Hue University Journal of Science: Natural Science
Vol. 134, No. 1S-2, 29–39, 2025 (Special Issue: CBA 2025)

pISSN 1859-1388
eISSN 2615-9678

Effects of dietary supplementation with turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) on growth performance and selected biological indices of Nile tilapia (*Oreochromis niloticus*)

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(*Received: 18 June 2025; Revised: 25 August 2025; Accepted: 25 August 2025*)

Abstract. This study investigated the synergistic effects of combined turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) supplementation on growth performance, feed efficiency, and physiological parameters of Nile tilapia (*Oreochromis niloticus*), hypothesizing that complementary antioxidant and anti-inflammatory pathways would enhance nutrient utilization and metabolic efficiency. Juvenile fish were fed four experimental diets for 90 days: a control diet and three diets containing combined turmeric and ginger with 1:1 ratio at 0.5% (0.25% turmeric + 0.25% ginger, TG0.5), 1.0% (0.5% turmeric + 0.5% ginger, TG1.0), and 2.0% (1.0% turmeric + 1.0% ginger, TG2.0) total inclusion levels. Growth performance was significantly enhanced with TG0.5 supplementation, achieving 44% higher final body weight (175.18 vs. 121.71 g), 57% greater weight gain (556.13 vs. 354.99%), 24% improved specific growth rate (2.29 vs. 1.84 %/day), and 26% better feed conversion efficiency (1.36 vs. 1.84) compared to the control group. Higher inclusion levels (TG1.0 and TG2.0) showed intermediate improvements without statistical significance. Importantly, no adverse effects were observed on survival rates (95-100%), hematological parameters, or somatic indices, indicating physiological safety across all inclusion levels. These findings demonstrate that moderate supplementation with combined turmeric and ginger (0.5% total, 1:1 ratio) significantly enhances growth performance and feed utilization in Nile tilapia through synergistic mechanisms without compromising fish health, supporting their application as effective natural feed alternatives in sustainable aquaculture systems.

Keywords: Nile tilapia; *Oreochromis niloticus*; turmeric; ginger; growth performance; feed conversion ratio; aquaculture

1 Introduction

Sustainable aquaculture is considered a key strategy for the long-term development of the aquaculture industry in Vietnam. However, the overuse of chemicals and antibiotics in aquaculture remains a common practice. This leads to several problems, including potential risks to consumer health due to antibiotic residues in fish, environmental pollution, and increased disease outbreaks caused by microbial imbalances [1,2]. Therefore, reducing antibiotic use and applying natural alternatives are necessary directions for producing safe and high-quality fish products.

The use of medicinal herbs in aquaculture is one of the potential solutions. Turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) are two widely available and cost-effective herbs known for their positive effects on fish growth, immunity, and disease resistance [3,4]. These herbs help enhance digestive enzyme activity, reduce inflammation, and support immune

DOI: 10.26459/hueunijns.v134i1S-2.7930

responses, thereby improving feed efficiency and fish survival [5-7].

Nile tilapia (*Oreochromis niloticus*) is one of the most cultured freshwater fish species globally due to its high adaptability, fast growth, and economic value. It can thrive in various water conditions and feed types, making it an ideal species for nutritional intervention studies [8-10].

Although many studies have investigated the individual effects of turmeric and ginger in aquaculture, their combined use remains insufficiently explored. Curcumin from turmeric offers liver-protective and antioxidant benefits, while gingerol and shogaol from ginger enhance digestion and reduce inflammation [3,4]. When used together, these compounds may complement each other, potentially improving growth and immune responses in fish. However, experimental evidence supporting their synergistic effects in *O. niloticus* remains understudied. We hypothesized that the 1:1 combination of turmeric and ginger would provide synergistic benefits through complementary antioxidant and anti-inflammatory pathways, with curcumin enhancing liver function and gingerol improving digestive processes. This study was therefore conducted to evaluate the effects of dietary supplementation with turmeric and ginger powder at different inclusion levels on growth performance, feed conversion, and selected biological indices in Nile tilapia. The findings aimed to provide scientific evidence for the use of herbal feed additives to improve aquaculture productivity and sustainability.

2 Materials and Methods

2.1 Experimental fish and study duration

The study was conducted from June 26, 2024, to April 30, 2025. Juvenile Nile tilapia (*O. niloticus*) with an average initial weight of 26.7 ± 6.2 g were obtained from the Research Institute for Aquaculture No.1 (Tu Son, Bac Ninh, Vietnam). Before starting the trial, fish were acclimatized for 2 weeks under laboratory conditions.

