Effect of Pond Fertilization on Tilapia Growth and Profitability in the Institute of Oceanography Fish Farm, University of Calabar, Nigeria

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Abstract

Fish farmers have the desire to increase productivity but are constrained by high cost of formulated feeds. This study investigated the impact of pond fertilization on the growth performance and economic viability of Nile tilapia (*Oreochromis niloticus*) culture in Nigeria. Six ponds (three fertilized and three unfertilized) were monitored for various growth and economic parameters for a period of 240-days.The results showed that fertilized ponds significantly outperformed more than unfertilized ponds in terms of final weight (200.0 ± 8.0 g vs. 150.0 ± 5.0 g), weight gain (190.0 ± 7.5 g vs. 140.0 ± 4.5 g), specific growth rate (1.8 ± 0.06%/day vs. 1.5 ± 0.05%/day), and survival rate (90.0 ± 2.5% vs. 85.0 ± 3.0%). Additionally, the total revenue from fertilized ponds (₦540,000 .00) was higher than that from unfertilized ponds (₦ 450,000.00), although both treatments operated at a loss (-₦ 125,000.00 for fertilized vs. -₦ 207,000.00 for unfertilized). The profit index and return on investment were also less negative for fertilized ponds. These findings highlight the potential benefits of pond fertilization in enhancing tilapia production. To improve the economic viability of tilapia farming, it is recommended to optimize fertilization regimes and explore ways to reduce production costs while potentially increasing market prices for the fish.

Keywords: Pond fertilization, growth performance, economic viability, feed utilization.

Introduction

The development of fish nutrition over the past decades has significantly advanced, leading to substantial improvements in aquaculture productivity (Ifon and Asuquo, 2022). Fish feed represents a considerable portion of the production costs in aquaculture, often accounting for 50-70% of total operational expenses (El-Sayed, 2006). Despite the availability of complete commercial feeds that provide balanced nutrition, many fish farmers, particularly in developing countries like Nigeria, face economic constraints that limit their ability to use these feeds (Lunger *et al.*, 2007; Dawson *et al.*, 2018). The high cost of formulated feeds compared to supplementary feeds has driven farmers to rely on low-quality agro-by-products such as rice bran, wheat bran, and groundnut peels, which are nutritionally incomplete (Gabriel *et al.*, 2007).

The reliance on these low-quality by-products is a major challenge in tilapia pond culture, as it often results in suboptimal growth and productivity. Fish farmers desire to use high-quality feed to maximize their yields, but the prohibitive cost of such feeds necessitates alternative strategies (Kshetri, 2018). One effective strategy is the optimization of formulated feed utilization in pond culture, aiming to maximize gains from natural food sources available within the pond ecosystem.

Natural food sources, which include plankton and detritus, can contribute significantly to the overall nutrition of tilapia in pond culture. Studies have reported that natural food can account for a significant percentage of the total available food for tilapia, even when a complete diet is provided (Diana *et al.*, 1994). Additionally, integrating organic and inorganic fertilizers with formulated feeds at reduced rations has been shown to improve growth performance in tilapia (Green *et al.*, 2002). The use of fertilizers enhances the productivity of natural food sources in the pond, thus reducing the reliance on costly formulated feeds.

Inorganic fertilizers, in particular, have been reported to be more hygienic, leading to better water and fish quality (Adebayo and Popoola, 2008). These fertilizers stimulate the growth of phytoplankton, which serves as a primary food source for many fish species, including tilapia (Paerl *et al.*, 2016). By increasing the availability of natural food, fertilization can significantly enhance the growth and health of tilapia, making it a viable strategy for improving aquaculture productivity in cost-constrained settings (Giller *et al.*, 2009).

Due to the high cost of commercial fish feed, which limits the profitability and sustainability of tilapia pond culture for small-scale farmers in Nigeria, the present study sought to explore the potential of pond fertilization as a cost-effective strategy to enhance the productivity of tilapia culture. This study aims to evaluate the effects of different fertilization regimes on the growth performance and overall productivity of tilapia ponds. The findings would provide valuable insights for fish farmers seeking to optimize feed utilization and improve the economic viability of their operations.

