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Growth Performance and Nutrient Utilisation of African Catfish, Clarias Gariepinus (Burchell, 1822) Fed Ginger Nanoparticles Supplemented Diets

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ABSTRACT

This study evaluated the growth performance and nutrient utilisation of African catfish (*Clarias gariepinus*) fed ginger nanoparticles supplemented diets. Three hundred African catfish (*Clarias gariepinus*) post juveniles of 14.11g ± 0.08 were divided into five groups and fed ginger nanoparticles supplemented diets for 56 days. The control (T1) received feed without ginger, while four other groups received feed with increasing amounts of ginger nanoparticles: 0.05g (T2), 0.10g (T3), 0.15g (T4), and 0.20g (T5) per 100g of feed formulated. Water quality parameters were monitored and were within recommended levels for culture of African catfish (*Clarias gariepinus*). Growth performance parameters such as initial and final weights, weight gain, feed conversion ratio (FCR), specific growth rate (SGR), and protein efficiency ratio (PER) were accessed after the feeding trials. The results showed significant improvements in growth performance with ginger nanoparticle supplementation. Fish in group T3 (0.10g) inclusion had the best growth performance with weight gain of 20.60g compared with 17.61g in the control group. The best FCR of 1.55 was recorded in group T3 (0.10g) inclusion compared with 2.05 recorded in control fish. The specific growth rate was 0.36% per day in T3 compared to 0.31% in control. Fish body composition also improved, with higher protein content (up to 67.20% in T5) compared to control (63.50%). T3 (0.10g ginger nanoparticles per 100g feed) is recommended as the optimal inclusion level. Therefore, the study shows that ginger nanoparticles supplementation improved the growth performance and nutrient utilisation in African catfish (*Clarias gariepinus*).

Keywords: African catfish, Growth performance, Ginger nanoparticles, Aquafeed, Supplementation.

INTRODUCTION

Aquaculture (the farming of aquatic organisms including fish, crustaceans, mollusks, and aquatic plants) has emerged as the fastest-growing sector of animal food production globally (FAO, 2022) to meet this rising aquatic food demand. It has surpassed capture fisheries in contributing to global fish supply and continues to play a pivotal role in reducing the pressure on wild fish stocks. However, the expansion of aquaculture brings several challenges, particularly the need to improve feed efficiency, ensure fish health, and maintain environmental sustainability (Dawood *et al*., 2021).

One of the critical determinants of successful aquaculture is nutrition. The quality and composition of fish feed directly affect growth rate, feed utilization, survival, and resistance to diseases (NRC, 2011). Traditionally, synthetic additives, antibiotics, and chemotherapeutics were used to enhance fish growth and control diseases. However, concerns over antibiotic resistance, residue accumulation, environmental impact, and consumer safety have spurred interest in alternative, eco-friendly feed additives (Van Hai, 2015; Hoseinifar *et al*., 2017).

Phytogenic feed additives derived from herbs, spices, and medicinal plants are increasingly recognized as viable and sustainable alternatives to synthetic additives. Among these, ginger (*Zingiber officinale*) has received considerable attention due to its bioactive compounds, including gingerols, shogaols, and zingerone, which exhibit potent antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory properties (Adel *et al*., 2016; Gabriel *et al*., 2015). Previous studies have shown that dietary inclusion of ginger can significantly enhance growth performance, improve hematological indices, boost immunity, and confer resistance against bacterial infections in various fish species including *Oreochromis niloticus*, *Oncorhynchus mykiss*, and *Clarias gariepinus* (Hussein *et al*., 2018; Bako *et al*., 2023; Ukenye *et al*., 2023).

Despite its proven efficacy, one of the limitations associated with the use of conventional ginger powder in aquafeed is its poor bioavailability, low solubility, and limited intestinal absorption. As a result, the full biological potential of its active compounds may not be fully harnessed when administered in bulk form (Hoseinifar *et al*., 2020). This limitation underscores the importance of improving the delivery and absorption of phytogenic compounds in aquaculture nutrition.

Recent advancements in nanotechnology offer innovative solutions to the aforementioned challenges. Nanotechnology involves manipulating materials at the nanoscale (1–100 nm) to enhance their physical, chemical, and biological properties. In aquaculture, the application of nanotechnology in the form of nanosupplements has been shown to improve nutrient bioavailability, enhance metabolic activity, and promote efficient feed utilization (Alishahi and Abdy, 2021). Nano-synthesized forms of minerals and phytobiotics such as nano-selenium, nano-zinc, and nano-curcumin have been reported to exert superior effects compared to their conventional counterparts in terms of growth performance, immune modulation, and antioxidative responses (Mahmoud *et al*., 2020; Khalafalla *et al*., 2021).

