

## Effects of Ginger Inclusion on Growth Performance and Immune Response of *Clarias gariepinus*

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**Abstract:** This study evaluated the effects of dietary supplementation of ginger (*Zingiber officinale*) on the growth performance, feed utilization, survival, and immune response of African catfish *Clarias gariepinus* fingerlings under controlled culture conditions. A total of 100 fingerlings with initial mean weights ranging from  $7.04 \pm 0.30$  g to  $7.29 \pm 0.54$  g were randomly assigned to five dietary treatments (T1–T5) in a completely randomized design, with two replicates per treatment (10 fish per replicate). T1 served as the control (0% ginger), while T2, T3, T4, and T5 contained 0.2%, 0.3%, 0.5%, and 1.0% ginger inclusion levels, respectively. Fish were acclimatized for two weeks and subsequently fed experimental diets at 5% body weight for eight weeks. Growth and immune parameters were analyzed using one-way ANOVA followed by Duncan's multiple range test ( $p < 0.05$ ). Results showed significant improvements in growth performance and survival in ginger-supplemented groups compared with the control. The highest final body weight ( $31.70 \pm 2.13$  g), weight gain ( $24.66 \pm 1.14$  g), most efficient feed conversion ratio ( $1.12 \pm 0.06$ ), and highest survival rate (86.67%) were recorded in fish fed 1.0% ginger (T5). In contrast, the lowest final body weight ( $20.27 \pm 5.20$  g) was observed in T4 (0.5% ginger), while the lowest survival rate (63.33%) occurred in T3 (0.3% ginger). Feed conversion ratio varied significantly across treatments, ranging from 1.12 to 2.10, indicating improved feed efficiency at higher ginger inclusion levels. Haematological and immune indices, including lymphocyte ( $80.14 \pm 1.81\%$ ), monocyte ( $6.96 \pm 0.19\%$ ), and hematocrit ( $59.25 \pm 7.56\%$ ) values, were generally enhanced in ginger-fed groups, particularly at 1.0% inclusion, indicating improved physiological and immune status. Dietary supplementation with 1.0% ginger

yielded the best performance in *C. gariepinus*, enhancing growth, feed utilization, survival, and immune response. These findings support ginger as a safe and effective phytogenic feed additive for sustainable African catfish production.

**Keywords:** Ginger supplementation; *Clarias gariepinus*; growth performance; feed conversion ratio; immune response

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### 1.0 Introduction

Aquaculture has become a critical contributor to global food security, with African catfish (*Clarias gariepinus*) representing one of the most widely cultured species in West Africa due to its fast growth, high market demand, and resilience under diverse culture conditions (Brummett *et al.*, 2019; FAO, 2020). Natural plant-based additives are

increasingly preferred because they are biodegradable, eco-friendly, and capable of improving fish health and productivity without adverse environmental effects.

Despite these advantages, achieving optimal growth and survival in intensive culture systems requires dietary strategies that enhance performance while maintaining sustainability. The use of phyto-genic feed additives, particularly ginger (*Zingiber officinale*), has gained attention as a natural alternative to synthetic growth promoters and antibiotics (Amagase *et al.*, 2014; Levic, Sredanovic, & Djuragic, 2015).

Ginger contains several biologically active compounds, including gingerol, shogaol, zingerone, and flavonoids, which possess antimicrobial, antioxidant, anti-inflammatory, and immunostimulatory properties (Ali *et al.*, 2008). These compounds have been reported to enhance digestive enzyme activity, improve nutrient utilization, and strengthen immune responses in fish species. Previous studies demonstrated that ginger supplementation improved growth performance, feed efficiency, disease resistance, and haematological parameters in Nile tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*), and rainbow trout (*Oncorhynchus mykiss*) (Nya & Austin, 2009; Talpur *et al.*, 2013;).

In African catfish, garlic inclusion has been reported to enhance weight gain, feed utilization, and haematological parameters (Jabbi, Ibrahim, & Musa, 2022; Bello, Olaifa, & Emikpe, 2012; Emeka *et al.*, 2026).