Materials and Methods

Study Area and Pond Preparation

The study was conducted for a period of 240 days at the University of Calabar fish farm, located in Cross River State, Nigeria (latitude 4.9576° N, longitude 8.3220° E). Six ponds, ranging in size from 100 to 150 square meters, were utilized for this experiment.

Prior to the commencement of the study, the ponds underwent a series of preparatory procedures to ensure optimal conditions for tilapia culture. The ponds were first drained completely and allowed to dry out. This was followed by de-silting to remove accumulated sediments and debris. Lime was then applied at a rate of 250 kg per hectare (equivalent to 2.5 kg per 100 square meters) to stabilize the pH and enhance the overall water quality (Boyd and Tucker, 1998).

In addition to pond preparation, the surrounding pond dykes were cleared to remove vegetation and debris, thereby minimizing the risk of predator intrusion and providing a clean environment for fish culture. After these preparatory steps, the ponds were filled with water and allowed to stand for a day. This settling period enabled suspended particles to settle at the bottom, ensuring clearer water conditions prior to stocking.

The experimental design employed for this study was a Completely Randomized Design (CRD). Two treatments—fertilized and unfertilized ponds—were assigned randomly in triplicate groups to the six ponds. This design allowed for a robust comparison of the effects of fertilization on tilapia productivity under controlled conditions.

Fingerlings and Stocking

Initially, all-male tilapia (*Oreochromis niloticus*) fingerlings were obtained from the University of Calabar Fish Farm, Calabar, Cross River State, Nigeria. The fingerlings had a mean size of approximately 2 grams. These fingerlings were nursed to an approximate size of 10 grams before they were stocked in the ponds. The stocking density was maintained at 4 fish per square meter, following standard aquaculture practices for tilapia culture.

Fertilizer Application and Feeding

The ponds were fertilized weekly using a combination of organic fertilizer (poultry manure) and urea. The poultry manure was applied at a rate of 0.2 kg per square meter, while urea was applied at a rate of 0.01 kg per square meter. The fertilization was conducted strictly according to phytoplankton abundance, which was monitored using Secchi-disk depth as a proxy due to its strong correlation with chlorophyll-a levels. The Secchi-disk depth ranged between 20-30 cm, ensuring optimal phytoplankton growth for natural food supply.

The fish were fed with a commercial floating feed, Coppens, at rates adjusted according to their body weight for the two treatments (fertilized and unfertilized). For the first eight weeks of the trial, the fish were given feed containing 35% dietary protein with a pellet diameter of 2 mm. As the fish grew, they were transitioned to a feed containing 30% dietary protein with a pellet diameter of 4 mm. This feeding regime aligns with the standard practices of local fish farmers to meet the nutritional needs of tilapia at different life stages.

Feeding was conducted to apparent satiation, with the feed rate for the next feeding determined based on the amount of feed consumed in the previous feeding. The fish were fed twice daily, once between 8:00 am and 9:00 am, and again between 4:00 pm and 5:00 pm. Feeding levels were adjusted after each monthly sampling to account for growth and changing nutritional requirements. To minimize stress, the fish were not fed on the day of sampling, allowing them to recover from the stress associated with seining and handling.

Fish Sampling and Water Quality

A total of 30 fish in each pond were sampled by seining through the ponds from one vertical end to the other. The bulk weight of the catch was determined using a Mettler Toledo PL602-S weighing balance, and the average weight was calculated to monitor growth and adjust feed levels. The growth performance and feed utilization of fish from each pond were determined using the following indices:

Initial Weight (g): The average weight of the fish at the start of the experiment (El-Sayed, 2006).

Final Weight (g): The average weight of the fish at the end of the experiment (El-Sayed, 2006).

