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Growth Performance and Nutrient Utilisation of *Clarias gariepinus* fed Turmeric (*Curcuma longa*) Based-Diet

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Abstract— *Dietary supplementation with herbal extract and plant-based additives in aquaculture has been noted for various beneficial roles; to increase fish production through the improvement of immunity and other physiological dysfunctions related to fish health. A 56 days feeding trial was conducted to evaluate the growth performance and nutrient utilization of Clarias gariepinus juveniles fed turmeric (Curcuma longa) based diet. Ten fish were stocked in twelve tanks each subjected to four treatments with three replicates. Four experimental treatments were formulated with varying Curcuma longa concentration included at 0% (Control), 1%, 3% and 5% with the treatments designated as D1 (Control), D2, D3 and D4 respectively. The growth performances, nutrients utilisation as well as the effects of the diets on the water quality were determined. Fish fed D4 with an inclusion level of 5% C. longa gave the least growth performance in terms of mean weight gain (MWG), specific growth rate (SGR), feed intake, and protein efficiency ratio (PER). Fish fed D2 with an inclusion level of 1% of C. longa had the best food conversion ratio (FCR) and followed by the fish fed D3 which had 3% inclusion of C. longa. The FCR of the fish fed D2 and D3 were significantly higher ($p<0.05$) than the fish fed other diets. Based on this study, it was concluded that the inclusion of turmeric in the diet of Clarias gariepinus should be minimized specifically within the range of 1% to 3% to enhance growth performance and improve nutrient utilization of the fish.*

Keywords— Clarias gariepinus; turmeric (Curcuma longa); growth performance; nutrient utilization, survival rate.

I. INTRODUCTION

Aquaculture is the practice of cultivating aquatic plants and animals, such as fish, shellfish and algae in controlled environments like ponds, tanks and cages. It has become an essential component of global food production by addressing the increasing demand for protein as the global population grows. Traditional fisheries have faced challenges like overfishing, environmental degradation, and fluctuating wild fish stocks, making sustainable seafood sources critical (FAO, 2020). Aquaculture stepped in to fill this gap by providing a controlled environment for raising seafood, ensuring a more predictable and consistent supply. It is the fastest growing food sector over the past 20 years with an average annual growth rate of 37% (Tacon, 2009), which has however decreased 3.5% for the period 2016-2021 (Mair et al., 2023) with recent projections indicating lower growth rate of 1.6% for the period 2022-2032 (FAO, 2024).

In Nigeria, consumption and demand for fish protein is increasing due to its affordability (Eyo and Ekanem, 2011). *C. gariepinus* is widely cultured in Nigeria under intensive management (Adewolu et al., 2009; Chika and Nathaniel, 2014). It is regarded as one of the most important aquaculture candidate because of its ability to tolerate a wide range of environmental conditions, high stocking densities under culture conditions, fast growth rate, high yield and high market value (Babalola and Apata, 2006). Increased production of fry and fingerlings with attributes of faster growth rate and higher environmental tolerance is essential to ensuring fish food security in Nigeria. *C. gariepinus*, (family Claridae), is a key species in Nigerian aquaculture due to its high nutritional value and ease of farming. It is a rich source of high-quality protein, essential fatty acids, and micronutrients like iron and zinc, making it beneficial for addressing malnutrition in the country (Adewumi and Olaleye,

2011). According to Clay (2009), *C. gariepinus* is generally considered to be one of the most important tropical catfish species for aquaculture in West Africa.

Proper Nutrition is fundamental to the success of aquaculture operations. This involves the provision of balanced diet to meet the specific nutritional requirements of the cultured species to support growth, health and well-being (NRC, 2011). Proper growth of fish depends largely on good nutrition and this is more pronounced with fish in enclosure as they require adequate nutrition (Omoruwou and Edema, 2011). The primary components of fish diets include protein, lipids, carbohydrates, vitamins, and minerals which are very vital for the building block of the animal's body and growth development. According to Tacon and Metican (2015), feeding is the act of providing food to living organisms which is critical for optimal growth performance, health of cultured fish and feed efficiency. Feed is the most expensive input in a profitable fish production. It accounts for about 70-80% of the total cost of fish production (El-Sayed, 2021; Kehinde et al., 2006). Fish culture requires high quality feeds containing necessary nutrients and complementary feed additives to keep fish healthy, grow fast and become more environmental friendly. Feed additives are substances added to the diet in trace amount to provide mechanism by which such dietary deficiencies can be addressed which benefits not only the nutrition and thus the growth rate of the animal concerned, but also its health and welfare in modern day fish farming.

