Assessment of Temperature and Feeding Frequency as Determinants of Growth Performance and Feed Utilization in African Catfish *Clarias gariepinus* (Burchell, 1822) Fingerlings

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Abstract
This study evaluated the effects of water temperature and feeding frequency on the growth performance and feed utilization of Clarias gariepinus fingerlings reared in the hatchery of the Federal College of Freshwater Fisheries Technology (FCFFT), Baga, Borno State, Nigeria. A total of 540 fingerlings (mean initial weight 6.4 ± 0.3 g) were stocked into 27 tanks in a 3 × 3 factorial design with three temperature regimes (24 °C, 27 °C, and 30 °C) and three feeding frequencies (once, thrice, and five times daily). After 56 days, fingerlings at 27 °C fed thrice daily achieved the highest mean weight gain (45.6 g), specific growth rate (3.74% day^{-1}), lowest feed conversion ratio (1.54), and highest protein efficiency ratio (1.63). Survival exceeded 90% across treatments. Once-daily feeding produced the poorest results (WG = 18.6 g; FCR = 3.23), while feeding five times daily increased feed intake but did not improve growth compared to thrice daily. Water quality parameters remained within safe limits, though dissolved oxygen was lowest (5.2 mg/L) and ammonia highest (0.42 mg/L) at 30 °C. These results confirm that optimal Performance of C. gariepinus fingerlings is achieved at 27-30 °C with thrice-daily feeding, providing practical guidance for hatchery management in Nigeria.
Keywords: *Clarias gariepinus*, temperature, feeding frequency, growth performance, feed utilization, hatchery management

Introduction

African catfish (Clarias gariepinus) is the most widely farmed freshwater species in Nigeria, valued for its rapid growth, resilience to harsh environments, and consumer preference. Hatchery production of fingerlings is a cornerstone of aquaculture in Borno State, where institutions such as the Federal College of Freshwater Fisheries Technology (FCFFT), Baga, play a critical role in supplying quality seed to farmers. For hatchery managers, optimizing environmental and feeding conditions is essential to maximize fingerling performance while minimizing production costs.

https://doi.org/10.5281/zenodo.18062277

Two of the most important variables in aquaculture management are water temperature and feeding frequency. Temperature strongly influences metabolic activity, feed intake, digestion, and growth efficiency in fish. African catfish generally thrive between 26-30 °C, with growth slowing at lower temperatures due to reduced enzyme activity, and stress occurring at higher temperatures due to increased metabolic demand and reduced oxygen solubility (Kasihmuddin et al., 2021; Hu et al., 2024).

Feeding frequency determines how daily feed rations are distributed and influences nutrient absorption, growth, and water quality. Low feeding frequency often limits growth due to underfeeding, while very high frequency may increase feed wastage, labor, and deterioration of water quality (Okomoda et al., 2019; Hassan et al., 2021). Previous studies have shown that intermediate frequencies (2-3 meals/day) optimize feed utilization and growth in catfish fingerlings, though site-specific conditions such as hatchery design and water quality may influence outcomes.

Growth performance is commonly measured by weight gain (WG), specific growth rate (SGR), and survival, while feed utilization is evaluated by feed conversion ratio (FCR) and protein efficiency ratio (PER). The interaction of temperature and feeding frequency is particularly important, as higher temperatures may increase digestive capacity and justify more frequent meals, whereas cooler conditions may limit nutrient assimilation (Hamed et al., 2024).This study therefore assessed the combined effects of temperature and feeding frequency on the growth and feed utilization of C. gariepinus fingerlings reared at FCFFT Baga, with the aim of developing evidence-based management recommendations for hatchery operations in Northeast Nigeria.

Materials and Methods Study Site

The experiment was conducted at the indoor hatchery unit of FCFFT, Baga (13°06′N, 13°49′E) between June and August 2024. The hatchery consists of indoor concrete tanks supplied with borehole water and aeration, routinely used for artificial breeding and nursery rearing of C. gariepinus.

Experimental Fish and Design

A total of 540 fingerlings (mean initial weight 6.4 ± 0.3 g) were obtained from the College's broodstock. Fish were acclimated for 7 days on a 40% crude protein commercial diet (Coppens). Thereafter, they were randomly stocked into 27 concrete tanks (200 L) at 20 fish per tank. A 3 × 3 factorial design was used: three temperature levels (24 °C, 27 °C, and 30 °C) and three feeding frequencies (once, thrice, and five times daily), each in triplicate.