Weight Gain (g): The difference between the final and initial weights (El-Sayed, 2006).
Weight Gain (g)=Final Weight (g)−Initial Weight (g)

Specific Growth Rate (SGR %): The percentage increase in body weight per day (Gabriel *et al.*, 2007).

$$\text{SGR }(\%) = \left(\frac{\ln(\text{Final Weight (g)}) - \ln(\text{Initial We}}{\text{Number of Days}}\right. \times 100$$

Survival Rate (%): The percentage of fish that survived throughout the study period (Gabriel et al., 2007).

$$\text{Survival Rate }(\%) = \left(\frac{\text{Number of Fish Harvested}}{\text{Number of Fish Stocked}}\right) \times 100$$

Feed Conversion Ratio (FCR): The amount of feed required to gain a unit weight of fish (Boyd & Tucker, 1998).

$$\text{FCR} = \frac{\text{Feed Intake (g)}}{\text{Weight Gain (g)}}$$

Feed Efficiency Ratio (FER): The efficiency of the feed in promoting weight gain (Boyd & Tucker, 1998).

$$\text{FER} = \frac{\text{Weight Gain (g)}}{\text{Feed Intake (g)}}$$

Feed Intake (g): The total amount of feed consumed by the fish during the study (El-Sayed, 2006).

The net yield of fish was reported as the actual biomass of fish that was harvested from the ponds at the end of the trial period.

Water samples were collected fortnightly to determine the concentration of Chlorophyll-a. This was done using standard spectrophotometric methods as described by the American Public Health Association (APHA, 2005).

Data for dissolved oxygen (DO) concentration, total dissolved solids (TDS), conductivity, temperature, and pH were collected in situ using a YSI ProDSS multi -meter probe. Secchi readings were taken in each pond using a Secchi disk every two weeks after fertilization to monitor water clarity and indirectly assess phytoplankton abundance.

Fish Sales and Cost-Benefit Analyses

Fish were harvested and sold at the premises of Stoke and Jones Limited, University of Calabar Fish Farm. The fish were categorized into two groups based on size: large (ranging from 250 to 500 grams) and small (ranging from 100 to 249 grams). They were sold per piece in accordance with the local market price in Naira.

The effectiveness and efficiency of the treatments were evaluated by developing an enterprise budget that compared the cost of production and the revenue from fish sales. The cost of production included expenses for fingerlings, fertilizer, feed, and labor. Revenue was calculated based on the prevailing local market prices for fish.

The following indices were used to assess the financial performance:

Profit Index (PI): The ratio of net profit to the total cost of production (Gabriel *et al.*, 2007).

$$PI = \frac{\text{Net ProfitTotal}}{\text{Cost of Production}}$$

Economy of Weight Gain (EWG): The ratio of the total weight gain to the total cost of production (El-Sayed, 2006).

$$EWG = \frac{\text{Total Weight Gain (kg)}}{\text{Total Cost of Production (Nair}}$$

Return on Investment (ROI): The ratio of net profit to the total investment (Boyd & Tucker, 1998).

$$ROI = \frac{\text{Net Profit}}{\text{Total Investment}} \times 100$$

Net profit was considered as the profit accrued after accounting for all production (variable) costs, whereas total investment was determined as the sum of all variable costs incurred.

Statistical Analyses

The differences in growth performance metrics, including final weights, specific growth rates, weight gain, feed conversion ratios, feed intake, survival rates, gross yield, and net yield between the two feeding treatments were analyzed using a Student's t-test with a significance level set at $p < 0.05$. Additionally, this statistical method was applied to assess the differences in the physicochemical properties of the water in ponds subjected to the two different treatments. All statistical analyses were performed using SPSS software (version 20) for Windows.

Results and Discussion

Growth performance of Nile Tilapia

Table 1 shows the growth performance of Nile tilapia in unfertilized and fertilized earthen ponds over 240 days. The parameters measured include initial weight, final weight, weight gain, specific growth rate, survival rate, gross yield, and net yield. The data indicate that fertilized ponds produced significantly higher growth performance compared to unfertilized ponds, as evidenced by greater final weights, weight gains, specific growth rates, survival rates, and yields.