Turmeric, (*C. longa*) is a widely available and cost-effective herbal ingredient, known for its medicinal properties primarily due to the presence of curcumin, a bioactive compound with antioxidant, anti-inflammatory and antimicrobial activities (Rapti et al., 2024; Siagian et al., 2024; Aderemi and Alabi, 2023; Louis, 2009). Primarily, it is categorized as a phytochemicals and bioactive compounds including phenolic compounds, flavonoids, β-carotene, vitamin C and vitamin E. The use of turmeric as feed additives in aquaculture has shown promising results in various studies (Siagian et al., 2024; Pal et al., 2020; Mahmoud and El-Lamie, 2014) in which its supplementation enhanced nutrient digestibility and utilization in *Clarias gariepinus*. Improved protein efficiency ratio (PER) and apparent digestibility coefficient (ADC) have been reported in fish fed turmeric based diets, indicating better nutrient absorption and utilization (Kumar, 2018). Nutrient utilization is a critical factor in aquaculture, as it directly impacts the growth performance of fish and the overall efficiency of the production system. One of the challenges associated with plant-based diets is the presence of anti-nutritional factors that can inhibit the absorption of essential nutrients, leading to reduced growth rates in fish. Turmeric has been shown to improve nutrient utilization by enhancing the activity of digestive enzymes, such as proteases, amylases, and lipases, which are responsible for breaking down proteins, carbohydrates, and fats, respectively (Olatunji et al., 2020).

While several studies have examined turmeric supplementation in fish diets, the optimal inclusion level for *C. gariepinus* remains unclear, with conflicting results across different studies. Furthermore, most studies have focused on either growth performance or health parameters, but few have comprehensively examined both growth and nutrient utilization simultaneously. This study therefore aims to evaluate the growth performances and nutrient utilization of *Clarias gariepinus* fed turmeric based diet, with the specific objective of identifying the optimal turmeric inclusion level for maximizing growth performance and feed efficiency.

II. MATERIALS AND METHODS

2.1 Experimental Study Area

The research was carried out at the Wet laboratory in the Department of Fisheries and Aquaculture Management, Faculty of Agricultural Science Research Farm, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria. Geographically, Ado Ekiti is located on latitude 7°35' and 7°47' north of the equator and longitude 5°11' and 5°16' east of the Greenwich meridian with geographical coordinates of approximately 7.7130°N latitude and 5.2765°E longitude.

2.2 Feed Ingredients and Experimental Diets

Four iso-nitrogenous diets were formulated containing 40% crude protein using fish meal, soybean meal, groundnut cake, maize, wheat offal, vitamin or mineral premix, salt, vegetable oil and turmeric (*Curcuma longa*). The dietary ingredients including fish meal, soybean meal, groundnut cake, maize, wheat offal, and vitamin/mineral premix were purchased from Metrovet Nigeria Limited, Ado-Ekiti. The vegetable oil, salt and turmeric were purchased from King's market, Ado Ekiti. The four experimental diets were formulated with varied levels of turmeric powder at 0%, 1%, 3%, and 5% respectively. It was pelletized with pelleting machine of 2mm die size. The pellet was sun dried, packed in well labeled air tight containers and stored in a cool and dry place until use. Table 1 shows the gross composition of the experimental diets.

TABLE 1
THE GROSS COMPOSITION OF THE EXPERIMENTAL DIETS

Ingredients	Diet 1 Control 0%	Diet 2 1%	Diet 3 3%	Diet 4 5%
Fish meal 65%	23.2	23.2	23.2	23.2
Soybean meal 44%	23.2	23.2	23.2	23.2
Groundnut cake meal 50%	23.2	23.2	23.2	23.2
Maize 10%	12.95	12.95	12.95	12.95
Wheat offal 14%	12.95	12.95	12.95	12.95
Turmeric (*Curcuma longa*)	0	1	3	5
Lysine (g)	0.5	0.5	0.5	0.5
Vit/Min Premix (g)	2.5	2.5	2.5	2.5
Salt (g)	0.5	0.5	0.5	0.5
Veg oil (g)	0.5	0.5	0.5	0.5
Methionine (g)	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**

2.3 Experimental Fish

One hundred and fifty (150) juveniles of *C. gariepinus* was procured from Adebayo fish farm in Ado-Ekiti and acclimatized in aerated tanks at the Wet laboratory in the Department of Fisheries and Aquaculture Management, Faculty of Agricultural Science Research Farm, Ekiti State University, Ado-Ekiti, Ekiti State to adapt before commencement of the experiment. After the acclimation period, the fish were weighed and randomly distributed into four groups, each receiving one of the experimental diets. Each dietary treatment was replicated thrice.