Feeding Regime

Fish were fed at 5% body weight/day, adjusted weekly based on biomass sampling. Feeding schedules were: once daily at 09:00 h; thrice daily at 09:00, 13:00, and 17:00 h; and five times daily at 07:00, 11:00, 15:00, 19:00, and 23:00 h. Uneaten feed was removed after 30 min, oven-dried, and weighed to determine actual feed intake.

Water Quality Monitoring

Water quality was monitored daily and maintained within safe limits. Temperature was adjusted using heaters according to treatment. Dissolved oxygen (DO) and pH were measured daily using a portable multiparameter meter (Hanna Instrument), while total ammonia nitrogen (TAN) was measured weekly using the phenate method. Aeration was provided to maintain DO above 5 mg/L.

Growth and Feed Utilization Indices

Fish were weighed weekly in bulk, and survival was recorded at the end of the experiment. Growth and feed utilization indices were calculated as follows:

$WG = Wf - Wi$

$SGR = 100 \times (\ln Wf - \ln Wi)/days$

FCR = Feed intake (g)/Weight gain (g)

PER = Weight gain (g)/Protein intake (g)

$Survival\ (\%) = (Nf/Ni) \times 100$

Statistical Analysis

https://doi.org/10.5281/zenodo.18062277

Data were analyzed using two-way ANOVA (temperature × feeding frequency) in SPSS v25. Means were compared using Tukey's HSD at $p < 0.05$.

Results

Growth Performance

Temperature and feeding frequency shown in Table 1 below significantly affected growth ($p < 0.05$). The best results were at 27 °C with thrice-daily feeding (WG = 45.6 g; SGR = 3.74% day^{-1}). Once-daily feeding produced the poorest growth across all temperatures (WG = 18.6 g; SGR = 2.43% day^{-1}).

Table 1. Growth performance of Clarias gariepinus fingerlings under different treatments.

Temperature	Feeding frequency	Final wt (g)	WG (g)	SGR (% day^{-1})
24 °C	1×	25.0 ± 1.2^{c}	18.6 ± 1.4^{c}	2.43 ± 0.11^{c}
24 °C	3×	40.0 ± 2.3^{b}	33.6 ± 2.1^{b}	3.27 ± 0.15^{b}
24 °C	5×	43.0 ± 2.1^{b}	36.6 ± 2.4^{b}	3.40 ± 0.14^{b}
27 °C	1×	28.0 ± 1.7^{c}	21.6 ± 1.6^{c}	2.64 ± 0.12^{c}
27 °C	3×	52.0 ± 2.8^{a}	45.6 ± 2.9^{a}	3.74 ± 0.13^{a}
27 °C	5×	48.0 ± 2.4^{ab}	41.6 ± 2.2^{ab}	3.60 ± 0.11^{ab}
30 °C	1×	30.0 ± 1.6^{c}	23.6 ± 1.7^{c}	2.76 ± 0.10^{c}
30 °C	3×	50.0 ± 2.5^{a}	43.6 ± 2.6^{a}	3.67 ± 0.12^{a}
30 °C	5×	46.0 ± 2.0^{ab}	39.6 ± 2.1^{ab}	3.52 ± 0.10^{ab}

Values are means ± SE (n = 3). Means within each column with different superscripts are significantly different ($p < 0.05$).

Feed Utilization and Survival

Feed utilization varied significantly as presented in Table 2. The best FCR (1.54) and PER (1.63) occurred at 27 °C with thrice-daily feeding, while the poorest values were observed in once-daily feeding. Feeding five times daily increased feed intake but slightly worsened FCR. Survival was consistently high (>90%) across treatments.

Table 2. Feed utilization and survival of Clarias gariepinus fingerlings.