2.2 Experimental design

The experiment was conducted at the aquatic experimental facility, Faculty of Biology, Hanoi National University of Education. A total of 160 fish were randomly distributed into 8 fiberglass tanks (volume: 300 L), with 20 fish per tank. Each dietary treatment was conducted in duplicate.

2.3 Diet preparation and treatments

A commercial pelleted diet (iFeed IFO3, Thiên Bang Vietnam Co., Ltd.) with 30% crude protein was used as the control diet. The experimental diets were prepared by supplementing turmeric and ginger powders at different concentrations. Four experimental diets were formulated: a control diet without supplementation (CON), and three diets supplemented with turmeric and ginger powders at different inclusion levels, referred to as TG0.5, TG1.0, and TG2.0, respectively. The abbreviation "TG" represents the combined use of turmeric (T) and ginger (G).

CON (Control): Basal diet without supplementation; TG0.5: Diet supplemented with 0.25% turmeric + 0.25% ginger; TG1.0: Diet supplemented with 0.5% turmeric + 0.5% ginger; TG2.0: Diet supplemented with 1.0% turmeric + 1.0% ginger.

Turmeric and ginger powders were initially mixed with water and then coated onto the feed pellets. All diets were stored at -30 °C until use.

In this study, a 1:1 ratio of turmeric and ginger was selected for all supplemented treatments based on prior research demonstrating synergistic effects between curcumin and gingerol at equal concentrations, with inclusion levels of

pISSN 1859-1388
eISSN 2615-9678

0.5%, 1.0%, and 2.0% chosen to encompass previously established optimal doses for growth and immune enhancement in aquaculture species [11].

2.4 Feeding and rearing conditions

Fish were fed to apparent satiation twice daily at 9:00 and 16:00 for 90 days. Uneaten feed and feces were siphoned out daily. Water quality parameters were monitored and maintained within optimal ranges: pH 6.9-7.1, dissolved oxygen 4.9-5.25 mg/L, and total dissolved solids 3.8-4.1 ppm. Aeration was provided continuously [12].

2.5 Sampling and measurements

At the end of the trial, fish were fasted for 24-48 hours before sampling. Growth parameters were measured, and samples were collected for biological indices.

Growth performance: Final weight, weight gain, specific growth rate ; Feed utilization: Feed intake, feed conversion ratio; Survival rate and condition factor; Hematological indices: Red blood cells (RBCs), white blood cells (WBCs); Somatic indices: Hepatosomatic index, gallbladder somatic index, and visceral somatic index

2.6 Analytical methods

Growth performance was calculated using the following formulas [13]:

Weight gain (%) = 100 × (Final weight - Initial weight) / Initial weight

Specific growth rate (%/day) = 100 × [ln(Final weight) - ln(Initial weight)] / Days

Feed intake (%body weight/day) = 100 × Total feed intake / [(Initial weight + Final weight)/2 × Days]

Feed conversion ratio = Feed intake / weight gain

Hepatosomatic index (%) = 100 × Liver weight / Body weight

Gallbladder somatic index (%) = 100 × Gallbladder weight / Body weight

Visceral somatic index (%) = 100 × Visceral organ weight / Body weight

Condition factor = 100 × Body weight / $(\text{Length})^3$

RBCs and WBCs were counted using a hemocytometer: Blood samples were first diluted with NaH-Hendrick solution (1:200 for RBCs and 1:20 for WBCs). A small volume of the diluted sample was then loaded into the counting chamber of the hemocytometer, and the cells were counted under a light microscope following standard procedures. The final cell concentrations were calculated using the average number of cells per grid and the dilution factor.

2.7 Statistical analysis

Data were analyzed using one-way analysis of variance (ANOVA). Tukey's post hoc test was applied to determine significant differences between means. Effect sizes were calculated as eta-squared (η^2) and interpreted using benchmarks commonly applied to partial eta-squared, following Cohen's (2013) conventions [14]. Differences were considered significant at $P < 0.05$. All values are presented as mean ($\bar{X}$) ± standard deviation (SD).