2.4 Experimental Procedure

Twelve aquaria tanks (60 cm × 30 cm × 30 cm, approximately 54 L capacity) were randomly stocked with ten fish in each tank used for the experiment comprising of four dietary levels with three replicates in a completely randomized design experiment. Fish were fed twice daily (morning between 8am to 9am, and evening between 4pm to 5pm) at 5% of their body weight. The weight of the fish was taken weekly using an electronic kitchen Salter Scale-1036, UK, and the feeding rates was adjusted accordingly to determine the feed allowance. The water quality of the culture media was monitored and kept at optimum during the period of the feeding experiment. The water quality parameters evaluated during the feeding trial include temperature, dissolved Oxygen (mg/l), and pH. The temperature was measured in °C by the use of mercury-in-glass thermometer; the dissolved oxygen was measured by the use of titration method as described by AOAC (2010) while the pH was measured by the use of a pH meter (Model: pHCal|ANALAB|HSN Code: 90278990). Groundwater sourced from a borehole was used for the experiment, and the photoperiod was maintained at a natural light-dark cycle (approximately 12:12 hours). All experimental procedures were conducted in accordance with the ethical guidelines for animal research, and the study was approved by the Institutional Animal Ethics Committee.

2.5 Determination of Growth Performance and Nutrient Utilisation

Data on feed utilisation and growth performances were collected on weekly basis using electronic kitchen Salter Scale-1036, UK. The growth parameters were calculated following the method described by AOAC (2010) as follows:

- **Weight Gain**: This refers to the increase in body weight of fish during the experimental period, typically measured in grams. It's an important indicator of fish growth and health. Weight Gain (WG) = Final Weight (g) (FW) - Initial Weight (g) (IW)
- **Mean Weight Gain**: This is the average weight gain of a group of fish during the experimental period. It's a useful metric to evaluate the growth performance of fish populations. The formula to calculate mean weight gain is: Mean Weight Gain (MWG) = Total weight gain of fish (g) / (Number of fish)

- **Specific Growth Rate (SGR)**: is a measure of the rate of weight gain per unit of body weight per unit of time. It's a useful metric to evaluate the growth performance of fish, taking into account their initial size. The formula to calculate SGR is: SGR = ($InW_2 - InW_1$) / time × 100. Where W_2 is the final weight in gram and W_1 is the initial weight in gram.
- **Food Conversion Ratio (FCR)**: is a measure of the efficiency with which fish convert feed into body weight. It's an important metric to evaluate feed utilization and nutritional efficiency. The formula to calculate FCR is: FCR = Feed intake / Weight Gain
- **Protein Efficiency Ratio (PER)**: is a measure of the efficiency with which fish utilize dietary protein for growth. It's used to evaluate the quality of protein sources in fish feed. The formula to calculate PER is: PER = Total weight gain (TWG) / Total protein consumed (TPC)
- **Food Intake**: This refers to the amount of feed consumed by fish during the experimental period. The formula to calculate food intake is: FI = Diet given / Number of fish
- **Survival Rate**: is the percentage of fish that survive over the experimental period. The formula to calculate Survival Rate is: SR = (Number of fish survived / Number of fish initially stocked) × 100

2.6 Proximate Analysis

The proximate analysis comprising the moisture content, protein, ash content, crude fibre, fat and nitrogen free extract (NFE) of the test ingredient and fish before and after the experiment were determined using the methods of AOAC (2010).

2.7 Statistical Analysis

The data generated from the experiments was subjected to one-way analysis of variance (ANOVA) to determine the significant differences among mean of the treatment groups. Post hoc-tests (Tukey's HSD) was conducted to identify specific differences between means at ($p<0.05$) significance level. All statistical analyses were performed using SPSS software (version 26.0, IBM Corp., Armonk, NY, USA).

III. RESULTS AND DISCUSSION

3.1 Proximate Analysis of the Diet

The result of the proximate analysis of the experimental diets is presented in Table 2. The moisture content were significantly different ($p<0.05$) from each other. Diet 3 had the highest moisture content value of 9.84±0.04 and the least was found in diet 2 which is 8.97±0.01. Diet 1 had the highest fat content of 7.29±0.05 and diet 4 of 6.14±0.02 had the lowest fat content. The fat were significantly different ($p<0.05$) in all diet. The ash content and crude fibre followed the same trend with diet 1 recording the highest value and diet 4 recording the lowest. The protein of the diet were significantly different ($p<0.05$) in all diet. Diet 4 had the highest protein value of 35.57±0.03 and diet 1 had the least protein value of 28.19±0.04. Diet 2 had the highest Nitrogen free extract value of 29.61±0.09 while diet 4 had the lowest which is 27.53±0.09.