Temperature	**Frequency**	**Feed Intake (G)**	**FCR**	**PER**	**Survival (%)**
24 °C	1×	60 ± 2.3^{c}	3.23 ± 0.15^{a}	0.78 ± 0.05^{c}	92 ± 1.5^{b}
24 °C	3×	90 ± 3.2^{b}	2.68 ± 0.12^{b}	0.93 ± 0.06^{bc}	94 ± 1.6^{b}
24 °C	5×	110 ± 4.0^{a}	3.01 ± 0.14^{ab}	0.83 ± 0.04^{c}	95 ± 1.2^{b}
27 °C	1×	65 ± 2.5^{c}	3.01 ± 0.16^{ab}	0.83 ± 0.05^{c}	93 ± 1.4^{b}
27 °C	3×	70 ± 2.8^{c}	1.54 ± 0.08^{c}	1.63 ± 0.07^{a}	97 ± 1.1^{a}
27 °C	5×	95 ± 3.5^{ab}	2.28 ± 0.11^{cd}	1.10 ± 0.06^{b}	96 ± 1.3^{a}
30 °C	1×	68 ± 2.9^{c}	2.88 ± 0.13^{b}	0.87 ± 0.05^{c}	93 ± 1.2^{b}
30 °C	3×	85 ± 3.1^{b}	1.95 ± 0.10^{c}	1.28 ± 0.06^{b}	96 ± 1.0^{a}
30 °C	5×	100 ± 3.7^{a}	2.53 ± 0.12^{bc}	0.99 ± 0.05^{bc}	95 ± 1.1^{b}

Values are means ± SE (n = 3). Means within each column with different superscripts are significantly different ($p < 0.05$).

Water Quality

Table 3 below shows the water parameters. Water quality remained within recommended ranges throughout the study. DO was lowest (5.2 mg/L) and TAN highest (0.42 mg/L) at 30 °C.

https://doi.org/10.5281/zenodo.18062277

Table 3. Mean water quality parameters during the experiment.

Temperature	DO (mg/L)	pH	TAN (mg/L)
24 °C	6.4 ± 0.3[a]	7.2 ± 0.2[ab]	0.25 ± 0.04[c]
27 °C	5.8 ± 0.2[ab]	7.4 ± 0.3[a]	0.30 ± 0.05[b]
30 °C	5.2 ± 0.4[b]	6.9 ± 0.2[b]	0.42 ± 0.07[a]

Values are means ± SE (n = 3). Means within each column with different superscripts are significantly different ($p < 0.05$).

The line chart (figure 1) shows that weight gain was lowest at 24 °C with once-daily feeding (18.6 g) and peaked at 27 °C with thrice-daily feeding (45.6 g). Growth declined slightly at 30 °C, particularly at higher feeding frequencies.