3 Results

3.1 Growth performance

As shown in Table 1, tilapia fed with different dietary treatments exhibited significant variations in growth performance. Initial body weights were statistically similar across all groups ($P > 0.05$). However, final weight, weight gain percentage, and specific growth rate were significantly influenced by the dietary treatments. At the end of the 90-day trial, fish fed the TG-supplemented diets showed higher final body weights and specific growth rate compared to the CON. The diet TG0.5 produced the highest final weight (175.18 ± 17.80 g) and specific growth rate (2.29 ± 0.12 %/day), significantly greater than the CON (121.71 ± 0.69 g; 1.84 ± 0.01 %/day) ($P < 0.05$). TG1.0 and TG2.0 also improved fish growth compared to CON but the differences were not statistically significant. The effect sizes (η^2) reported for final weight, weight gain, and specific growth rate are all large (≥ 0.76), indicating that turmeric-ginger supplementation had a strong impact on growth performance parameters in Nile tilapia.

Table 1. Body weight, weight gain and specific growth rate of tilapia under different dietary treatments ($\bar{X}$ ± SD)

Index	CON	TG0.5	TG1.0	TG2.0	*P*-value	Effect size (η^2)
Initial weight (g)	26.75 ± 6.17^a	26.70 ± 7.73^a	26.70 ± 5.24^a	26.70 ± 6.24^a	0.918	0.00
Final weight (g)	121.71 ± 0.69^a	175.18 ± 17.80^b	151.85 ± 19.87^{ab}	159.00 ± 14.99^{ab}	0.048	0.76
Weight gain (%)	354.99 ± 2.58^a	556.13 ± 66.68^b	468.72 ± 74.42^{ab}	495.50 ± 56.14^{ab}	0.049	0.76
Specific growth rate (% body weight/day)	1.84 ± 0.01^a	2.29 ± 0.12^b	2.11 ± 0.16^{ab}	2.17 ± 0.12^b	0.046	0.80

Values within the same row with different superscript letters are significantly different.

CON: Basal diet without supplementation; TG0.5: Diet supplemented with 0.25% turmeric + 0.25% ginger; TG1.0: Diet supplemented with 0.5% turmeric + 0.5% ginger; TG2.0: Diet supplemented with 1.0% turmeric + 1.0% ginger.

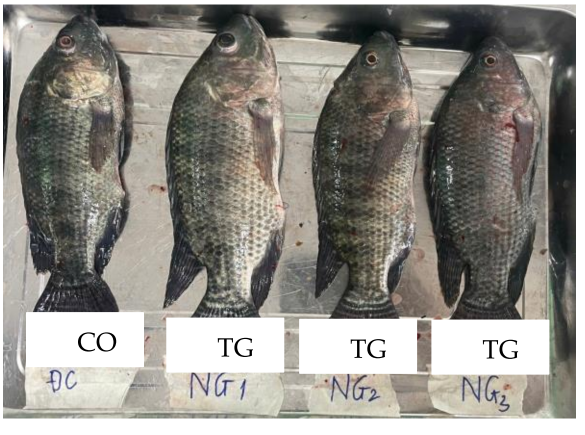

Fig. 1. Experimental tilapia at the end of the trial

Fig. 1 visually supports these findings, with the TG0.5 fish appearing visibly larger than the others, followed by TG1.0 and TG2.0. The CON exhibited the smallest size at the end of the trial.

These results suggest that the 0.5% dietary supplementation (TG0.5) was the most effective in enhancing the growth performance of tilapia under the given experimental conditions.

3.2 Feed utilization

Fig. 2 illustrates the effects of different dietary treatments on Feed intake (A) and Feed conversion ratio (B) in experimental tilapia.

In Fig. 2A, feed intake did not differ significantly among the groups. All dietary treatments (TG0.5, TG1.0, TG2.0) showed similar feed intake levels compared to CON, suggesting no statistically significant differences ($P > 0.05$).

In Fig. 2B, however, dietary treatments had a significant impact on the feed conversion ratio. The TG0.5 and TG2.0 groups exhibited significantly lower feed conversion ratio (1.36 ± 0.06 and 1.38 ± 0.15, respectively), compared to the CON (1.84 ± 0.15) ($P < 0.05$), indicating better feed efficiency. The TG1.0 group showed an intermediate value, not significantly different from either CON or TG0.5.

 pISSN 1859-1388
eISSN 2615-9678

These results suggest that dietary supplementation, particularly at 0.5% and 2.0% inclusion levels, may improve feed efficiency in tilapia without adversely affecting feed intake.