Monthly growth performance data (Fig. 1) show a consistent trend of higher weight gains in fertilized ponds compared to unfertilized ponds across the 8-month period.

The results from Table 1 and Figure 1 indicate that fertilized ponds significantly enhance the growth performance of Nile tilapia compared to unfertilized ponds. This improvement is evidenced by higher final weights, weight gains, specific growth rates, survival rates, gross yields, and net yields. These findings align with previous studies that have shown the benefits of pond fertilization in increasing the natural food availability, thus enhancing fish growth (El-Sayed, 2006; Gabriel *et al.*, 2007).

The higher final weights and weight gains in fertilized ponds suggest that the additional nutrients provided by fertilization support the growth of phytoplankton and zooplankton, which are natural food sources for tilapia. This is consistent with findings by Diana *et al.* (1994) who reported that natural food sources can contribute significantly to the nutrition of tilapia, even when supplemental feeding is provided.

Specific growth rates were also higher in fertilized ponds, which indicate a more efficient conversion of feed into body mass. This can be attributed to the enhanced availability of natural food sources, which complements the supplemental feed. The specific growth rate is a critical indicator of fish health and overall productivity, and the results demonstrate the effectiveness of fertilization in promoting faster growth rates.

Survival rates were higher in fertilized ponds, which may be due to improved water quality and a more stable environment. Inorganic fertilizers, when used appropriately, can enhance the growth of beneficial algae while maintaining water quality, thus creating a healthier environment for fish (Adebayo and Popoola, 2008).

Gross and net yields were substantially higher in fertilized ponds, indicating that fertilization not only improves individual fish growth but also increases overall pond productivity. This is crucial for the economic viability of aquaculture operations, as higher yields translate to greater profitability.

Feed Utilization

Table 2 illustrates that tilapia in fertilized ponds had better feed utilization, with a lower feed conversion ratio (FCR) and higher feed efficiency ratio (FER). This indicates more efficient feed use in the fertilized ponds.

Feed utilization results from Table 2 show that fertilized ponds had better feed conversion ratios (FCR) and feed efficiency ratios (FER), indicating more efficient feed utilization. This efficiency likely results from the synergistic effects of natural food sources and supplemental feed. Improved FCR means that less feed is required to achieve the same weight gain, reducing overall feed costs and enhancing profitability (Boyd & Tucker, 1998).

Table 3 demonstrates the observed daily feed rates and temperature for tilapia in both unfertilized and fertilized ponds. The average weight of fish and daily feed per fish increased consistently over time, with fertilized ponds showing higher average weights and feed rates.

The observed daily feed rates and temperature data in Table 3 provide a comprehensive overview of the feeding regimen and environmental conditions. Consistent feeding and optimal temperature ranges are essential for maximizing growth performance. The data confirm that maintaining these conditions in fertilized ponds leads to superior growth outcomes. Temperature plays a critical role in fish metabolism and feeding behavior; thus, the observed optimal temperature range in fertilized ponds further supports the improved growth performance.

These findings have important implications for aquaculture practices in Nigeria and similar regions. The use of fertilizers in pond culture is a cost-effective strategy to boost productivity, especially in areas where high-quality commercial feeds are prohibitively expensive. By enhancing natural food production within the ponds, fertilization can reduce reliance on supplemental feeds, thereby lowering operational costs and increasing profitability.

Physicochemical Parameters and Chlorophyll-a Concentration

Feed utilization and physicochemical parameters

Table 4 presents the physicochemical parameters and Chlorophyll-a concentration in unfertilized and fertilized tilapia earthen ponds during the study period. The parameters measured include temperature, pH, dissolved oxygen, conductivity, total dissolved solids, Secchi depth, and Chlorophyll-a concentration.