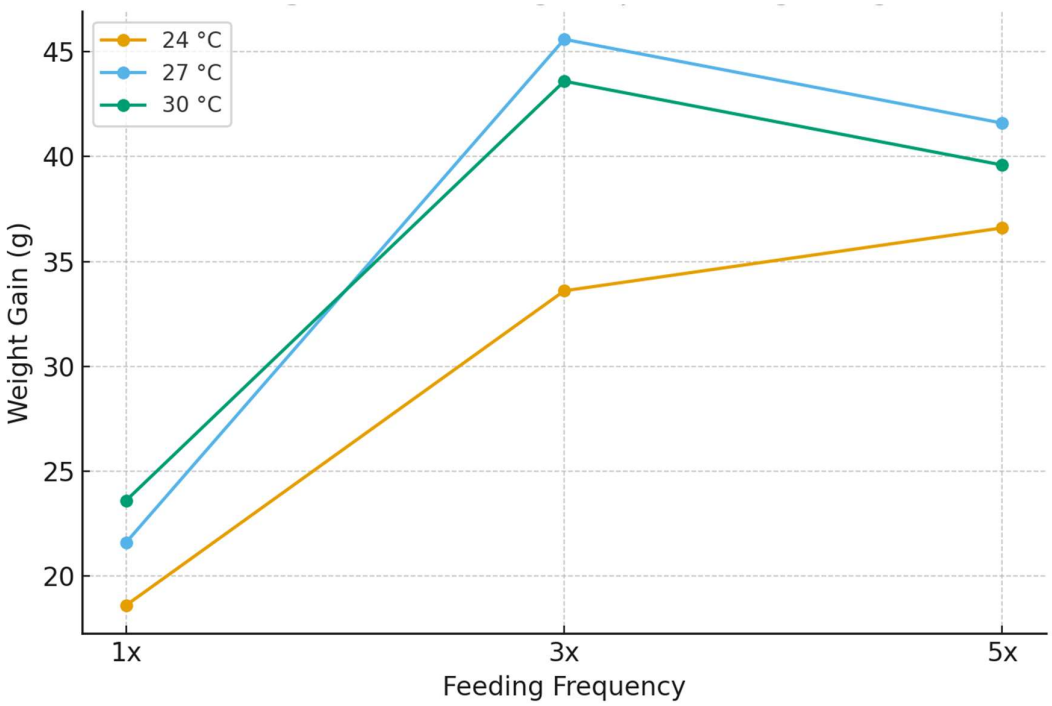

Figure 1. Weight Gain of C. gariepinusfingerligs

The bar chart below (figure 2) indicates that FCR was highest (3.23) at 24 °C with once-daily feeding and lowest (1.54) at 27 °C with thrice-daily feeding, demonstrating superior feed efficiency under intermediate conditions.

https://doi.org/10.5281/zenodo.18062277

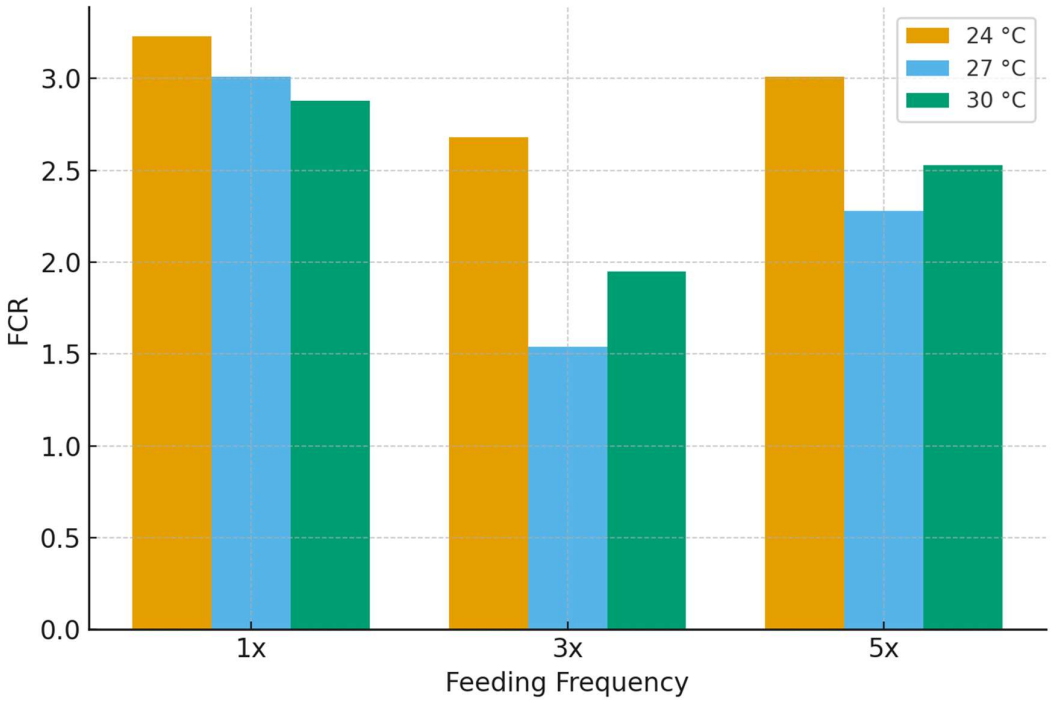

Figure 2. Feed Conversion Ratio (FCR)of C. gariepinus fingerligs

The bar chart (figure 3) shows PER improved significantly at 27 °C with thrice-daily feeding (1.63), compared to values below 1.0 at once-daily feeding across all temperatures, confirming more efficient protein utilization under optimal regimes.

