integrate fish farming with hydroponic plant cultivation, creating a symbiotic environment where fish waste provides nutrients for plants, and plants help purify the water for fish (Oniga et al., 2018). This closed-loop system not only maximizes resource use but also offers dual outputs: fish and plant crops. For instance, growing pepper plants (Capsicum spp.) in aquaponic systems can contribute to both water purification and food production, making the system economically attractive and environmentally sustainable (Danner et al., 2019; Rajalakshmi et al., 2022). Given the distinct characteristics and potential benefits of traditional pond systems with water hyacinth and aquaponic systems with pepper plants, it is imperative to conduct a comparative analysis (Karim et al., 2011; Pucher et al., 2015). This study aims to evaluate the growth performance of African catfish and assess water quality parameters in both systems. By evaluating the growth rates and overall health of African catfish in a traditional pond system incorporating water

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hyacinth versus an aquaponic system with pepper plants, Assessing and comparing the water quality parameters, including pH, temperature, dissolved oxygen, ammonia, and nitrate levels, in both systems and determining the impact of each system on nutrient cycling and overall aquaculture sustainability to identify the most efficient and sustainable method for optimizing fish growth and maintaining water quality (Hasanzadeh et al., 2020; Khudoyberdiev et al., 2023).

The results of this study will provide valuable insights for aquaculture practitioners and researchers, guiding the implementation of best practices in fish farming (Weitzman et al., 2024). The comparative analysis will help determine the viability and effectiveness of integrating plant-based water filtration in traditional and modern aquaculture systems, ultimately contributing to the advancement of sustainable aquaculture technologies (Neori et al., 2004; Subasinghe et al., 2009).

Materials and methods

The study took place on a private farm at Nike Layout, Enugu State, Nigeria, spanning from January 2023 to February 2023. Two plastic ponds, each with an average area of 1m², were prepared by filling them with an equal volume of water. Subsequently, twenty (Chauhan and Mishra, 2022) post-juvenile African catfish were introduced into each pond after being randomly selected and weighed.

To create experimental conditions, water hyacinth was introduced to cover approximately 20% of the surface area of one of the ponds, designated as 'pond A', while pond B remained free of water hyacinth but incorporated with a pepper media grow-bed (Aquaponic system) (Hindelang et al., 2014; Varasteh Moakher et al., 2021). The fish were provided with commercially available floating feed pellets containing 45% Nitrogen (Craig et al., 2017). The feeding rate was set at 200g per - pond for one month. At the conclusion of each week, five fish were randomly selected to assess their growth and development (McCormick and Hoey, 2004; Zheng, 2024).

Additionally, water samples were collected from the ponds every seven days for a period of one month to analyze the water quality and evaluate the impact of water hyacinth and the pepper media. These samples were collected using 150cl plastic bottles and subjected to laboratory water analysis, which considered various selected aquatic parameters. Statistical methods, such as ANOVA and t-tests were used to compare fish growth and water quality parameters between the two systems to correlate and determine the relationships and impacts.

Physicochemical analysis and equipment

The following physicochemical properties were investigated; pH using HANNA HI 4212 model pH meter (Eze and Eze 2018), Nitrite using Diazotisation method (Sreekumar et al.,

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2003; Kumar, 2024), Nitrate by cadmium reduction method using HACH DR 890 (Ibikunle and Adelani, 2019), Ammonia by Nesslerisation method using UV-vissible spec (Sasongko, 2018), Total Alkalinity using potentionmetric titration (Kerr et al., 2021), Dissolved oxygen using winkler with azide modification method (Ruchhoft et al., 1938), BOD-5 using winkler's method, COD by closed Reflux Digestion (Gisbert et al., 2022).

Results and discussion

Numerous factors can either hinder or enhance the growth rate of any living organism, and catfish is no exception (Gisbert *et al*., 2022). Figure 1 provides a visual representation of the growth rate comparison of the fish in pond A (pond with water hycinth) and pond B (pepper-media-based asuaponic system).

Table 1 represents the results of statistical analysis (ANOVA) of weight of fish in both systems. A comprehensive overview of fish growth and variations in water quality parameters on a weekly basis throughout the entire experimental period is presented in Table 2. Detailed comparisons of all the water quality parameters are depicted in Figures 2 through 11.