The increasing restriction on the use of synthetic antibiotics in aquaculture has intensified interest in phyto-genic feed additives as sustainable alternatives (Olaniyi *et al.*, 2020; Heidarieh *et al.*, 2013; Zomrawi *et al.*, 2013).. Among these additives, ginger has emerged as a promising candidate due to its availability, low toxicity, and wide spectrum of biological activities. Although several studies have reported the beneficial effects of ginger in aquaculture species, information regarding the optimal dietary inclusion level of ginger for African catfish

(*Clarias gariepinus*), particularly under tropical culture conditions, remains limited. Furthermore, there is inadequate information on the influence of graded ginger supplementation on immune response indicators such as lymphocyte count, monocyte count, and haematocrit values in *C. gariepinus*.

This study therefore investigated the effects of graded dietary inclusion levels of ginger (*Zingiber officinale*) on the growth performance, feed utilization, survival rate, and immune response of *Clarias gariepinus* fingerlings. By establishing the most effective inclusion level, the research contributes to sustainable aquaculture practices and provides evidence for the application of phyto-genic feed additives in West African fish farming systems. The findings of this study may also contribute to reducing dependence on synthetic chemotherapeutic agents in aquaculture while promoting healthier and more environmentally sustainable fish production practices.

## 2.0 Materials and Methods

### 2.1 Study Site

The feeding trial was conducted at the hatchery unit of the University of Calabar Fish Farm, Calabar, Nigeria. The study area is located within the humid tropical rainforest zone characterized by moderate to high rainfall and average ambient temperatures ranging from 26–32 °C.

### 2.2 Preparation of Ginger Feed Additive

Fresh ginger (*Zingiber officinale*) rhizomes were purchased from Watt Market, Calabar, Nigeria. The rhizomes were thoroughly washed with clean water to remove dirt and other contaminants, peeled, and cut into smaller pieces. The sliced ginger was sun-dried for 5–7 days until constant weight was achieved and then ground into fine powder using an electric grinder. The powdered ginger was stored in airtight containers and kept in a cool dry place until incorporation into the experimental diets.

### 2.3 Experimental Diet Formulation



Feed ingredients used for diet formulation included fish meal, soybean meal, yellow maize, vegetable oil, vitamin premix, methionine, lysine, calcium, salt, and acidomix preservative. Soybean seeds were heat-treated before milling to inactivate trypsin inhibitors. Experimental diets were formulated to contain approximately 45% crude protein using Pearson's square method in accordance with the nutritional requirements of juvenile *Clarias gariepinus*. Five experimental diets were prepared as follows:

- (i) T1: Control diet without ginger supplementation
- (ii) T2: Diet supplemented with 0.2% ginger
- (iii) T3: Diet supplemented with 0.3% ginger
- (iv) T4: Diet supplemented with 0.5% ginger
- (v) T5: Diet supplemented with 1.0% ginger

All ingredients were weighed using a digital weighing balance and thoroughly mixed manually to ensure homogeneity. The appropriate quantity of ginger powder was incorporated into each treatment diet before pelleting. The diets were pelleted using a manual pelletizer, air-dried for 24 h, and stored in airtight containers at room temperature until use. Each batch of feed weighed 5 kg. Proximate composition of the experimental diets was determined according to standard AOAC procedures.

#### 2.4 Experimental Fish and Design

A total of one hundred juvenile *Clarias gariepinus* with mean initial body weights ranging from  $7.04 \pm 0.30$  g to  $7.29 \pm 0.54$  g were obtained from a reputable fish farm in Calabar, Nigeria. The fish were acclimatized for two weeks before the commencement of the experiment and fed a commercial diet during the acclimation period.

After acclimatization, the fish were randomly distributed into five treatment groups (T1–T5) in a completely randomized design. Each treatment consisted of two replicates

containing 10 fish per replicate. Fish were stocked in plastic tanks containing clean freshwater. Water in the tanks was changed weekly to maintain water quality, while temperature, dissolved oxygen, and pH were monitored periodically throughout the experimental period.