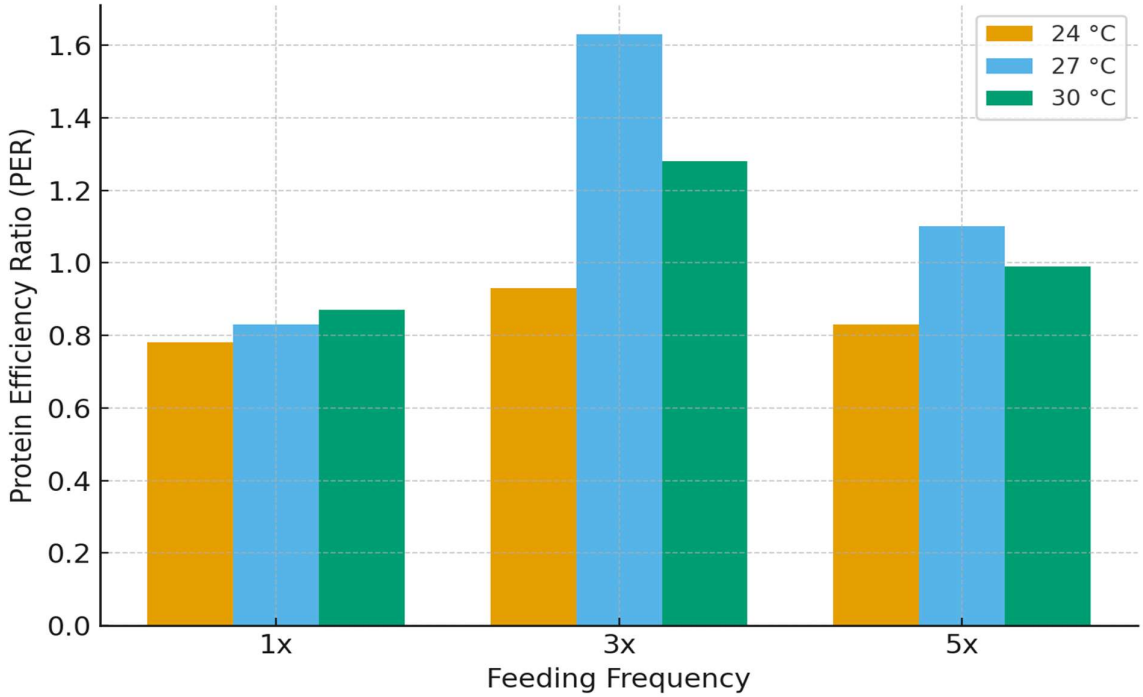

Figure 3. Protein Efficiency Ratio (PER) of C. gariepinus fingerligs

The line chart below (Figure 1) reveals consistently high survival across treatments (>90%), with the highest (97%) recorded at 27 °C and thrice-daily feeding. Survival was lowest (92%) at 24 °C with once-daily feeding.