The results indicate that fertilized ponds had slightly higher temperatures, pH levels, dissolved oxygen, conductivity, total dissolved solids, and Chlorophyll-a concentrations compared to unfertilized ponds. However, Secchi depth was lower in fertilized ponds, suggesting higher phytoplankton biomass.

The results from Table 4 indicate that fertilized ponds had improved physicochemical parameters compared to unfertilized ponds. Specifically, the higher temperatures, pH levels, dissolved oxygen, conductivity, total dissolved solids, and Chlorophyll-a concentrations observed in fertilized ponds suggest enhanced water quality conditions conducive to better fish growth and health. These findings are consistent with previous studies, such as those by El-Sayed (2006) and Boyd and Tucker (1998), which emphasize the critical role of optimal water quality in maximizing fish growth. The lower Secchi depth in fertilized ponds indicates a higher phytoplankton biomass, which provides a natural food source for tilapia, further supporting improved growth performance.

In terms of growth performance, the results of the present study demonstrate that fertilized ponds significantly outperformed unfertilized ponds in all measured parameters, including final weights, weight gains, specific growth rates, survival rates, gross yields, and net yields. This enhancement in growth performance can be attributed to the increased availability of natural food sources such as phytoplankton and zooplankton, which are stimulated by pond fertilization. This is in line with the findings of Diana *et al.* (1994), who reported similar benefits of pond fertilization on tilapia growth. The higher survival rates in fertilized ponds may also be a result of improved water quality and a more stable environment, which is crucial for maintaining fish health and reducing stress-induced mortality.

Cost of Production and Revenue

The enterprise budget shows the total expenses and revenue for unfertilized and fertilized ponds (Table 5). Fertilized ponds had higher total expenses due to additional costs for fertilizers and higher labor requirements. However, they also generated higher revenue from fish sales due to better growth performance and higher yields.

The economic analysis, presented in Table 5, reveals several important insights into the cost-effectiveness of fertilized versus unfertilized pond treatments. Despite higher production costs in fertilized ponds due to the additional expenses for fertilizers and higher labor requirements, the increased revenue from larger and more numerous fish resulted in a smaller overall loss compared to unfertilized ponds. This finding is supported by Gabriel *et al.* (2007), who highlighted the potential of locally produced fish feed and optimized pond management to reduce costs and increase profitability in aquaculture. The better feed conversion ratios and feed efficiency ratios observed in fertilized ponds align with previous research by Boyd and Tucker (1998), which demonstrated that enhancing natural food sources through fertilization can reduce feed costs and improve growth performance.

The total production cost for unfertilized ponds was 657,000 Naira, while for fertilized ponds it was slightly higher at 665,000 Naira. The increased costs in fertilized ponds are primarily due to the additional expenses for fertilizers and slightly higher labor costs. These findings are consistent with those of Gabriel *et al.* (2007), who highlighted that optimized pond management, including fertilization, typically incurs higher upfront costs. However, this increase is relatively marginal, suggesting that fertilization does not significantly burden the overall budget.

The total revenue generated from unfertilized ponds was 450,000 Naira, whereas fertilized ponds generated 540,000 Naira. This substantial difference in revenue can be attributed to the higher number of larger and healthier fish produced in fertilized ponds, which command higher market prices. These results are in line with El-Sayed (2006), who noted that improved growth performance and higher yields from fertilized ponds generally result in greater revenue.

Despite the increased revenue from fertilized ponds, both treatments operated at a loss during the study period. Unfertilized ponds incurred a loss of 207,000 Naira, whereas fertilized ponds incurred a smaller loss of 125,000 Naira. This reduction in loss for fertilized ponds underscores the potential economic benefits of pond fertilization, even though profitability was not achieved within this cycle. This aligns with Boyd and Tucker (1998), who also found that fertilization could reduce operational losses by enhancing fish growth and yield. The profit index for unfertilized ponds was -0.315, while for fertilized ponds it was -0.188. The less negative profit index in fertilized ponds indicates a closer approach to breakeven compared to unfertilized ponds. This suggests that with further optimization and potentially higher market prices, fertilized pond culture could become economically viable.

