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Evaluation of Tilapia (*Oreochromis niloticus*) Survival and Growth in Aquaculture Systems with Different Feed Types

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Proper feeding is crucial for promoting fast and healthy growth in fish, contributing to increased overall production. However, access to high-nutritional feed is not always feasible. Utilizing locally available ingredients presents a potential solution to this challenge. Consequently, this research aims to assess the impact of locally available feed ingredients on the growth and production of

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tilapia (*O. niloticus*) in Liberia. Three types of fish feed were prepared, namely Africa Rice fish feed (diet 1), soybeans fish feed (diet 2), and Gbarnga fish feed (control), each with distinct compositions. These feeds were evaluated to determine their effects on the growth and production performance of tilapia fish for the duration of 31 weeks. Fifty fish with an initial body weight of 12 g each were stocked in each hapa net. Data on survival rate (%), feed conversion ratio (FCR), and growth (g) were collected and compared. The growth results revealed a statistically significant difference ($P < 0.001$) among the three selected fish feed types. Diet 1 exhibited a higher average mean weight of 1521.67 g per 92 fish followed by the control with an average mean weight of 1315.56 g per 88 fish, while diet 2 demonstrated comparatively lower growth, 1164.44 g per 96 fish. Survival rate and FCR, however, exhibited no significant differences. Notably, the cost of food supplies, particularly proteins, may constrain farmers' access to feed processing and formulation technology. Consequently, the findings of this study are expected to address challenges related to feed formulation and processing, providing valuable insights for the enhancement of fish farming practices.

Keywords: Tilapia (Oreochromis niloticus); aquaculture systems; feed ingredients; survival rate.

1. INTRODUCTION

Fish, known for their natural nutritional content, flavor, and digestibility, are highly favored by consumers [1]. On a global scale, aquaculture stands out as the fastest-growing food-producing industry, especially considering the projected increase in the global population to 9.3 billion by 2050 [2,3]. A critical concern in the context of African food systems is ensuring that 2.4 billion people have access to a healthy and sustainable diet by 2050 [4]. However, this reliance on fish as a major protein source poses significant pressure on capture fisheries, which are depleting rapidly due to issues, such as overfishing, illegal activities, and poor governance [5,6].

Tilapia, the second most farmed fish globally, has experienced a remarkable fourfold increase in production over the past decade due to its suitability for aquaculture, marketability, and stable market prices [7]. The Nile tilapia (*O. niloticus*), originally native to Africa and the Middle East [8], has become a key species in global aquaculture, especially for human consumption. However, the challenge faced by many nations in relying on wild-caught fish for farming exacerbates the depletion of fish stocks. The culture of tilapia is a major sector in global aquaculture, with Nile tilapia emerging as the top cultured species, though concerns about genetic deterioration accompany its continual production growth [9,10].

Since 1984, Tilapia has exhibited a steadfast annual growth rate of 12%, as documented by Ogello et al. [11]. Presently constituting approximately 3.8% of the world's cultured fish and shellfish production, amounting to a substantial 40 million tons [12], global Tilapia production surpassed 2.2 million metric tons in 2002. Notably, 68% of this production originated from aquaculture, indicating a noteworthy rise from 57% recorded in 2000 (FAO, 2001). These statistics underscore Tilapia's significant contribution to the thriving aquaculture industry and its escalating global importance in meeting seafood demands.

Tilapia, often referred to as the "aquatic chicken," thrives in ponds, cages, tanks, and rice paddle fields, exhibiting accelerated growth and enhanced nutritional value when provided with the right feed [13]. Despite the progress made in African aquaculture over decades [14], the heavy reliance on imported feed and ingredients has led to increased costs and challenges for farmers, contributing to a slow pace of aquaculture development, particularly in West African countries, including Liberia.

In Liberia, aquaculture is in its early stages and faces substantial challenges, including the lack of affordable and nutritious feeds, scarcity of fast-growing and improved fish fingerlings, and limited diversification of candidate species. To advance the DeSIRA-Integrated Rice-Fish Farming System (IRFFS) Project, an innovative approach has been introduced, formulating pelleted fish feed from locally available ingredients. This research aims to evaluate the impact of the formulated diet on critical parameters, such as survival rate, FCR, and the growth of tilapia fingerlings, representing a crucial step towards overcoming challenges in Liberia's aquaculture sector and promoting sustainable practices through locally sourced feed.

2. MATERIALS AND METHODS

2.1 Study Site

The study took place in an earthen pond situated at the Central Agricultural Research Institute (CARI) dam site in Suakoko, Bong County, Liberia, at coordinates 7.013331º latitude and -9.573475º longitude. The pond, constructed by the Africa Rice Center, offers an ideal environment for year-round crops and fish farming, benefitting from an ambient temperature range of 23 °C to 31 °C. This location, marked by the existing pond infrastructure, was chosen for its suitability to support the research objectives and the simultaneous cultivation of crops and fish.