https://doi.org/10.5281/zenodo.18062277

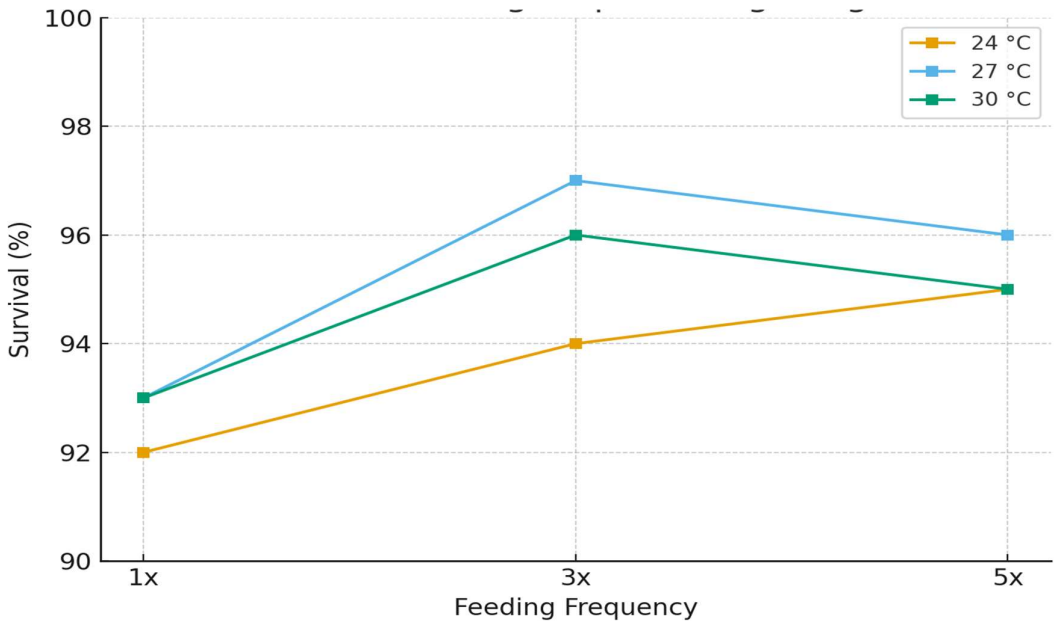

Figure 4. Survival (%)of C. gariepinus fingerligs

Discussion

The best growth occurred at 27 °C with thrice-daily feeding (WG = 45.6 g; SGR = 3.74% day⁻¹). At 24 °C, growth was poor (WG = 18.6 g), reflecting reduced metabolism and slower digestion in cooler water (Kasihmuddin et al., 2021). Similar findings were reported by Hu et al. (2024), who noted decreased enzyme activity under suboptimal thermal regimes. Although growth at 30 °C was good (WG = 43.6 g), it did not surpass 27 °C, possibly due to increased metabolic stress and reduced oxygen availability. These results agree with Hamed et al. (2024), who observed stress responses above 30 °C. Thus, maintaining nursery water between 27-29 °C is optimal for hatchery practice.

Feeding frequency also had clear effects. Once-daily feeding led to poor growth (WG = 18.6 g; FCR = 3.23), as nutrient demand was unmet. Thrice-daily feeding provided steady nutrient availability, yielding the best growth and FCR (1.54). Feeding five times daily increased intake (95-100 g) but slightly worsened FCR (2.28-2.53), suggesting feed wastage and nutrient leaching. Similar trends were reported by Okomoda et al. (2019), who found thrice-daily feeding optimal for catfish fry, and by Hassan et al. (2021), who warned against excessive feeding. Contradictory results from Adewolu et al. (2008), who recommended higher frequencies, may reflect pond-based systems with higher competition. In controlled hatchery tanks, three meals per day appear most efficient.

Feed utilization patterns support this conclusion. The best FCR (1.54) and PER (1.63) were at 27 °C with thrice-daily feeding. Poorer values at once-daily feeding (FCR > 3.0) show that fish could not effectively convert feed to biomass. Similar FCR ranges (1.4-2.0) were reported in other catfish hatcheries (Okomoda et al., 2019; Kasihmuddin et al., 2021). Feed is the costliest input in aquaculture, making efficient utilization crucial for profitability. Thus, thrice-daily feeding at optimal temperature balances growth with cost efficiency.

Survival exceeded 90% across treatments, with the highest at 27 °C and thrice-daily feeding (97%). This agrees with Hassan et al. (2021), who reported high hatchery survival under good feeding regimes. Lower survival at 24 °C with once-daily feeding (92%) may be due to stress, cannibalism, or malnutrition. Compared with pond systems, where survival may drop below 80% due to predation and fluctuating water quality (Adeoye etal., 2019),

https://doi.org/10.5281/zenodo.18062277

hatchery-controlled environments clearly improve outcomes.

Water quality parameters remained within recommended limits (FAO, 2022). DO declined from 6.4 mg/L at 24 °C to 5.2 mg/L at 30 °C due to reduced oxygen solubility, which may have limited growth efficiency at higher temperatures. pH values (6.9-7.6) were within the optimal range (6.5-8.0). TAN increased with temperature and feeding intensity, peaking at 0.42 mg/L at 30 °C. Although below harmful levels, elevated ammonia can impair gill function and reduce feed efficiency (Akinwole and Faturoti, 2007). These findings highlight the importance of balancing feed input with water quality management in hatcheries.

The weight gain showed that fingerlings performed poorly at 24 °C (18.6–36.6 g) compared to 27 °C (21.6-45.6 g) and 30 °C (23.6-43.6 g). The best growth was at 27 °C with thrice-daily feeding (45.6 g), followed closely by 30 °C with thrice-daily feeding (43.6 g). This confirms that C. gariepinus fingerlings thrive in moderately warm conditions. Lower growth at 24 °C is attributable to reduced metabolism and slower gastric evacuation, limiting nutrient assimilation (Kasihmuddin et al., 2021). While 30 °C still supported high growth, it did not exceed 27 °C, possibly due to higher metabolic oxygen demand and slight stress from reduced dissolved oxygen (Hu et al., 2024). Similar optimal ranges were reported by Hamed et al. (2024) for tilapia and by Langi (2024) for African catfish, who both identified 27-29 °C as growth-optimal. However, in some studies (Adewolu et al., 2008), catfish achieved peak growth even at 31 °C, likely due to larger pond volumes and fluctuating natural conditions. Thus, the hatchery-controlled environment in Baga emphasizes 27 °C as the practical optimum.