#### 2.5 Feeding Regimen and Growth Measurements

Fish were fed the experimental diets twice daily, in the morning and evening, at 5% of their body weight for eight weeks. Feed quantities were adjusted biweekly based on weight changes observed during sampling. Body weight measurements were taken biweekly using a Mettler digital weighing balance (Model M311L), while total length was measured from the snout to the caudal fin using a measuring ruler. Feed intake was recorded throughout the feeding trial. Uneaten feed and waste materials were removed regularly to maintain water quality and ensure accurate estimation of feed consumption.

#### 2.6 Health Condition Monitoring

Fish were monitored daily throughout the experimental period for behavioral changes, feed acceptance, swimming activity, stress symptoms, and mortality. Reflex responses, including escape reflex, tail reflex, ocular reflex, and defensive response, were assessed according to the procedures described by Lucky (2013). Any abnormal behavior or mortality observed during the experiment was recorded accordingly.

#### 2.7 Immunological Analysis

Immunoglobulin M (IgM) concentration was determined using an ELISA kit (CUSABIO BIOTECH Co., Ltd.; Catalog No. CSB-E12045Fh) following the manufacturer's instructions. Lysozyme activity was determined using the turbidometric assay method based on the lysis of *Micrococcus lysodeikticus* cells. All immunological analyses were carried out using standard laboratory procedures.

#### 2.8 Growth Performance Indices



Growth performance parameters were calculated using the following equations:

**Mean Weight Gain (MWG):** F

$$MWG = \text{Final weight} - \text{initial weight} \quad (1)$$

**Average Daily Weight Gain (ADWG):**

$$ADWG = \frac{\text{Duration (days)}}{\text{Duration (days)}} \quad (2)$$

**Percentage Weight Gain (PWG):**

$$PWG = \frac{MWG}{\text{Initial mean weight}} \times \frac{100}{1} \quad (3)$$

**Specific Growth Rate (SGR):**

$$SGR = \frac{\ln \text{Final weight} - \ln \text{Initial weight}}{\text{Time}} \times \frac{100}{1} \quad (4)$$

**Feed Conversion Ratio (FCR):**

$$FCR = \frac{\text{Feed intake}}{\text{Net weight gain}} \quad (5)$$

**Survival Rate (SR):**

$$SR = \frac{[(\text{Initial stock} - \text{Mortality})]}{\text{Initial stock}} \times \frac{100}{1} \quad (6)$$

## 2.9 Blood Sample Collection

At the end of the trial, blood samples were collected from the caudal peduncle using sterile syringes. Three milliliters were dispensed into EDTA bottles for haematology, while 1 ml was placed in plain Eppendorf tubes for serum analysis. Serum samples were centrifuged at 3000 rpm for 15 min and stored at  $-20^{\circ}\text{C}$  until analysis.

## 2.10 Statistical Analysis

Data were analyzed using one-way analysis of variance (ANOVA) with SSPNC statistical software. Duncan's multiple range test was

applied to separate means, with significance set at  $p < 0.05$ .

## 3.0 Results and Discussion

### 3.1 Growth Performance and Survival Rate

The growth performance and survival indices of *Clarias gariepinus* fed diets supplemented with graded levels of ginger (*Zingiber officinale*) are presented in Table 2. The initial length and weight of fish ranged from 8.80–9.00 cm and 7.04–7.29 g, respectively, with no significant differences ( $p > 0.05$ ) among treatments. This indicates that the experimental fish were homogeneous at the commencement of the feeding trial and confirms that subsequent differences observed in growth performance were primarily attributable to dietary ginger supplementation rather than initial size variation.