2.2 Experimental Design

To establish optimal conditions for the study, the pond, measuring 50 m x 47 m x 1.5 m (length, breadth, and depth, respectively), underwent a meticulous preparation process. Initially, the pond was drained and sun-dried for a period of 14 days, serving the dual purpose of controlling unwanted fish and predators. The pond sterilization process involved sun-drying and the application of 24 kg of hydrated lime for disinfection. Following this, the pond was refilled with natural reservoir water, deemed suitable for aquaculture production. Pond fertilization was intentionally omitted to restrict phytoplankton growth, ensuring a controlled environment during the 20-week experimental trial. An inlet pipe, well-equipped with a fine filter sock, was employed to supply water into the pond, preventing the entry of debris, unwanted fish species, and predators.

Within the experimental pond, nine hapa nets were strategically deployed for feed trials, aiming to assess the survival rate and growth performance of *O. niloticus*. Each hapa net accommodated 50 fish fingerlings, each weighing an average of 12 g. The hapa nets, measuring 3 m x 2.5 m x 1 m in depth, were imported from Thailand and recommended by Africa Rice Center Fish Technicians for testing three distinct feed compositions. In a randomized block design, all hapa nets were mounted in the pond with three replications for each local feed treatment, totaling nine hapa nets for the experiment (Fig. 1).

To ensure stability, the hapa nets were positioned 30 cm above the water surface and 20 cm above the pond's bottom. Bamboo poles were utilized for securing the nets against strong water currents. The fish were acclimatized for two days before stocking to the hapa nets. After the stocking, fish feeding commenced with a four-time daily ration of formulated feed (15 g). Each hapa net was meticulously labeled, equipped with identification tags, and subjected to daily inspections. Fish sampling occurred at 14-day intervals throughout the study period, providing essential data for the research.

Fig. 1. Experimental set up with nine hapa nets in the pond

2.3 Feed Processing and Feeding

In preparing the feed, a careful formulation process involved combining locally sourced ingredients, such as fish scraps, soybean, palm kernel cake, cassava flour, rice bran, palm oil, and a vitamin premix. These components, procured from local vendors, underwent a comprehensive preparation sequence including sorting, drying, mixing, grinding, weighing, and pelletizing. Feeding was done four times a day at 10% of body weight in the first two weeks and was adjusted in line with their bodyweight till the end of the experiment.

To achieve the required fine particle size, a high-speed hammer mill (ATR-34 A) at the CARI feed processing facility was utilized for grinding soybean, dry cassava, fish scraps, and rice bran. Each ground ingredient was then stored separately in labeled barrels. A unique pre-processing step was introduced for the soybean component (20 kg), involving a 24-hour soak in a 1 m^3 container of clean water to reduce antioxidant activity. Subsequently, it was dried in a custom-made charcoal oven (34 °C, 20 kg capacity) fabricated by the post-harvest and processing unit at the Africa Rice center. Three distinct feed treatments were employed: Africa Rice fish feed (diet 1), Soybean fish feed (diet 2), and Gbarnga fish feed (control). The nutrient composition of each treatment is detailed in Table 1, providing a comprehensive overview of the diverse nutritional profiles incorporated into the experimental diets.

2.4 Data Collection Procedure

To evaluate the growth rate, data on the average body weight gain of the fish was systematically collected at 14-day intervals throughout the study period. The total weight of fish within each hapa net was carefully measured, providing the basis for calculating the new feed ration. This calculation took into account the average body weight and survival rate in each hapa net, ensuring a tailored feeding approach. To determine the survival rate and the biomass production, the following formula was used: Survival (%) = (Number of fish harvested/Number of fish stocked) x 100. Biomass production (g/fish) = Final mean body weight − initial mean body weight.

Furthermore, the FCR, a crucial metric in aquaculture, was determined upon the conclusion of the research. Following the methodology outlined by Biswas et al. [15], the survival rate and growth (biomass production) were calculated using established parameters. This comprehensive approach to data collection and analysis allowed for a thorough assessment of the experimental outcomes, providing valuable insights into the performance of the tilapia fingerlings in response to the formulated feed treatments.

2.5 Statistical Analysis

The collected data underwent rigorous statistical analysis using IBM SPSS v25 to derive meaningful insights. One-way ANOVA was applied to assess the means among the sampling parameters: survival rate, FCR, and growth. Post hoc analysis was conducted using the Tukey-Kramer Honestly Significance Difference (HSD) test, set at a 5% alpha level, to discern significant differences between means. In addition, pairwise correlation analysis was employed, utilizing Pearson's product-moment correlation, to investigate potential relationships among the growth, FCR, and survival rates.

3. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

3.1.1 pH

The pH values remain relatively stable across the 31 weeks, fluctuating within a narrow range from 6.2 to 6.3, with a mean pH of 6.25. These values fall slightly below the generally acceptable range for aquaculture (typically 6.5 to 9) [16]. However, the consistent pH levels suggest a well-maintained and stable aquatic environment, crucial for the health and well-being of aquatic organisms.

3.1.2 Electrical Conductivity (EC)

The EC values exhibit slight variations from 24.9 to 26.1 Ns/cm during period, with a mean value of 25.60 Ns/cm. EC is an indicator of the water's ability to conduct an electric current, often correlated with the concentration of dissolved salts and minerals. The observed variations, while minor, could be influenced by factors such as temperature, salinity, or dissolved ion content. The values fall within an acceptable range for freshwater aquaculture, indicating a consistent and suitable environment for fish cultivation.

Table 1. Nutrient composition (percentage) of feed ingredients in experimental treatments

Ingredients	Diet 1	Diet 2	Control
Fish waste meal	14	0	25
Beer spent	0	0	15
Soybean	35	45	0
Cassava flour	15	30	20
Wheat bran	0	0	25
Kernel Cake	10	0	9.8
Rice bran	20	20	0
Palm oil	5.8	4.8	5
Vitamin premix	0.2	0.2	0.2
Total	100	100	100

3.1.3 Total Dissolved Solids (TDS)

Total dissolved solids, measuring the concentration of dissolved substances in water, show a modest fluctuation from 20.0 to 22.0 ml/L, with a mean value of 21.00 ml/L. TDS is an essential parameter as high concentrations can impact water quality and affect fish health [17]. The observed values fall within acceptable limits for freshwater aquaculture, suggesting a balanced and stable aquatic environment.

The overall analysis indicates that the water quality parameters, as reflected in the pH, EC, and TDS, are well-maintained and suitable for tilapia aquaculture. The consistency and adherence to acceptable ranges suggest a stable environment that is conducive to the health and growth of tilapia fingerlings. Regular monitoring of these water quality parameters is essential for successful aquaculture practices, and the observed values in this study align with the optimal conditions for tilapia cultivation.

3.2 Survival Rate

The ANOVA results (Table 2) for the survival rate of tilapia fingerlings under the influence of three different feed types reveal statistically insignificant differences (P = 0.467). Notably, Diet 2 exhibited the highest survival rate with 96% ± 1.98, closely followed by Diet 1 at 92% ± 4.48. The control group showed a slightly lower survival rate at 88% ± 6.85. Despite the variations, the P-value suggests that these differences are not statistically significant; indicating that the selected feed types did not exert a significant influence on the survival rates of the tilapia fingerlings.

3.3 Feed Conversion Ratio (FCR)

Feed conversion ratio (FCR) is the most commonly used metric; it is calculated by dividing the total weight of feed administered to an animal over its lifetime by the weight gain [18,19]. The FCR results in Table 2 demonstrate no significant variations among the three feed types, with a P-value of 0.961. The FCR values for Diet 1, Diet 2, and the control group are comparable, ranging from 1.76 to 1.84. This statistical insignificance suggests that the different feed formulations did not lead to significant differences in the efficiency of converting feed into fish biomass. The uniformity in FCR values across the feed types indicates a consistent feed conversion performance among the experimental groups.

3.4 Growth

The ANOVA results (Table 2) for the growth of tilapia fingerlings, exhibit a highly significant difference among the three feed types (P < 0.001). Diet 1 stands out with the highest mean growth of 1521.67 g ± 47.33, followed by the control group at 1315.56 g ± 96.48. Diet 2, while demonstrating a respectable growth rate of 1164.44 g ± 26.06, lags behind the other two groups. This significant difference in growth indicates that the choice of feed type significantly impacted the overall growth performance of the tilapia fingerlings. The results suggest that Diet 1, in particular, led to superior growth compared to the other feed types, emphasizing the importance of feed composition in achieving optimal growth outcomes in aquaculture practices. Mengistu et al. [6] stated that there are significant differences in productivity. Additionally, variations in the growth rate and FCR have an impact on the yield gap, the difference between the top performers and the bottom ones. According to Ngongolo and Magendero [10] protein, energy, and mineral sources are all necessary for the growth of fish.

The impact of protein composition in fish feed on the growth and performance of fish has been consistently highlighted in various studies [20]. Particularly, commercial feed, when compared to both fishmeal-based and non-fishmeal-based feeds, demonstrated a superior growth rate in fish [21]. However, the specific composition of the commercial feed, undisclosed by the manufacturer, complicates pinpointing the exact cause of the growth disparity [22]. A potential contributing factor could be the subpar quality of the fishmeal used in the local fishmeal-based feed, sourced from the local market [23].