Nano-synthesized ginger, in particular, has gained recent attention due to its enhanced solubility, increased surface area, and higher bioavailability. Through green synthesis methods, nano-ginger can be produced using plant extracts and safe reducing agents, making it a sustainable and environmentally benign innovation (Barathikannan *et al*., 2019). However, empirical data on the dietary application of nano-synthesized ginger in aquaculture, especially in *Clarias gariepinus*, remain scarce. This study aims to investigate the dietary effect of nano-synthesized ginger on the growth performance and nutrient utilization of African catfish.

MATERIALS AND METHOD

Experimental Site

This study was carried out at the Teaching and Research Farm of the Department of Fisheries and Aquaculture Technology, The Federal University of Technology, Akure, Ondo State Nigeria. Three hundred (300) African catfish (*Clarias gariepinu*s) post juveniles with average weight (14.11g ± 0.08) sourced from reliable fish farm in Akure, Ondo state. The experimental fish were acclimatized for 7days in tanks in the farm and introduced into fifteen indoor rectangular tanks with three replicate per treatment. During this period they were fed with a commercial diet of 40%CP.

Preparation of Experimental Diet

The formulation of the diet was through Pearson's Square Method using 40% protein (Table 1). The various ingredients were ground with hammer mill, weighed and mix for homogeneity and pelleted using a pelleting machine (Hobart Ltd, London, UK). The pelleted feed was sun dried to a constant moisture level then packed in airtight polyethylene bags and stored. Diets were analyzed for their proximate composition using of AOAC (2024). Nano encapsulated ginger were supplemented as follows: T1 was the control with 0.00g nano encapsulated ginger supplementation, T2 had 0.05g nano encapsulated ginger supplementation, T3 with 0.10g nano encapsulated ginger supplementation, T4 had 0.15g of nano encapsulated ginger supplementation and T5 has supplementation of 0.20g nano encapsulated ginger supplementation. The different diet dough was individually run through a sieve with 2 mm dye and resulting stands were cut into pellets and sun-dried separately. The resulting diets were stored separately in labeled dry air-dried plastic container.

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Table 1: Composition of the experimental diet in g/100g containing various levels of nano synthesized ginger for Clarias gariepinus

INGREDIENTS	T1	T2	T3	T4	T5
Fishmeal (72% CP)	29.95	29.95	29.95	29.95	29.95
Soya bean meal (45% CP)	9.75	9.75	9.75	9.75	9.75
Wheat Offal (15% CP)	8.00	8.00	8.00	8.00	8.00
Groundnut Cake (45% CP)	26.00	26.00	26.00	26.00	26.00
Yellow maize (10% CP)	18.00	18.00	18.00	18.00	18.00
Soya bean oil	5.00	5.00	5.00	5.00	5.00
Vitamin Premix	2.00	2.00	2.00	2.00	2.00
Sodium Alginate	2.00	2.00	2.00	2.00	2.00
Nano-encapsulated Ginger	0.00	0.05	0.10	0.15	0.20

Premix manufactured by Chemiconsult International Limited, Ikeja, Lagos, Nigeria

Vitamins supplied mg/100g diet: vitamin B1 (Thiamine) 1.2mg; vitamin B2 (Riboflavine) 2.4mg; vitamin B3 (Niacin) 10mg; vitamin B5 (Pantothenic acid) 4.0mg; vitamin B6 (Pyridoxine) 2.0mg; vitamin B7 (Biotin) 0.2mg; vitamin B9 (Folic acid) 0.4mg; vitamin K 2.0mg; vitamin B12 (Cyanocobalamin) 10.0mg; vitamin C (Ascorbic acid) 150mg, chlorine 160mg.

Experimental Design

Completely randomized design (CRD) was used in allocating of *C. gariepinus* juveniles to the experimental tanks for the feeding trials. During the study, the fish were fed to satiation with the experimental diet twice daily between (8.00 hours- 9.00 and 16.00- 17.00 GMT). The water in the plastic tanks changed at least twice in a week to remove the foul smell developed by the waste and excreta of the fish.

Physio-chemical Parameters Determination

Temperature, pH and dissolved oxygen were measured weekly, HANNA multi parameter water checker instrument was used to measure the water quality parameters.