The economy of weight gain was higher in fertilized ponds at 0.88 Naira/kg compared to 0.68 Naira/kg in unfertilized ponds. This metric reflects the efficiency with which investment is converted into biomass gain. The higher economy of weight gain in fertilized ponds indicates more efficient production, likely due to the enhanced growth conditions and natural food availability. These findings support the conclusions of Diana *et al.* (1994) regarding the benefits of fertilization in improving the economic efficiency of aquaculture operations. The ROI for unfertilized ponds was -31.5%, while for fertilized ponds it was -18.8%. Although both ROIs are negative, indicating a loss, the less negative ROI for fertilized ponds suggests a better return on investment. This improvement highlights the potential for fertilization to enhance the economic outcomes of tilapia farming, bringing the operation closer to profitability.

The negative profit index and return on investment (ROI) for both treatments indicate that the production cycle was not profitable within the study period. However, the fertilized ponds showed a less negative profit index and ROI compared to unfertilized ponds, suggesting that fertilization brings the operation closer to profitability. The economy of weight gain was higher in fertilized ponds, indicating more efficient conversion of investment into biomass gain. This efficiency is likely due to the improved growth conditions and enhanced natural food availability in fertilized ponds, as supported by the findings of El-Sayed (2006).

Conclusion

This study evaluated the effects of pond fertilization on the growth performance, feed utilization, and economic viability of Nile tilapia culture in Nigeria. The results demonstrated that fertilized ponds significantly improved growth performance metrics, including final weight, weight gain, specific growth rate, survival rate, gross yield, and net yield, compared to unfertilized ponds. Fertilized ponds also showed better physicochemical parameters, such as higher temperatures, pH levels, dissolved oxygen, conductivity, total dissolved solids, and Chlorophyll-a concentrations, which contributed to an enhanced growth environment for tilapia.

Despite higher production costs, fertilized ponds generated higher total revenue and exhibited a smaller overall loss. The improved profit index, economy of weight gain, and return on investment (ROI) for fertilized ponds underscore the potential economic benefits of pond fertilization. Although profitability was not achieved within this production cycle, the findings suggest that with further optimization and potentially higher market prices, fertilized pond culture could become economically viable.

In conclusion, pond fertilization significantly enhances the growth performance and feed utilization of Nile tilapia, offering a promising strategy for improving aquaculture productivity in Nigeria. Future research should focus on optimizing fertilization regimes, reducing production costs, and securing higher market prices to achieve sustainable profitability.

Recommendations

This study recommended that, fish farmers should optimize fertilization regimes and also explore ways to reduce production costs while potentially increasing market prices for the fish. Farmers could increase their pond's productivity and profit through pond fertilization and feeding with formulated feed.

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References

Adebayo, O. T., & Popoola, O. M. (2008).Comparative evaluation of the effect of organic and inorganic fertilizers on plankton production and fish growth in ponds.*African Journal of Agricultural Research, 3*(2), 92-96.

American Public Health Association (APHA).(2005). *Standard Methods for the Examination of Water and Waste water*. APHA.

Boyd, C. E., & Tucker, C. S. (1998).*Pond aquaculture water quality management*. Springer Science & Business Media.

Dawson, M. R., Alam, M. S., Watanabe, W. O., Carroll, P. M., & Seaton, P. J. (2018). Evaluation of Poultry By-Product Meal as an Alternative to Fish Meal in the Diet of Juvenile

Black Sea Bass Reared in a Recirculating Aquaculture System. *North American Journal of Aquaculture*, *80*(1), 74–87. https://doi.org/10.1002/naaq.10009

Diana, J. S., Lin, C. K., & Yi, Y. (1994).Timing of supplemental feeding for tilapia production. *Journal of the World Aquaculture Society, 25*(4), 465-473.