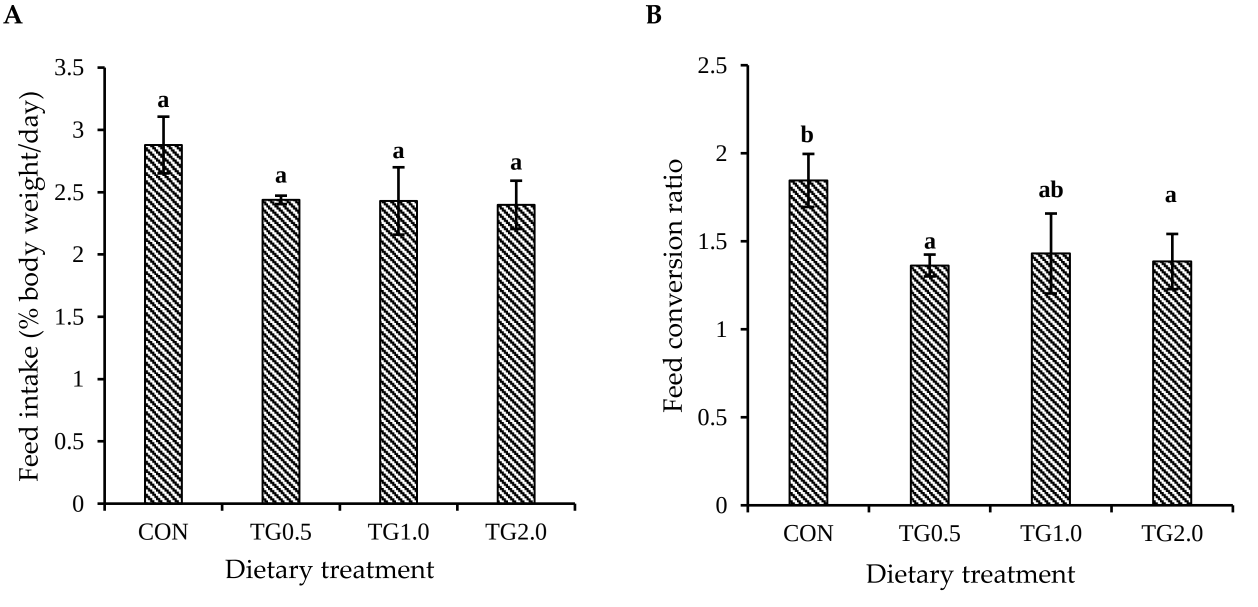

Fig. 2. Feed intake (A) and feed conversion ratio (B) of tilapia under different dietary treatments

Columns with different letters indicate statistically significant differences (P < 0.05).

CON: Basal diet without supplementation; TG0.5: Diet supplemented with 0.25% turmeric + 0.25% ginger; TG1.0: Diet supplemented with 0.5% turmeric + 0.5% ginger; TG2.0: Diet supplemented with 1.0% turmeric + 1.0% ginger

3.3 Survival rate and condition factor

Table 2 presents the survival rate and condition factor of experimental tilapia subjected to different dietary treatments.

The survival rate was high across all groups, ranging from 95% to 100%, with no significant differences observed among treatments. Both TG1.0 and TG2.0 groups achieved 100% survival, while CON and TG0.5 showed 95%.

The condition factor, which reflects the general health and robustness of the fish, was significantly affected by the dietary treatments. The TG0.5 group exhibited the highest condition factor (829.57 ± 57.27%), which was significantly higher than that of the CON (667.09 ± 18.46%, $P < 0.05$). The TG1.0 and TG2.0 groups also showed numerically higher condition factors than the control, but the differences were not statistically significant from either the control or TG0.5.

The effect size for condition factor in Table 2 is 0.81, indicating a large and biologically meaningful effect of turmeric-ginger supplementation on fish condition.

These results indicate that dietary supplementation, particularly at 0.5%, can improve the physiological condition of tilapia without compromising survival.

Table 2. Survival rate and condition factor of tilapia under different dietary treatments

Index	CON	TG0.5	TG1.0	TG2.0	*P*-value	Effect size (η^2)
Survival rate (%)	95	95	100	100	-	-
Condition factor ($\bar{X}$ ± SD)	667.09 ± 18.46^a	829.57 ± 57.27^b	750.19 ± 71.70^{ab}	775.07 ± 40.97^{ab}	0.044	0.81

Values within the same row with different superscript letters are significantly different.