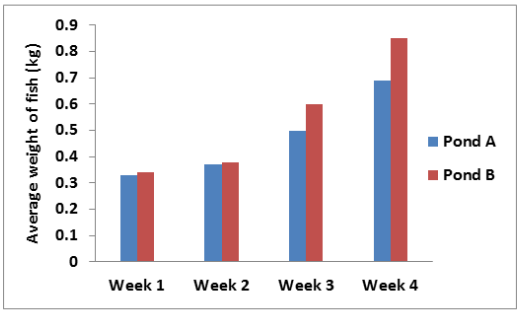

Figure 1: Fish growth rate in pond with and without (controlled) water hyacinth.

Table 1: ANOVA table for fish growth rate Parameters for both systems.

Source	ANOVA result			
	SS	df	MS	
Between-treatments	0.0194	1	0.0194	F = 0.33843
Within-treatments	0.4576	8	0.0572	
Total	0.477	9		

The *f-ratio* value is 0.33843. The *p-value* is 0.576757. The result is not significant at $p<0.05$

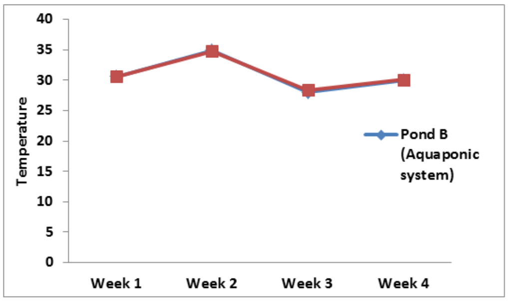

Figure 2: weekly variations of water temperature (˚C) in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

The progressive week are represented from week 1 to week 4 as shown in Figure 3. At week one, the average weight of fish in pond A is 0.34kg and and pond B is 0.33kg, week shows a slight difference as average weight of pond A becomes 0.38 and pond B 0.37. At week three the fish weight at pond A rose to 0.6 and pond be 0.5, then at the las week, the average weight of fish in pond A and B were about 0.85kg and 0.69kg respectively. The interpretation

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of the ANOVA results in Table 1, based on the stated hypothesis follows the decision rule which states that; if *p*-value< x-level (0.05) reject H_o; otherwise accept H_o.

Therefore, the weight of African catfish stocked on fish ponds with water hyacinth (pond A) does not have any significant difference with the weight of catfish stocked pepper media-base Aquaponic system (pond A).

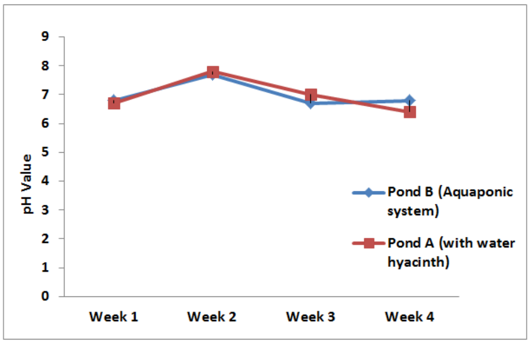

Figure 3: weekly variations of pH value in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

Statistical analysis

Table 2 further illustrate that African catfish stocked on fish ponds with water hyacinth (pond A) does not have any significant difference with the catfish stocked on Aquponics system (pond B), as it was observed that there is no significant mean different on the water quality of the two fish ponds. (34.80ºC) and minimum (28.40ºC) temperature degrees were obtained in pond A during the 4 weeks, respectively. The variation in water temperature was related to differences in air temperature throughout the period of culture.

The pH of the pond A ranges from 6.7mg/L to 7.7mg/L with the highest pH recorded in the second week. Pond B ranges from 6.4mg/L to 7.8 and the highest pH value was recorded on the second week. Comparing the pH value of the two ponds show a relative close values.

Table 2: Mean values (and ranges) of physico-chemical properties of pond water affected by water hyacinth cover and pepper media base Aquponic system during the experimental period.