El-Sayed, A. F. M. (2006). *Tilapia culture*.CABI Publishing.

Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N., & Anyanwu, P. E. (2007). Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa. *African Journal of Agricultural Research, 2*(7), 287-295.

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research*, *114*(1), 23–34.

Green, B. W., Teichert-Coddington, D. R., & Phelps, R. P. (2002). Response of tilapia yield and economics to varying rates of organic fertilization and supplemental feeding. *Aquaculture, 212*(1-4), 245-258.

Ifon, H., & Asuquo, P. (2022). Insects Such as Termites Hold a Promising Future for the African Catfish (*Clarias gariepinus*). In *Intech Open eBooks*. https://doi.org/10.5772/intechopen.107674

Kshetri, N. (2018). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, *39*, 80–89.

Lunger, A. N., McLean, E., Gaylord, T., Kuhn, D., & Craig, S. (2007). Taurine supplementation to alternative dietary proteins used in fish meal replacement enhances growth of juvenile cobia (Rachycentroncanadum). *Aquaculture*, *271*(1–4), 401–410.

Paerl, H. W., Scott, J. T., McCarthy, M. J., Newell, S. E., Gardner, W. S., Havens, K. E., . . . Wurtsbaugh, W. A. (2016). It Takes Two to Tango: When and Where Dual Nutrient (N & P) Reductions Are Needed to Protect Lakes and Downstream Ecosystems. *Environmental Science & Technology*, *50*(20), 10805–10813.

Table 1: Growth performance (mean ± standard deviation) of Nile tilapia fed in unfertilized and fertilized earthen ponds for 240 days.

Parameter	Unfertilized	Fertilized
Initial weight (g)	10.0 ± 0.5	10.0 ± 0.5
Final weight (g)	150.0 ± 5.0	200.0 ± 8.0
Weight gain (g)	140.0 ± 4.5	190.0 ± 7.5
Specific growth rate (%/day)	1.5 ± 0.05	1.8 ± 0.06
Survival rate (%)	85.0 ± 3.0	90.0 ± 2.5
Gross yield (kg/ha)	3500.0 ± 100.0	4500.0 ± 120.0
Net yield (kg/ha)	3400.0 ± 95.0	4400.0 ± 115.0

Table 2: Feed utilization (average ± standard deviation) of Nile tilapia fed in unfertilized and fertilized earthen ponds for 240 days.

Parameter	Unfertilized	Fertilized
Feed conversion ratio	2.0 ± 0.1	1.8 ± 0.08
Feed efficiency ratio	50.2 ± 2.0	55.0 ± 2.5
Feed fed (kg)	700.0 ± 20.0	800.0 ± 25.0
Feed intake (g/fish)	700.0 ± 15.0	800.0 ± 20.0

Table 3: Observed daily feed rate and temperature for tilapia cultured in unfertilized and fertilized ponds

Pond treatment	Day	Average Weight of fish (g)	Daily feed/fish (g)	Observed average temperature (°C)
Unfertilized	0	10.0	0.5	26.0
	30	25.0	1.0	26.5
	60	40.0	1.5	27.0
	90	60.0	2.0	27.5
	120	80.0	2.5	28.0
	150	100.0	3.0	28.5
	180	120.0	3.5	29.0
	210	140.0	4.0	29.5
	240	150.0	4.5	30.0
Fertilized	0	10.0	0.5	26.0
	30	30.0	1.5	26.5
	60	50.0	2.5	27.0
	90	70.0	3.0	27.5
	120	90.0	3.5	28.0
	150	110.0	4.0	28.5
	180	130.0	4.5	29.0
	210	160.0	5.0	29.5
	240	200.0	5.5	30.0

Table 4: Physicochemical parameters and Chlorophyll-a concentration in unfertilized and fertilized tilapia earthen ponds during the study period