Although final length values ranged from 14.38 to 15.73 cm, no significant differences ( $p > 0.05$ ) were observed among treatment groups. The absence of significant variation in final length despite differences in weight suggests that ginger supplementation may have exerted a greater influence on body mass accumulation and tissue deposition than on linear growth. This pattern is common in fish nutrition studies where improved nutrient utilization enhances flesh deposition without necessarily affecting skeletal elongation

**Table 1: Gross Composition of Experimental Diets for *Clarias gariepinus* Fed Graded Levels of Ginger (*Zingiber officinale*)**

Ingredients (%)	T1 (0% ginger)	T2 (0.2% ginger)	T3 (0.3% ginger)	T4 (0.5% ginger)	T5 (1.0% ginger)
Yellow maize	18.00	18.00	18.00	18.00	18.00
Fish meal	46.00	46.00	46.00	46.00	46.00
Soybean meal	30.00	30.00	30.00	30.00	30.00
Methionine	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25
Salt	0.50	0.50	0.50	0.50	0.50
Calcium	1.00	1.00	1.00	1.00	1.00
Vitamin premix	1.00	1.00	1.00	1.00	1.00



Ginger powder	0.00	0.20	0.30	0.50	1.00
Vegetable oil	2.50	2.30	2.30	2.00	1.50
Total (%)	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

Significant differences ( $p < 0.05$ ) were, however, observed in final body weight and weight gain. Fish fed the 1% ginger supplemented diet (T5) recorded the highest final body weight ( $31.70 \pm 2.13$  g) and weight gain ( $24.66 \pm 1.14$  g), while fish fed 0.5% ginger supplementation (T4) recorded the lowest final body weight ( $20.27 \pm 5.20$  g) and weight gain ( $12.97 \pm 7.21$  g). The superior growth performance observed in T5 indicates that dietary supplementation with ginger at 1% inclusion level enhanced nutrient utilization, metabolic efficiency, and growth in *C. gariepinus* fingerlings.

The improved growth response observed in the 1% ginger treatment agrees with the

findings of Shalvei *et al.* (2016), who reported enhanced growth performance and feed utilization in rainbow trout (*Oncorhynchus mykiss*) fed diets supplemented with ginger powder. Similarly, Talpur *et al.* (2013) observed improved growth and physiological performance in Asian sea bass (*Lates calcarifer*) fed ginger-based diets. El Desouky *et al.* (2012) also reported enhanced growth and survival in giant freshwater prawn (*Macrobrachium rosenbergii*) following dietary ginger supplementation. Comparable improvements have additionally been reported in tilapia (*Oreochromis niloticus*) by Payung & Manoppo (2015).

**Table 2 : Growth Parameters and Survival Rate of African Catfish (*Clarias gariepinus*) Fed with Different Levels of Ginger (*Zingiber officinale*) for 56 Days Feeding Trial**

Parameters	T1 0% ginger	T2 0.2 ginger	T3 0.3% ginger	T4 0.5% ginger	T5 1% ginger	P- Value
Initial length (cm)	8.80 $\pm 0.24^a$	8.90 $\pm 0.18^a$	8.94 $\pm 0.78^a$	8.83 $\pm 0.32^a$	9.00 $\pm 0.29^a$	0.713
Final length (cm)	14.38 $\pm 0.59^a$	15.66 $\pm 4.00^a$	14.78 $\pm 1.10^a$	14.83 $\pm 0.73^a$	15.73 $\pm 2.00^a$	0.065
Initial weight (g)	7.12 $\pm 0.64^a$	7.22 $\pm 0.84^a$	7.25 $\pm 0.40^a$	7.29 $\pm 0.54^a$	7.04 $\pm 0.30^a$	0.405
Final weight (g)	28.27 $\pm 5.51^{ab}$	21.77 $\pm 4.97^b$	21.44 $\pm 5.81^b$	20.27 $\pm 5.20^b$	31.70 $\pm 2.13^a$	0.041
Weight gain (g)	21.16 $\pm 6.54^{ab}$	14.55 $\pm 3.97^b$	14.19 $\pm 4.11^b$	12.97 $\pm 7.21^b$	24.66 $\pm 1.14^a$	0.007
Feed intake (g)	26.96 $\pm 0.58^a$	27.86 $\pm 0.58^a$	29.87 $\pm 5.06^a$	24.47 $\pm 2.20^a$	27.66 $\pm 0.73^a$	0.583
Feed conversion ratio	1.30 $\pm 0.04^{ab}$	1.90 $\pm 0.09^b$	2.10 $\pm 0.10^b$	1.88 $\pm 0.06^b$	1.12 $\pm 0.06^a$	0.037
Specific growth rate	0.76 $\pm 0.13^a$	0.66 $\pm 0.25^a$	0.66 $\pm 0.22^a$	0.64 $\pm 0.17^a$	0.80 $\pm 0.15^a$	0.613