Parameter	Original Stream (Mean + SD)	Pond A Without hyacinth (Mean+ SD)	Pond B With hyacinth (Mean+ SD)	F-Value	*P*-Value
Temperature	30.80±0.01	30.88±2.90	30.98±2.72	0.003	0.997**
pH	6.80±0.01	7.00±0.47	6.98±0.60	0.115	0.893**
Total Alkalinity	14.00±0.01	104.50±56.44	103.00±78.12	1.619	0.264**
Nitrate	2.60±0.01	8.60±5.63	23.20±17.47	2.456	0.156**
Nitrite	0.05±0.01	0.15±0.27	0.81±1.43	0.644	0.554**
Ammonia	0.50±0.01	16.90±13.46	14.33±11.76	1.383	0.312**
Dissolved Oxygen	7.20±0.01	2.33±1.81	3.85±3.48	2.398	0.161**
BOD	4.10±0.01	270.50±320.83	257.50±264.24	0.732	0.514**
COD	5.00±0.01	348.50±306.49	346.50±256.52	1.371	0.314**

** - The mean difference is not significant at the 0.05 level.

Descriptive analysis

The variation of temperature in the two ponds during the study period shows that from week1 to week 4, the value of temperature in pond A and B were almost the same. The maximum

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Dissolve oxygen effect the growth, survival, distribution, behavior and physiology of fish and other aquatic organism. At Pond A, from the first week to the third week the DO has gone down to 1.0mg/L. Despite the necessary change of water in the pond at this point, the DO remain at the level of 1mg/L until the fourth week when it rose while at Pond B, the dissolved oxygen descended from 8.1mg/L to 1.0ng/l then rose to 5.0mg/L in week four as seen in Figure 4.

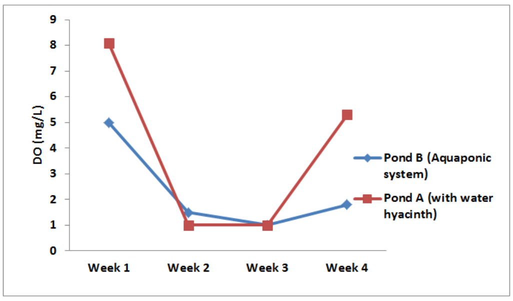

Figure 4: Weekly variations of dissolved oxygen in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

The total alkalinity was recorded at 50mg/L at the first week and at week two to both ponds have high total alkalinity and pond A was found to be higher at this point. Week 3 and 4 shows a strong descend in the value of alkalinity as seen in Figure 5.

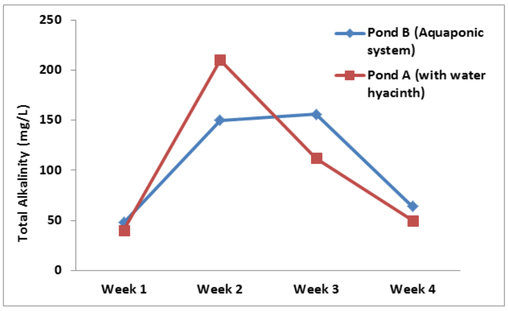

Figure 5: Weekly variations of Total Alkalinity in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

In Figure 6, the BOD of pond B increased steadily from 30mg/L to 730mg/L at the end of third week, before declining with average value of 320$\pm$ 270 mg/L. The BOD in pond A rose from 40 to 590mg/L with an average value of 264.24$\pm$257.50mg/L,

In Figure 7, the COD also increased similarly from 35 to 760mg/L within the same period before decreasing to 231mg/L. The average value of COD in pond B was 348.50$\pm$306.49. The COD in Pond A increased from 46mg/L to 610mg/L at the third week before declining with an average value of 346.50$\pm$256.52mg/L.