Survival rates showed no variability between replicates (SD = 0).

CON: Basal diet without supplementation; TG0.5: Diet supplemented with 0.25% turmeric + 0.25% ginger; TG1.0: Diet supplemented with 0.5% turmeric + 0.5% ginger; TG2.0: Diet supplemented with 1.0% turmeric + 1.0% ginger.

3.4 Hematological parameters

Table 3 shows the RBCs and WBCs counts of experimental animals under different dietary treatments.

There were no statistically significant differences in red blood cell and white blood cell counts among the treatment groups. Red blood cell counts ranged from 2.19×10^6 to 2.82×10^6 cells/mL, and WBC counts from $9.0 \times 10^4$to 14.6×10^4cells/mL. The effect sizes for RBC and WBC counts in Table 3 are small to moderate (η^2 = 0.23 and 0.36, respectively), indicating that turmeric-ginger supplementation had limited impact on hematological parameters.

Table 3. Red and white blood cell counts of tilapia under different dietary treatments ($\bar{X}$ ± SD)

Index	CON	TG0.5	TG1.0	TG2.0	*P*-value	Effect size (η^2)
Red blood cells (10^6)	2.63 ± 0.749	2.82 ± 0.456	2.19 ± 0.257	2.49 ± 0.446	0.519	0.23
White blood cells (10^4)	9.33 ± 2.020	11.1 ± 0.577	9.0 ± 0.866	14.6 ± 7.005	0.289	0.36

CON: Basal diet without supplementation; TG0.5: Diet supplemented with 0.25% turmeric + 0.25% ginger; TG1.0: Diet supplemented with 0.5% turmeric + 0.5% ginger; TG2.0: Diet supplemented with 1.0% turmeric + 1.0% ginger.

3.5 Somatic indices

Fig. 3 presents the somatic indices of Nile tilapia fed with different dietary treatments. Across all three indices, no statistically significant differences were observed among treatments ($P >$ 0.05). In Fig. 3A, hepatosomatic index ranged from approximately 1.2 to 1.5 across treatments, with TG2.0 showing a numerically higher hepatosomatic index, but not significantly different from the CON or other groups. In Fig. 3B, TG0.5 and TG1.0 had slightly higher gallbladder somatic index than CON and TG2.0, though again without statistical significance. In Fig. 3C, a similar pattern was observed: TG0.5 and TG2.0 showed numerically higher visceral somatic index values compared to CON and TG1.0, but no significant treatment effect was detected.

These results indicate that the dietary treatments did not have a measurable impact on the liver, gallbladder, or visceral indices of Nile tilapia under the given experimental conditions.

Hue University Journal of Science: Natural Science
Vol. 134, No. 1S-2, 29–39, 2025 (Special Issue: CBA 2025)