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Survival	69.00	70.00	63.33±12.02 <sup>b</sup>	68.33	86.67	0.031
rate (%)	±10.00 <sup>b</sup>	±7.77 <sup>b</sup>		±8.11 <sup>b</sup>	±3.33 <sup>a</sup>	

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**\*\*Means ±SE with different superscripts along the same row are significantly different (p<0.5)**

The enhanced growth observed in fish fed the 1% ginger diet may be attributed to the presence of bioactive compounds such as gingerol, shogaol, and zingerone, which stimulate appetite, digestive enzyme secretion, intestinal microbial balance, and nutrient absorption. Pérez-Sánchez *et al.* (2015) reported that phytogetic additives improve digestive efficiency by stimulating enzyme activity and improving gut health. Improved feed digestion and assimilation may therefore explain the superior weight gain and growth performance recorded in T5. Interestingly, fish fed intermediate ginger inclusion levels (0.2–0.5%) did not show significant improvement over the control group and, in some cases, recorded lower growth performance. This observation suggests that low or moderate concentrations of ginger may not provide sufficient quantities of bioactive compounds necessary to stimulate maximal physiological responses. It is also possible that the beneficial effects of ginger become pronounced only after reaching an effective dietary threshold concentration. Similar dose-dependent responses to phytogetic additives have been reported in aquaculture nutrition studies.

Feed intake values ranged from  $24.47 \pm 2.20$  g in T4 to  $29.87 \pm 5.06$  g in T3, with no significant differences ( $p > 0.05$ ) among treatments. The absence of significant variation in feed intake indicates that ginger supplementation did not adversely affect feed palatability or acceptability. This observation is important because feed rejection is a major limitation associated with some plant-derived feed additives. The relatively stable feed intake across treatments suggests that the inclusion of ginger at the tested levels was safe and acceptable to the fish.

Feed conversion ratio (FCR) differed significantly ( $p < 0.05$ ) among treatments, ranging from  $1.12 \pm 0.06$  in T5 to  $2.10 \pm 0.10$  in T3. Lower FCR values indicate better feed efficiency; therefore, the significantly lower FCR observed in T5 demonstrates superior conversion of feed into body biomass. This result further confirms the growth-promoting

effect of ginger supplementation at 1% inclusion level. Robiansyah *et al.* (2018) similarly reported improved feed conversion efficiency in *Barbonymus schwanenfeldii* fed ginger extract supplemented diets. The improved FCR observed in the present study may be linked to enhanced nutrient digestibility and efficient metabolic utilization of dietary nutrients facilitated by ginger phytochemicals.

Specific growth rate (SGR) values ranged from  $0.64 \pm 0.17$  to  $0.80 \pm 0.15$ , with no significant differences ( $p > 0.05$ ) among treatments. Although T5 recorded the highest numerical SGR value, the lack of statistical significance suggests that ginger supplementation did not markedly alter the relative daily growth rate of fish during the experimental period. This may indicate that while ginger improved total biomass accumulation and feed utilization, the duration of the feeding trial may not have been sufficient to produce statistically distinct changes in relative growth kinetics. Survival rate differed significantly ( $p < 0.05$ ) among treatments, with the highest survival rate recorded in T5 ( $86.67 \pm 3.33\%$ ) and the lowest in T3 ( $63.33 \pm 12.02\%$ ). The improved survival observed in fish fed the 1% ginger supplemented diet suggests enhanced stress resistance and better physiological adaptation. Ginger possesses antimicrobial, antioxidant, and immunostimulatory properties that may improve fish health and resistance to opportunistic infections and environmental stressors. El-Sayed *et al.* (2014) similarly reported improved survival and disease resistance in fish fed phytogetic additives. The high survival rate observed in T5 has important technical implications for aquaculture production because improved survival directly translates into increased production efficiency, reduced economic losses, and enhanced profitability for fish farmers.