Beyond the protein content, challenges arise in achieving a balanced amino acid profile and ensuring the digestibility of nutrients within the diet [24]. The high cost associated with many nutrient sources, particularly proteins, poses a significant constraint, limiting farmers' access to feed processing and formulation technology. This economic challenge often leads to a trade-off between feed cost and the nutritional value of the diet [25].

Moreover, a critical challenge stems from the limited knowledge of feed formulation and processing among farmers. Feeds are predominantly formulated in laboratories rather than under real farming conditions. Consequently, farmers, unaware of the nutritional requirements of their farmed fish species, purchase these feeds. This lack of knowledge increases the risk of administering inappropriate feed quantities or even the wrong types of feed meant for different fish species. Research findings on feed formulation and nutrient utilization, though available, are often confined within academic circles, failing to reach the farmers who urgently need to implement effective feeding strategies. Addressing these knowledge gaps is crucial for enhancing the sustainability and efficiency of aquaculture practices.

3.5 Correlation Analysis

Table 3 presents a correlation matrix showing the Pearson correlation coefficients between survival rate, FCR, and fish total weight. Each value in the matrix ranges from -1 to 1, with 1 indicating a perfect positive correlation, -1 indicating a perfect negative correlation, and 0 indicating no correlation. The correlation coefficient between survival rate and FCR is -0.671, indicating a moderately strong negative correlation. This suggests that as the survival rate increases, the FCR tends to decrease, and vice versa. A negative correlation is expected in aquaculture, as a lower FCR is generally desirable, indicating more efficient feed conversion. The correlation coefficient between survival rate and fish total weight is 0.304, indicating a weak positive correlation. This suggests that there is a mild tendency for higher survival rates to be associated with higher fish total weights. However, the correlation is not strong, and other factors likely contribute to the fish total weight.

The correlation coefficient between FCR and fish total weight is 0.266, indicating a weak positive correlation. This implies that as the FCR increases, there is a slight tendency for fish total weight to also increase. However, the correlation is not strong, suggesting that FCR alone may not be a decisive factor in determining fish total weight. The correlation table reveals interesting relationships among the variables. The negative correlation between survival rate and FCR aligns with aquaculture goals, indicating that higher survival rates are associated with more efficient feed conversion. The positive correlations involving survival rate and fish total weight, as well as FCR and fish total weight, suggest some

Table 2. Analysis of variance (ANOVA) results (mean ± SE) of the three selected feed types

Feed type	Survival rate (%)	FCR	Growth (g)
Diet 1	(92 ± 4.48) ^{a*}	(1.84 ± 0.18) ^{a}	(1521.67 ± 47.33)^{a}
Diet 2	(96 ± 1.98) ^{a}	(1.77 ± 0.10) ^{a}	(1164.44 ± 26.06)^{b}
Control	(88 ± 6.85) ^{a}	(1.76 ± 0.16) ^{a}	(1315.56 ± 96.48)^{ab}
P-value	0.4669	0.9613	<0.0001

** Means with the same superscripts along the columns were not significantly different*

Table 3. Pearson correlation coefficients between the variables

	Survival rate (%)	FCR	Fish total weight (g)
Survival rate (%)	1		
FCR	0.671**	1	
Fish total weight (g)	0.304	0.266	1

***Correlation is significant at the 0.01 level (2-tailed)* interdependence but not strong causation. It implies that factors beyond survival rate and FCR play roles in determining the final fish total weight. Understanding these correlations aids in optimizing aquaculture practices, emphasizing the need to balance survival rates, feed conversion efficiency, and overall fish growth for successful and sustainable operations.

4. CONCLUSION

In assessing the intricate dynamics of tilapia fingerling cultivation, our investigation centered on survival rates, FCR, growth performance, and key water quality parameters. The nuanced analysis of survival rates across diverse feed types indicated no statistically significant differences, suggesting that the selected feed formulations minimally influenced the survival rates of tilapia fingerlings. Despite Diet 2 showing the highest survival rate, these variations were not deemed statistically significant, emphasizing the relative stability observed.

Furthermore, the examination of FCR values underscored a commendable uniformity across different feed types, with no significant variations detected. This consistent performance in feed conversion efficiency highlights a stable foundation for biomass conversion, contributing to the overall resilience of the aquaculture system. However, the most notable divergence emerged in the growth performance category, with Diet 1 outshining others, followed by the control group and Diet 2. This divergence underscores the profound impact of feed composition on tilapia growth, accentuating the pivotal role of appropriate feed types in achieving optimal outcomes.

The correlation analysis showed intriguing relationships among survival rates, FCR, and fish total weight, offering insights into the delicate balance required for holistic aquaculture success. In essence, this study illuminates the critical interplay between feed composition and water quality in tilapia fingerling cultivation, contributing valuable knowledge for sustainable aquaculture practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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