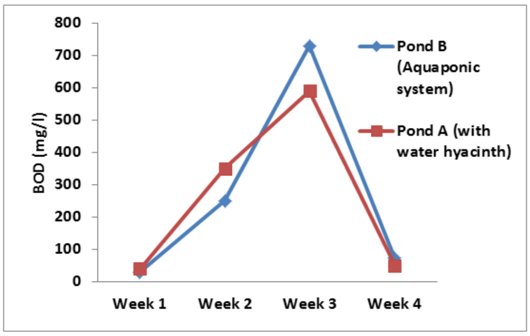

Figure 6: Weekly variations of BOD plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

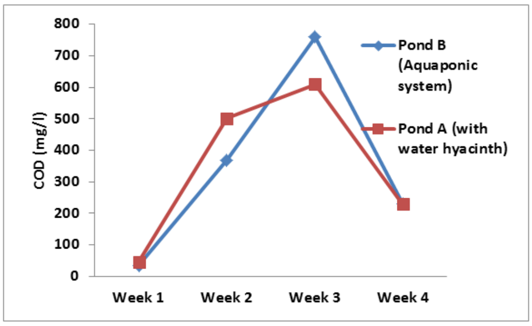

Figure 7: Weekly variations of COD in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

The Nitrate of the pond A ranges from 2.1mg/L to 43.7mg/L with the highest

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Nitrate recorded in the second week. Pond B ranges from 1.7mg/L to 15.1mg/L and the highest Nitrate value was recorded on the second week, as seen in Figure 8.

The Nitrite of the pond A ranges from 0.01mg/L to 0.56mg/L with the highest Nitrite recorded in the first week. Pond B ranges from 0.01mg/L to 2.95mg/L and the highest Nitrite value was recorded on the first week, as seen in Figure 9.

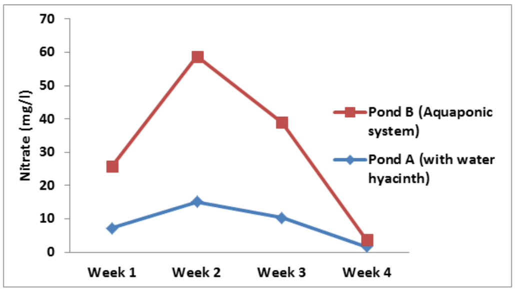

Figure 8: Weekly variations of Nitrate in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

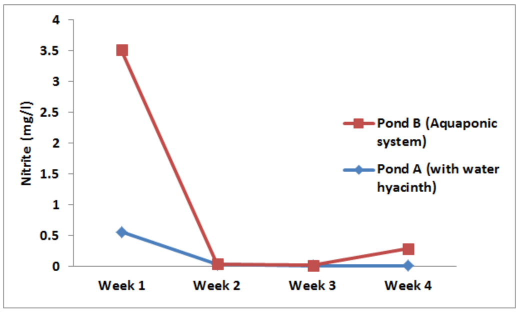

Figure 9: Weekly variations of Nitrite in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

The Ammonia of the pond A ranges from 5.4mg/L to 33mg/L with the highest Ammonia recorded in the third week. Pond B ranges from 3.8mg/L to 25mg/L and the highest Ammonia value was recorded on the third week, as seen in Figure 10.

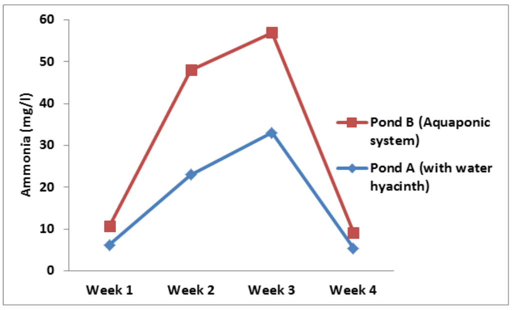

Figure 10: Weekly variations of Ammonia in plastic ponds with water hyacinth (pond A) and media base Aquaponic system (pond B).

Conclusion

The average weight gain of fish in pond A and B were analyzed and observed that there was no significant difference in the growth of the fish, even though the fishes in pond B attained a higher average weight than those in pond A. The result of the ANOVA test carried out at 5% level of significant for both pond A and B, indicates that there was no significant difference between the fish and water in the two ponds. This implies that the introduction of water hyacinth in pond B has no adverse effect on the growth of the fish and water quality. To further ascertain this result, it is recommended that this experiment is conducted on other aquacultural facilities such trampoline pond, concrete pond etc.

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