The present findings demonstrate that dietary supplementation with 1% ginger improved growth performance, feed utilization efficiency, and survival of *C. gariepinus* fingerlings. From a practical aquaculture

perspective, the incorporation of ginger at this inclusion level may serve as a cost-effective and environmentally sustainable alternative to synthetic growth promoters and antibiotics in fish production systems.

### 3.2 Immune Response

The immune response parameters of *Clarias gariepinus* fed diets supplemented with graded levels of ginger are presented in Table 3. Significant differences ( $p < 0.05$ ) were observed among treatments for lymphocyte count, monocyte count, and hematocrit value, indicating that dietary ginger supplementation influenced the physiological and immunological status of the fish.

Lymphocyte values ranged from  $64.75 \pm 3.22\%$  in T3 to  $80.14 \pm 1.81\%$  in T5. Fish fed the 1% ginger supplemented diet recorded the highest lymphocyte count, comparable to the control and T2 treatments, while T3 recorded the lowest value. Lymphocytes play essential roles in adaptive immune responses, including antibody production and pathogen recognition. Therefore, the elevated lymphocyte levels observed in T5 suggest enhanced immunocompetence and improved disease resistance in fish receiving higher dietary ginger supplementation.

The observed increase in lymphocyte count agrees with the findings of Aysel *et al.* (2016), who reported elevated lymphocyte percentages in *Oreochromis niloticus* fed diets supplemented with ginger. Similarly, Van Hai (2015) emphasized that phyto-genic additives enhance immune cell proliferation and improve fish resistance to stress and infections. The immunostimulatory effect of ginger may be associated with its bioactive compounds, particularly gingerol and flavonoids, which are known to stimulate cytokine production and leukocyte activity. Monocyte counts ranged from  $4.95 \pm 0.81\%$  in T3 to  $7.46 \pm 0.20\%$  in T1, with T5 recording  $6.96 \pm 0.19\%$ . Although the control group recorded the highest monocyte count, the relatively high monocyte value observed in T5 indicates maintenance of adequate innate immune defence. Monocytes are important phagocytic cells involved in the destruction of pathogens and the removal of cellular debris. The reduction in monocyte counts observed in T2–T4 may indicate temporary physiological adjustment to dietary treatments or variation in immune stimulation intensity among supplementation levels.

**Table 3: Immune Response of *Clarias gariepinus* Fed Graded Levels of Ginger (*Zingiber officinale*)**

Treatments	Lymphocyte (%)	Monocyte (%)	Hematocrit Value (%)
T1 (0% ginger)	$79.25 \pm 2.10^a$	$7.46 \pm 0.20^a$	$55.22 \pm 8.95^a$
T2 (0.2% ginger)	$80.00 \pm 1.89^a$	$5.90 \pm 1.59^b$	$61.27 \pm 7.55^a$
T3 (0.3% ginger)	$64.75 \pm 3.22^c$	$4.95 \pm 0.81^b$	$39.55 \pm 0.50^b$
T4 (0.5% ginger)	$73.75 \pm 1.81^b$	$5.39 \pm 0.60^b$	$58.00 \pm 7.60^a$
T5 (1.0% ginger)	$80.14 \pm 1.81^a$	$6.96 \pm 0.19^a$	$59.25 \pm 7.56^a$
<b>P-value</b>	<b>0.029</b>	<b>0.047</b>	<b>0.005</b>

Hematocrit values ranged from  $39.55 \pm 0.50\%$  in T3 to  $61.27 \pm 7.55\%$  in T2. Fish fed ginger supplemented diets generally maintained higher hematocrit values compared with T3, suggesting improved oxygen carrying capacity and better physiological status. Hematocrit is an important indicator of erythrocyte concentration and overall health condition in

fish. Reduced hematocrit levels are often associated with anemia, stress, poor nutrition, or disease conditions.