Growth Performance and nutrient utilisation of *Clarias gariepinus* fed with Nano encapsulated ginger Calculation on growth performance and nutrient utilisation were carried out using the expression below: Weight gain (g) = Final body weight – Initial body weight

$$\text{Specific Growth Rate (\%/day)} = \frac{In\ final\ body\ weight - In\ initial\ body\ weight}{Duration\ of\ feeding}\ X\ 100$$

Feed Intake (g) = Total amount of feed given (g) X number of days

$$\text{Feed Conversion Ratio} = \frac{Feed\ Intake}{Weight\ gain}$$

$$\text{Feed Efficiency Ratio} = \frac{Weight\ gain}{Feed\ intake}$$

$$\text{Protein Efficiency Ratio} = \frac{Weight\ of\ fish}{Protein\ fed}$$

Statistical Analysis: Analysis of variance (ANOVA) was used to assess the impact of dietary treatments on their response variables. Data were analysed using Statistical Packages for Social Sciences (SPSS) version 23.0 (IBM Corporation, Armonk, USA) with P-level of 0.5.

RESULTS

The water quality parameters during the current study remained relatively stable across the groups (Table 2). There were no significant differences (p>0.05) in the temperature, pH and Dissolved oxygen recorded among the treatments.

Table 2: Water quality Parameters

Parameter	**T1**	**T2**	**T3**	**T4**	**T5**
Temperature (°C)	26.5 ± 0.05^a	26.6 ± 0.09^a	26.5 ± 0.09^a	26.4 ± 0.02^a	26.4 ± 0.00^a
pH	6.9 ± 0.08^a	6.8 ± 0.03^a	6.9 ± 0.01^a	6.9 ± 0.01^a	6.9 ± 0.01^a
DO (mg/L)	5.1 ± 0.03^a	4.9 ± 0.03^a	4.8 ± 0.03^a	5.2 ± 0.03^a	4.9 ± 0.03^a

Key= Temp ―Temperature, DO ―Dissolved oxygen, pH ― Hydrogen ion concentration

Growth Performance and Nutrient utilization of African catfish (*Clarias gariepinus*) post juveniles fed with the nano encapsulated ginger supplemented diets

The proximate analysis of the experimental diets revealed that the diets were isonitrogenous (Table 1). The growth performance and nutrient utilisation of *C. gariepinus* fed with nano encapsulated supplemented diets is presented in Table 3. The initial body weight varied from approximately from 14.26g to 13.78g with T5 had the lowest while T3 has the highest and there was significant difference (p<0.05) with T5 when compared to the other treatments. The final body weight varied approximately from 34.86g to 30.32g with T5 having the lowest while T3 had the highest and there was significant difference (p<0.05) among the treatments when compared with T1. The body weight gain varied from approximately from 16.54g to 20.60g with T5 having the lowest while T3 had the highest and there was significant differences (p<0.05) among the treatment. There was no significant difference recorded in the feed intake. There was significant difference (p<0.05) recorded in the feed conversion ratio when T1 was compared with T2, T3, T4. There was significant difference (p<0.05) recorded in the feed conversion ratio when T1 was compared with T2, T3, T4. There was significant difference (p<0.05) recorded in the feed efficiency ratio, specific growth rate and the protein efficiency ratio. Finally, there was no significant difference in the mortality rate across the treatment group.

Table 3: Growth performance and nutrient utilization of African catfish (*Clarias gariepinus*) juveniles fed with the nano encapsulated ginger supplemented diets.

Parameters	**T1**	**T2**	**T3**	**T4**	**T5**
IW (g)	14.11 ± 0.08^b	14.10 ± 0.18^b	14.26 ± 0.03^b	14.10 ± 0.15^b	13.78 ± 0.13^a
FW (g)	31.73 ± 0.32^b	34.36 ± 0.18^c	34.86 ± 0.23^c	34.24 ± 0.59^c	30.32 ± 0.17^a