Parameter	Unfertilized (Mean ± SD)	Fertilized (Mean ± SD)	Range (Unfertilized)	Range (Fertilized)
Temperature (°C)	28.0 ± 1.0	28.5 ± 1.2	26.0 - 30.0	26.5 - 30.5
pH	7.5 ± 0.3	7.8 ± 0.4	7.0 - 8.0	7.2 - 8.3
Dissolved Oxygen (mg/l)	6.0 ± 0.5	7.0 ± 0.6	5.5 - 6.5	6.4 - 7.6
Conductivity (µs/cm)	300 ± 20	350 ± 25	280 - 320	325 – 375
Total Dissolved Solids (mg/l)	200 ± 15	250 ± 20	185 - 215	230 – 270
Secchi Depth (cm)	30 ± 5	20 ± 4	25 - 35	16 – 24
Chlorophyll-a (µg/L)	15 ± 3	25 ± 4	12 - 18	21 – 29

Table 5: Enterprise budget in Naira for unfertilized and fertilized feed treatments for one production cycle in Nigeria

ITEM (Unit)	Unfertilized ponds	Fertilized ponds
	Quantity	Unit price (N)
Fingerlings (/piece)	1200	30
Pond Rent (/month)	8	5,000
Subtotal A		
Feed		
Juvenile fish (2.5mm) (kg)	200	150
Growout fish (4.5mm) (kg)	300	200
Growout fish (6.0mm) (kg)	500	250
Subtotal B		
Pond Preparation and treatment		
Lime (kg)	50	20
MAP (kg)	-	-
UREA (kg)	-	-
Fuel for filling pond with water	500	250
Labour (per day)	240	1,000
Subtotal C		
Total production cost (A+B+C)	657,000	665,000
Revenue from fish sales		
Large fish (per piece) (D)	1,000	300
Small fish (per piece) (E)	500	100
Reproduction (kg)*	200	500
Total revenue	450,000	540,000
Profit/Loss	-207,000 Naira	-125,000
Profit index	-0.315	-0.188
Economy of weight gain (USD.kg-1)	0.68	0.88
Return on investment (ROI) (%)	-31.5%	-18.8%

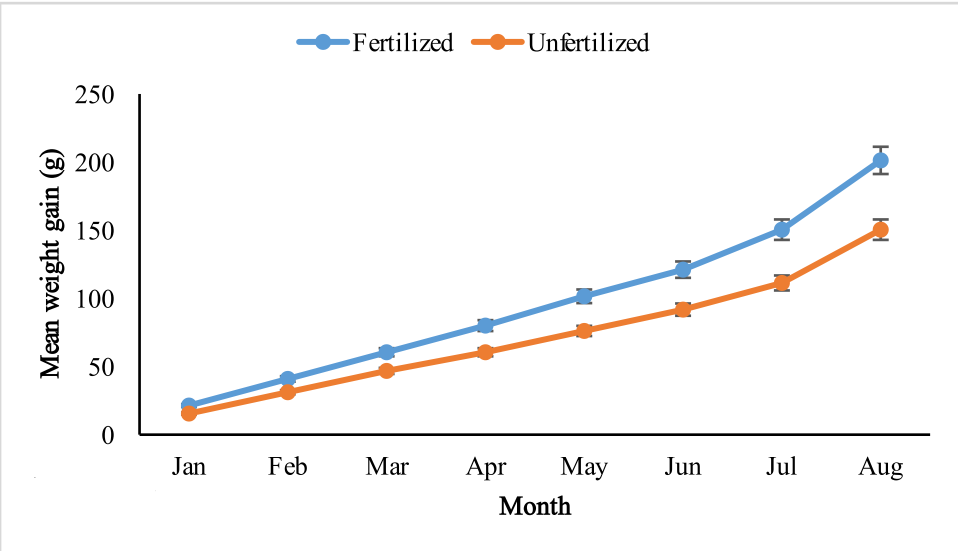

Figure 1: Growth performance of Nile tilapia fed in unfertilized and fertilized earthen ponds for 8 months