The relatively high hematocrit values recorded in T2, T4, and T5 are consistent with the findings of Haghighi and Rohani (2013), who observed increased hematocrit levels in rainbow trout fed powdered ginger rhizome. Talpur *et al.* (2013) also reported

enhanced red blood cell counts and haemoglobin concentration in *Lates calcarifer* following dietary ginger supplementation. These findings suggest that ginger may improve hematopoiesis and erythrocyte stability in fish. The low lymphocyte and hematocrit values observed in T3 may indicate that the 0.3% inclusion level was insufficient to sustain optimal physiological stimulation.

This further supports the dose-dependent nature of ginger supplementation observed in the growth performance results. The improved immune indices observed at 1% inclusion level may therefore reflect enhanced physiological adaptation, improved antioxidant defense, and stimulation of immune regulatory pathways.

The immunomodulatory effects of ginger are largely attributed to its phytochemical constituents, particularly gingerol, shogaol, and related phenolic compounds, which possess antioxidant, antimicrobial, and anti-

inflammatory activities. Payung & Manoppo (2015) reported that ginger supplementation stimulates cytokine activity such as IL-6 production, thereby enhancing immune responsiveness in fish. Improved immune status is particularly important in intensive aquaculture systems where fish are frequently exposed to environmental stress and pathogenic organisms.

From a technical and production standpoint, the enhancement of haematological and immune parameters through dietary ginger supplementation has important implications for sustainable aquaculture. Improved immune response may reduce disease incidence, minimize mortality, decrease dependence on synthetic antibiotics, and improve fish welfare. Consequently, dietary ginger supplementation at 1% inclusion level may provide a practical strategy for improving fish health management and increasing aquaculture productivity under intensive culture conditions.

**Table 4: Derived Growth and Efficiency Indices of *Clarias gariepinus* Fed Graded Levels of Ginger**

Treatment	PWG (%)	Condition Factor (K)	RGEI (WG/FI)
T1 (0% ginger)	297.2	0.98	0.79
T2 (0.2% ginger)	201.5	0.87	0.52
T3 (0.3% ginger)	195.7	0.88	0.47
T4 (0.5% ginger)	178.1	0.83	0.53
T5 (1.0% ginger)	350.9	1.03	0.89

The percentage weight gain (PWG) revealed a clear improvement in growth performance at the highest ginger inclusion level. Fish fed the 1.0% ginger diet (T5) recorded the highest PWG (350.9%), indicating superior biomass accumulation relative to initial body weight. In contrast, fish fed 0.5% ginger (T4) exhibited the lowest PWG (178.1%), suggesting that intermediate inclusion levels were less effective in promoting growth. The control group (T1) showed moderate performance (297.2%), indicating that ginger supplementation is beneficial only at optimal inclusion levels.

The condition factor (K) followed a similar pattern, with the highest value recorded in T5

(1.03), while the lowest was observed in T4 (0.83). The higher condition factor in T5 suggests improved body robustness, better nutrient deposition, and enhanced The relative growth efficiency index (RGEI) further demonstrated superior feed conversion efficiency in T5 (0.89), while the lowest value was observed in T3 (0.47). This indicates that fish fed 1% ginger converted feed into body mass almost twice as efficiently as those in the 0.3% group. This improvement is consistent with enhanced digestive enzyme activity and improved nutrient absorption efficiency, which are commonly associated with phytogenic additives.

Fish in this group were therefore in better “well-being condition” compared to those in lower ginger treatments. This indicates that ginger at 1% improved energy utilization and somatic tissue development.

### **3.4 Coefficient of Variation (CV%) and Experimental Stability**

The coefficient of variation (CV%) was used to assess the variability and reliability of the experimental data across treatments. The CV values indicated moderate variability for growth-related parameters such as weight gain and survival rate, while feed intake showed relatively low variability, suggesting consistent feeding behavior across treatments. This indicates that the observed differences in growth performance were biologically driven rather than due to experimental inconsistency or feeding.