The Food conversion ratio (FCR) demonstrated that once-daily feeding produced poor efficiency (FCR = 3.23 at 24 °C), while thrice-daily feeding at 27 °C yielded the most efficient conversion (FCR = 1.54). High FCR values (>3.0) indicate inefficient nutrient use, with much of the feed wasted or not assimilated. The improvement at higher frequencies (3×) is due to steady nutrient supply matching digestive capacity, while the worsening at 5× (2.28-3.01) likely reflects feed wastage and water quality deterioration. These findings are consistent with Okomoda et al. (2019), who reported best FCR in C. gariepinus fry at intermediate feeding frequencies, and with Hassan et al. (2021), who showed that excessive feeding increased costs without improving efficiency. Contrastingly, Adeoye et al. (2019) found that higher frequencies improved FCR in pond-reared catfish fingerlings, likely because competition and nutrient loss in ponds necessitate more frequent meals. This difference highlights how hatchery systems, with minimal competition, respond optimally to moderate feeding.

Protein efficiency ratio (PER) was highest at 27 °C with thrice-daily feeding (1.63), indicating the most effective protein utilization under these conditions. Once-daily feeding resulted in poor PER (<0.9 across temperatures), reflecting insufficient protein assimilation when meals are limited. At five meals per day, PER decreased slightly (1.10 at 27 °C and 0.99 at 30 °C), suggesting that while more protein was ingested, some was wasted or catabolized for energy rather than growth. Efficient protein use requires a balance between supply and metabolic demand; overfeeding may exceed digestive enzyme capacity, leading to nitrogenous waste (Kasihmuddin et al., 2021). Similar trends were observed by Langi (2024), who noted reduced PER under excessive feeding in C. gariepinus. In contrast, Adewolu et al. (2008) reported improved PER at four meals/day in outdoor systems, suggesting that in ponds, higher feeding frequency may better match competition and fluctuating natural food availability. The controlled hatchery results here support three meals/day as the most protein-efficient.

Survival rate was high across all treatments (>90%), confirming the resilience of C. gariepinus and the suitability of hatchery conditions. The highest survival (97%) occurred at 27 °C with thrice-daily feeding,

https://doi.org/10.5281/zenodo.18062277

while the lowest (92%) was recorded at 24 °C with once-daily feeding. This suggests that optimal conditions reduce stress and cannibalism, while cooler water and low feeding increase competition and stress-induced mortality. These findings are consistent with Hassan et al. (2021), who reported >90% survival in hatchery catfish when fed adequately, and contrast with Adeoye et al. (2019), who observed survival <80% in pond systems due to predation and water fluctuations. The implication is that hatchery control minimizes mortality, but management lapses (inadequate feeding or poor thermal regulation) can still reduce survival.

Conclusion

This study confirms that optimal hatchery performance of Clarias gariepinus fingerlings is achieved at 27-30 °C and with thrice-daily feeding. This regime maximizes growth, ensures efficient feed utilization, and maintains high survival, while keeping water quality within safe limits. Hatchery managers and farmers in Nigeria can adopt these practices to improve fingerling production efficiency and profitability.

Recommendation

Based on the findings of this study, it is recommended that hatchery managers and fish farmers rear Clarias gariepinus fingerlings at optimal water temperatures of 27-30 °C while adopting thrice-daily feeding schedules, as this regime produced the highest weight gain (45.6 g), best specific growth rate (3.74% day^{-1}), lowest feed conversion ratio (1.54), highest protein efficiency ratio (1.63), and maximum survival (97%). Feeding once daily should be avoided due to poor growth and inefficient feed utilization, while excessive feeding frequencies (five times daily) should be discouraged as they do not significantly improve growth but increase feed waste and ammonia buildup. Proper monitoring of water quality, particularly dissolved oxygen and ammonia, is also essential to sustain high productivity. Adopting these practices will improve hatchery efficiency, reduce feed costs, and ensure the consistent production of robust fingerlings for aquaculture in Nigeria.

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