TABLE 2
THE PROXIMATE COMPOSITION OF THE EXPERIMENTAL DIETS

Parameters	Diet 1 (Control)	Diet 2	Diet 3	Diet 4
Moisture	9.14±0.03c	8.97±0.01d	9.84±0.04a	9.44±0.02b
Fat	7.29±0.05a	6.65±0.04b	6.30±0.02c	6.14±0.02d
Ash	16.49±0.07a	15.73±0.03b	14.53±0.03c	13.68±0.04d
Protein	28.19±0.04d	30.31±0.03c	33.32±0.02b	35.57±0.03a
Fibre	9.87±0.03a	8.75±0.05b	8.06±0.04c	7.65±0.03d
NFE	29.03±0.06b	29.61±0.09a	27.96±0.03c	27.53±0.09d

Mean and standard deviation with different superscripts along the same row are significantly different (p<0.05). NFE = Nitrogen Free Extract

3.2 Growth and Nutrient Utilization of the Experimental Fish

Table 3 shows the results of the growth and nutrient utilization of the experimental fish fed the various diets. Highest weight gain of 32.33±2.35 was found in fish fed diet 1, followed by fish fed with diet 2 (23.83±0.13). The least weight gain was found in fish fed with diet 4 (14.2±0.67). The weight gain of all the diets were significantly different ($p<0.05$) from each other. Fish fed diet 1 had the highest mean weight gain of 3.36±0.36 and fish fed diet 4 had the lowest mean weight gain of 1.85±0.05. Diet 1, diet 2 and diet 3 were not significantly different ($p>0.05$). Fish fed diet 1 survived most with the best value of 96.67% while fish fed diet 3 recorded the highest mortality (70.00±10.00). The food conversion ratio (FCR) of the fish fed diet 2 had the best value of 0.79±0.06, while fish fed diet 1 had the poorest value of 1.23±0.13.

TABLE 3
GROWTH AND NUTRIENT UTILIZATION OF THE EXPERIMENTAL FISH

Parameters	Diet 1 (Control)	Diet 2	Diet 3	Diet 4
Initial weight	71.87±6.07a	55.80±1.25b	63.30±3.64ab	63.37±2.72ab
Final weight	104.20±5.39a	79.63±1.28b	82.39±2.78b	77.57±3.41b
Weight gain	32.33±2.35a	23.83±0.13b	19.09±0.99c	14.20±0.67d
MWG	3.36±0.36a	2.87±0.19a	2.75±0.28a	1.85±0.05b
SGR	0.67±0.08a	0.64±0.02a	0.47±0.04b	0.36±0.00b
Feed intake	4.10±0.00	2.27±0.00	2.49±0.00	2.15±0.00
FCR	1.23±0.13a	0.79±0.06b	0.91±0.09b	1.16±0.03a
PER	1.14±0.08a	0.79±0.01b	0.57±0.03c	0.40±0.02d
Survival rate	96.67±5.77a	83.33±5.77ab	70.00±10.00b	76.67±5.77b

Mean and standard deviation with different superscripts along the same row are significantly different ($p<0.05$) from one another. Where; MWG = mean weight gain; SGR = specific growth rate; FCR = food conversion ratio; PER = protein efficiency ratio

3.3 Carcass Composition of the Experiment Fish

The carcass composition of the experimental fish are presented in Table 4. The moisture content of all the diets was not significantly different ($p>0.05$) from each other. Fish fed diet 4 had highest moisture content value of 11.22±0.20 and the least value was obtained in fish fed D1 (10.59±0.56). Highest fat value was found in fish fed D1 (14.19±0.08) and the lowest was obtained in diet 4 (12.94±0.20). The fat contents in D2 and D3 were not significantly different ($p>0.05$) from each other. Fish fed diet 1 had the highest protein content of 58.80±0.11 and the lowest was found in fish fed diet 4 (53.63±0.03). The protein contents of the fish were significantly different ($p<0.05$) in all treatments.