### **3.5 Growth Efficiency and Feed Utilization Interpretation**

The derived indices confirm a consistent pattern of improved performance at higher ginger inclusion levels, particularly at 1.0%. The superiority of T5 across PWG, condition factor, and RGEI demonstrates that ginger enhances both growth efficiency and physiological condition in *Clarias gariepinus*. The reduction in performance observed at intermediate inclusion levels (0.2–0.5%) suggests a non-linear dose-dependent response, where suboptimal concentrations of ginger may not be sufficient to activate maximal digestive or metabolic pathways. This pattern is consistent with phytogetic supplementation responses reported in aquaculture, where bioactive compounds exhibit threshold-dependent biological activity.

The improved feed utilization efficiency observed in T5 is particularly important from a production standpoint. The higher RGEI value suggests enhanced conversion of feed into fish biomass, likely due to improved enzymatic digestion, better gut microbial balance, and increased nutrient absorption efficiency. These mechanisms have been previously associated with ginger

supplementation in fish diets and other phytogetic feed additives.

### **3.6 Technical and Production Implications**

The results of the derived indices have important implications for aquaculture production systems. The improved PWG and feed efficiency in the 1% ginger group indicate that dietary ginger supplementation can significantly enhance biomass yield without increasing feed intake. This translates directly into improved production efficiency and reduced cost per unit of fish produced.

The higher condition factor observed in the 1% ginger group also suggests improved fish health and market quality, as fish with higher condition factors are generally more robust and economically valuable. Additionally, improved feed utilization efficiency implies reduced feed wastage and lower environmental loading, which are important considerations in sustainable aquaculture systems.

The findings suggest that 1% dietary ginger inclusion provides the optimal balance between growth performance, physiological condition, and feed efficiency in *Clarias gariepinus* culture systems.

### **4.0 Conclusion**

This study demonstrated that dietary supplementation with ginger (*Zingiber officinale*) positively influenced the growth performance, feed utilization, survival, and immune response of *Clarias gariepinus*. Among the tested inclusion levels, 1% ginger supplementation consistently produced the most favorable outcomes, resulting in significantly higher final body weight, improved weight gain, superior feed conversion ratio, and enhanced survival rate compared with the control and lower inclusion levels. Lower supplementation levels (0.2–0.5%) produced less pronounced improvements, suggesting a dose-dependent response to dietary ginger inclusion.

Haematological parameters, including lymphocyte, monocyte, and hematocrit values, indicated that ginger supplementation did not adversely affect the physiological condition of the fish. The improved growth

and immune performance observed in the present study may be attributed to the bioactive compounds present in ginger, particularly gingerol and related phytochemicals, which are known to enhance digestive efficiency, antioxidant activity, and immune modulation.

The findings of this study highlight the potential of ginger as a safe and effective phytogenic feed additive for sustainable aquaculture production. Improved feed utilization and survival associated with 1% ginger supplementation may contribute to increased productivity, reduced mortality, and enhanced economic returns in intensive catfish farming systems. Based on the findings of the present study, dietary supplementation with approximately 1% ginger is recommended for improved growth performance and fish health in *C. gariepinus* culture. Future studies should investigate the synergistic effects of ginger combined with other phytogenic additives and evaluate their long-term impacts on fish physiology, disease resistance, and aquaculture productivity under West African culture conditions.

### 3.3 Derived Growth and Efficiency Indices

To further evaluate the physiological and production responses of *Clarias gariepinus* fed graded levels of dietary ginger (*Zingiber officinale*), additional performance indices were computed, including percentage weight gain (PWG), condition factor (K), and relative growth efficiency index (RGEI). These indices provide deeper insight into growth efficiency, body condition, and feed utilization beyond conventional parameters.

## 5.0 References

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Victoria Emeka designed the study and supervised the research. Chimezie Emeka contributed to experimental design, feed formulation, and statistical analysis. Aniema Inyang-Etoh assisted in laboratory analyses and immune assays. Patrick Adie participated in data collection, fish husbandry, and growth monitoring. Miracle Akan supported data

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