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WG (g)	17.61 ± 0.36^{b}	20.26 ± 0.21^{c}	20.60 ± 0.20^{c}	20.13 ± 0.69^{c}	16.54 ± 0.29^{a}
%WG	124.75 ± 2.99^{a}	143.72 ± 2.93^{b}	144.38 ± 1.12^{b}	142.83 ± 6.08^{b}	120.01 ± 3.14^{a}
FI (g)	36.10 ± 0.00	34.70 ± 0.00	31.96 ± 0.00	35.16 ± 0.00	34.70 ± 0.00
FCR	2.05 ± 0.05^{c}	1.71 ± 0.02^{b}	1.55 ± 0.02^{a}	1.75 ± 0.06^{b}	2.10 ± 0.03^{c}
FER	0.48 ± 0.01^{a}	0.58 ± 0.01^{b}	0.64 ± 0.01^{c}	0.57 ± 0.02^{b}	0.47 ± 0.01^{a}
SGR (%/day)	0.31 ± 0.01^{b}	0.36 ± 0.00^{c}	0.36 ± 0.00^{c}	0.35 ± 0.01^{c}	0.29 ± 0.01^{a}
PER	0.35 ± 0.01^{a}	0.41 ± 0.00^{b}	0.43 ± 0.00^{c}	0.41 ± 0.01^{b}	0.34 ± 0.01^{a}
MOR (%)	1.67 ± 0.07^{a}	1.33 ± 0.03^{a}	1.33 ± 0.63^{a}	1.33 ± 0.90^{a}	1.33 ± 0.06^{a}

Values as mean ± SD. Values with different alphabet superscript along a column for each parameter were significantly different ($p<0.05$).

IW= Initial weight, FW= Final weight Gain, WG= Weight Gain, %WG = Percentage Weight Gain**,** FI= Feed Intake, FCR= Feed Conversion Ratio, FER= Feed Efficiency Ratio, SGR= Specific growth rate, PI= Protein Intake, PER= Protein Efficiency Ratio, MOR (%) = Mortality.

DISCUSSION

Water Quality Parameters

The absence of significant differences in temperature (26.4–26.6°C), pH (6.8–6.9) and dissolved oxygen (4.8–5.2 mg/L) across treatments (T1–T5) indicates that ginger nanoparticle incorporation did not adversely affect the culture environment. This stability is crucial in aquaculture, as fluctuations in these parameters can stress fish, impair growth, and increase susceptibility to diseases. Similar stability has been reported in studies using ginger supplements in African catfish (*Clarias gariepinus*) systems. For instance, a study on *Clarias gariepinus* fingerlings fed ginger root powder (up to 2%) for 8 weeks found no significant alterations in water quality metrics like pH, dissolved oxygen, and temperature, attributing this to ginger's non-toxic nature and lack of residual environmental impact (Olufayo, 2019). The current results reinforce that ginger nanoparticles, even at varying levels (escalating from T1 as control to T5), maintains optimal conditions for catfish culture, which typically thrives at pH (6.5–8.0), temperatures (25–30°C), and DO (>4 mg/L).

Growth performance and nutrient utilization of African catfish (*Clarias gariepinus*) juveniles fed with the nano encapsulated ginger supplemented diets.

Growth metrics varied significantly ($P < 0.05$), with initial weights (13.78–14.26 g) showing minor differences, but final weights (30.32–34.86 g), weight gain (16.54–20.60 g), and percentage weight gain (120.01–144.38%) peaking in T3. Feed conversion ratio (FCR) was lowest (best) in T3 (1.55), while feed efficiency ratio (FER; 0.64), specific growth rate (SGR; 0.36%/day), and protein efficiency ratio (PER; 0.43) also excelled in T3. Mortality rates (1.33–1.67%) showed no significant differences ($p>0.05$). The weight gain of the fish fed diets supplemented with 0.10g of nano encapsulated ginger was significantly higher and better when compared to the control and other groups. The percentage efficiency ratio was higher in the group fed with 0.10g of nano encapsulated ginger. This indicated that inclusion at this level was very effective on fish growth. The findings of this study are in agreement with the report of Korni *et al.* (2021)**,** who observed that the inclusion of ginger and its nanoparticles in the diet of *Clarias gariepinus* significantly enhanced growth performance, feed conversion ratio and overall physiological health. The result of the present study showcased that the various level of nano encapsulated ginger in diets played an undeniable role in fish growth and utilisation of feed by the experimental African catfish (*Clarias gariepinus*).

CONCLUSION

This study demonstrates that nano synthesized ginger nanoparticles (GNP) are an effective dietary additive for African catfish (*Clarias gariepinus*) juveniles, significantly enhancing growth performance. Fish fed with 0.10g/100g of nano encapsulated ginger supplemented diet had the highest growth performance and nutrient utilisation in the present study. The fish fed with 0.10g/100g of nano encapsulated ginger may also be chosen by fish farmers involved in fish farming for efficient growth and sustainable fish production.

RECOMMENDATION

Based on the result obtained from this study, it is recommended to incorporate ginger nanoparticles at a dietary inclusion level of 0.10g as evidenced by the optimal performance in treatment T3.

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