TABLE 4
CARCASS COMPOSITION OF THE EXPERIMENTAL FISH

Parameters	Fish fed Diet 1 (Control)	Fish fed Diet 2	Fish fed Diet 3	Fish fed Diet 4
Moisture	10.59±0.56a	11.04±0.27a	10.97±0.20a	11.22±0.20a
Fat	14.19±0.08a	13.48±0.07b	13.38±0.19b	12.94±0.20c
Ash	9.97±0.15c	10.44±0.04b	10.59±0.13ab	10.75±0.03a
Protein	58.80±0.11a	56.19±0.12b	55.31±0.26c	53.63±0.03d
NFE	6.27±0.82c	8.74±0.41b	9.75±0.28b	11.47±0.01a

Mean and standard deviation with different superscript along the same row are significantly different ($p<0.05$) from one another. Where; NFE = Nitrogen Free Extract

3.4 The Water Quality Parameters

Table 5 shows the results of the water quality parameters monitored during the experiment. The temperature and dissolved oxygen ranged from 19.33°C - 20°C and 5.46 - 6.51 mg/l respectively, while the pH value ranged between 6.48 - 6.71. There were no significant difference ($p>0.05$) between the treatment for the temperature and pH.

TABLE 5
WATER QUALITY PARAMETERS OF THE EXPERIMENTAL TREATMENTS

Treatment	Temp °C	pH	DO (mg/l)
D1	19.33±1.15	6.71±0.11	5.98±0.18b
D2	19.67±0.58	6.48±0.25	5.46±0.09c
D3	20.00±0.00	6.51±0.25	6.51±0.06a
D4	19.67±0.58	6.60±0.25	5.77±0.13b

Mean value with the same superscript in the same column are not significantly different (P>0.05). Where; DO = Dissolve Oxygen

3.5 Discussion

This study focused on the utilization of *Curcuma longa* in the diet of *C. gariepinus*. The results reflected the effects of turmeric (*Curcuma longa*) inclusion on the growth performance and nutrient utilization of *C. gariepinus*. The indices of growth examined in this study revealed that weight gain, mean weight gain and specific growth rate varied significantly ($p<0.05$) between dietary treatments. The study highlights the significant impact of diet composition on the growth, nutrient utilization, and survival of the experimental fish. Fish fed D1 showed the highest weight gain (32.33±2.35 g), suggesting the provision of an optimal nutrient balance for growth. In contrast, D4 resulted in the lowest weight gain (14.2±0.67 g), indicating potential nutritional imbalance due to excessive addition of turmeric in the diet. The statistically significant differences in weight gain ($p<0.05$) emphasize the importance of diet formulation in fish growth. The mean weight gain of D1 resulted in the highest mean weight gain (3.36±0.36 g) and Diet 4 the lowest (1.85±0.05 g). This concentration is considered optimal as turmeric supplementation in feed can enhance catfish digestion, thereby improving the absorption of feed nutrients as reported by Siagian and Heltonika (2023). However, no significant differences ($p>0.05$) were found among fish fed D1, D2, and D3, suggesting these diets provide similar benefits in terms of mean weight gain. Survival rates also varied across treatments. D1 had the highest survival rate (96.67%), indicating it supports both growth and overall health. On the other hand, D3 had the highest mortality rate (70.00%), possibly due to nutritional imbalances negatively affecting fish vitality.

Feed consumption is influenced by palatability. Palatability is the level of acceptance shown by cultivated animals to consume a given feed ingredient within a certain period. The palatability of feed is determined by the shape, size, taste, smell, aroma, and colour, which are the feed's physical and chemical factors. Feed efficiency, measured by the food conversion ratio (FCR), was analyzed. D2 recorded the best FCR (0.79±0.06), showing efficient feed utilization. Despite promoting the highest weight gain, D1 had the least efficient FCR (1.23±0.13), suggesting that more feed was required to achieve maximum growth. The feed conversion ratio obtained by fish containing 1% inclusion level of turmeric is lower in comparison with other diets. This suggests that a lower level of turmeric inclusion improved feed efficiency, possibly due to its known digestive enhancing properties (Adikwu, 2003). This implies that turmeric should be included in fish diet in a minimal amount. This study is in agreement with Fagnon et al. (2020) and Cahyani et al. (2021) who showed that the higher effect sizes observed when fed curcumin at lower inclusion levels and suggested that feeding low levels of phytochemicals might be beneficial and its content in turmeric should be analysed for quite homogeneous feed. These findings align with previous research, which emphasizes the importance of balanced diet formulation in aquaculture. Studies on African catfish (*C. gariepinus*) have shown that variations in crude protein levels significantly impact growth, FCR, and survival, reinforcing the need for optimized dietary formulations (Henry et al., 2019).

The reduced growth performance at higher turmeric inclusion levels (5%) may be attributed to several factors. High concentrations of phytochemicals can have anti-nutritional effects, including reduced feed palatability, interference with nutrient absorption, or toxicity at elevated doses. Curcumin, while beneficial at low concentrations, may exhibit pro-oxidant or inhibitory effects on digestive enzymes at higher levels, leading to reduced nutrient utilization and growth. Additionally, the

presence of other compounds in turmeric, such as essential oils and resins, may affect feed palatability and reduce feed intake at high inclusion levels.

The carcass composition of the fish shows the amount of protein retained in the fish body. The study revealed significant difference ($p<0.05$) in protein values across the diet. The carcass crude protein of the control diet with no inclusion of turmeric had the highest value of 58.80 while fish fed diet 4 with 5% inclusion level of turmeric had the lowest protein value of 53.63. This result is consistent with the work of Akinwande et al. (2016), who reported that high levels of certain plant extracts in fish diets can lead to decreased protein deposition due to potential anti-nutritional factors or reduced feed palatability. The decreased protein deposition at higher turmeric levels may be attributed to reduced protein synthesis, increased protein catabolism, or impaired protein digestibility.

The water quality parameters in this study were monitored during the experimental period to assess their impact on *Clarias gariepinus*. The results showed variation in the parameters with significant differences ($p>0.05$) observed among some of the dietary treatments, indicating that dietary composition may have to some extent influenced the water quality.

The recorded water temperature ranged from 19.33°C to 20°C. This is slightly below the optimal temperature range for *Clarias gariepinus*, which typically thrives in temperature between 25°C and 30°C (Ogunji and Awoke, 2017). Lower temperature can slow down metabolic activities and affect growth rate. This suboptimal temperature may have influenced the overall growth performance, potentially masking some of the effects of turmeric supplementation. Future studies should consider conducting experiments at optimal temperatures to fully evaluate the effects of turmeric.

The dissolved oxygen levels during the study ranged from 5.46 mg/l to 6.51 mg/l. The values fall within the acceptable range for *C. gariepinus*, which can tolerate DO level as low as 3 mg/l, though optimal level for growth are typically above 5 mg/l (Olowofeso et al., 2020; Torrans et al., 2015).

The pH value recorded ranged between 6.48 and 6.71 which is within the acceptable range for *Clarias gariepinus* (6.5-8.5) (Boyd and Tucker, 2022). A stable pH is essential for maintaining optimal enzymatic activity and overall physiological functions in fish. The slight variations among diets indicate that different feed formulation might have influenced water chemistry, potentially through variation in metabolic waste production.

IV. CONCLUSION AND RECOMMENDATION

The finding of this study indicates that turmeric (*Curcuma longa*) possesses potential as a functional feed additive for *C. gariepinus*. However, its inclusion in fish diets must be carefully regulated to prevent adverse effects on growth and nutrient utilization.

The results demonstrated that high levels of turmeric inclusion, specifically at 5% significantly reduced feed intake, growth performance and nutrient utilization. On the other hand, a moderate turmeric inclusion level of 1-3% showed better results compared to higher levels. The study strongly suggests that turmeric, when used as a dietary additive, should be included in minimal amounts to avoid negative effects on overall fish development. The reduced growth at higher turmeric levels may be attributed to anti-nutritional effects, reduced palatability, or interference with nutrient absorption at elevated concentrations.

Limitations of the Study: The study was conducted over a 56-day period, which may not capture long-term effects of turmeric supplementation. The study was conducted at a suboptimal temperature (19-20°C vs. optimal 25-30°C), which may have influenced growth performance. The study did not examine immune parameters, disease resistance, or histopathological effects. Future research should address these limitations.

Recommendations: The study recommends that future researchers should explore the effects of incorporating lower concentrations of turmeric, specifically within the range of 1% to 3%. The goal of such investigations would be to identify the optimal balance that maximizes both the health benefits of turmeric and its impact on the overall growth performance of the fish. By conducting these studies, researchers can determine whether lower turmeric levels still provide significant advantages in terms of immunity, disease resistance, and overall physiological well-being while maintaining or improving growth rates. Future studies should also examine the mechanisms underlying the observed effects, including digestive enzyme activity, gut microbiota composition, and immune function, to provide a more comprehensive understanding of turmeric's role in fish nutrition.

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this manuscript.

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