pISSN 1859-1388
eISSN 2615-9678

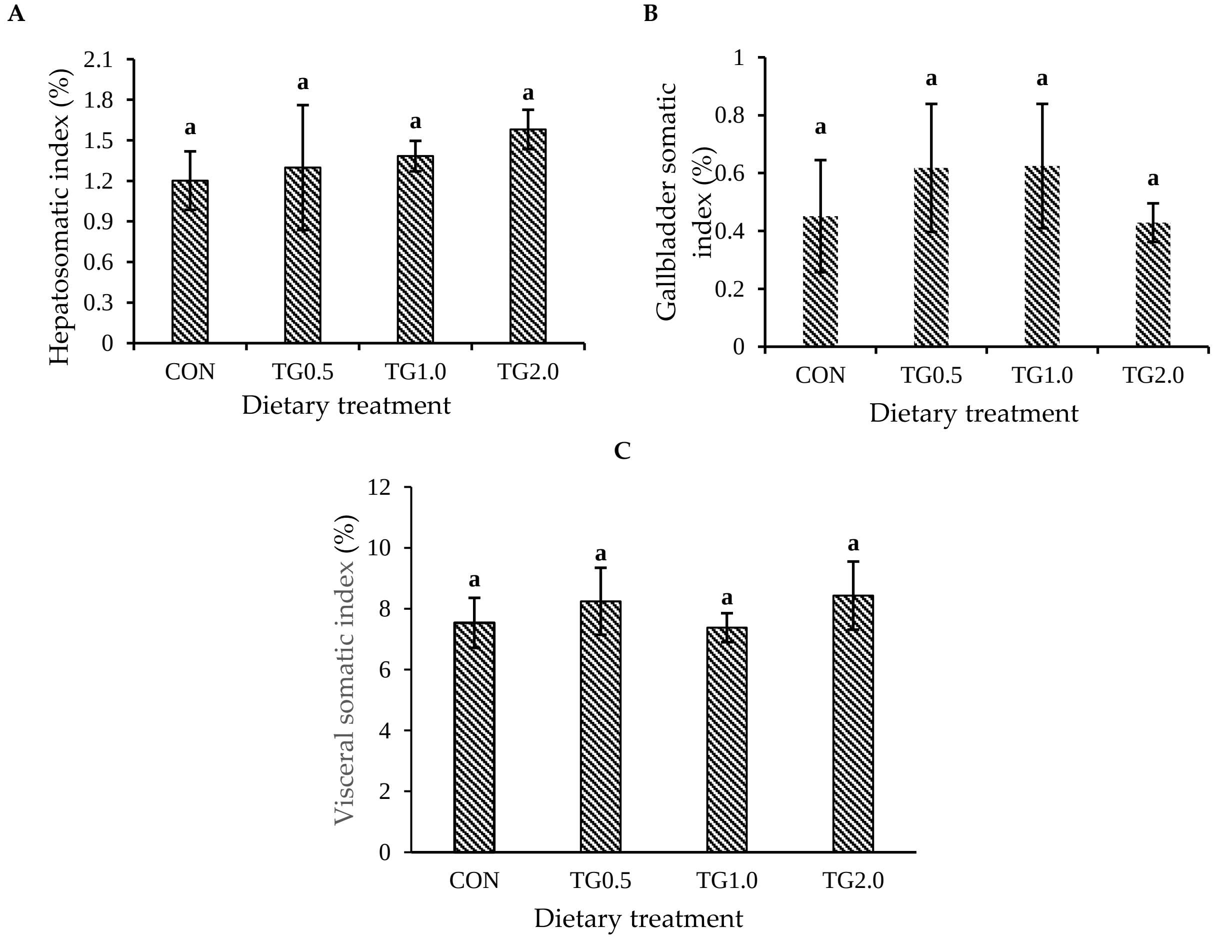

Fig. 3. Somatic indices of tilapia under different dietary treatments

(A) Hepatosomatic index; (B) Gallbladder somatic index; (C) Visceral somatic index

Columns with the same letter are not significantly different (P > 0.05).

CON: Basal diet without supplementation; TG0.5: Diet supplemented with 0.25% turmeric + 0.25% ginger; TG1.0: Diet supplemented with 0.5% turmeric + 0.5% ginger; TG2.0: Diet supplemented with 1.0% turmeric + 1.0% ginger.

4 Discussion

The results of this study demonstrated that dietary supplementation with turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) significantly improved the growth performance and feed conversion ratio of Nile tilapia (*O. niloticus*), particularly at the inclusion level of 0.5% for each herb (TG0.5). This aligns with the findings of Wangkahart et al. [1], who reported that herbal feed additives enhance nutrient absorption and immune response in fish, ultimately leading to better growth.

The improvement in growth parameters such as final weight, weight gain, and specific growth rate observed in TG0.5 may be attributed to the bioactive compounds in turmeric (e.g., curcumin) and ginger (e.g., gingerol, shogaol), which have been shown to stimulate digestive enzyme activity, increase bile secretion, and improve gut morphology [3,15,16]. The superior growth performance observed with TG0.5 supplementation can be attributed to synergistic mechanisms of curcumin and gingerol at multiple physiological levels. Curcumin, in particular, enhances liver function and antioxidative capacity, contributing to improved metabolism and nutrient utilization. Curcumin enhances digestive enzyme activities by upregulating pancreatic amylase, protease, and lipase gene expression through activation of transcription factors such as CREB and STAT3, thereby improving nutrient utilization efficiency [17]. Gingerol and other phenolics in ginger have antibacterial and anti-inflammatory effects that may reduce subclinical infections, supporting better energy allocation toward growth [16,18]. Gingerol stimulates gastric motility and bile acid secretion via cholecystokinin (CCK) release, facilitating lipid emulsification and absorption. At the metabolic level, these bioactive compounds modulate key pathways including enhanced glucose metabolism through AMPK activation and improved fatty acid β-oxidation, contributing to better feed conversion efficiency. Curcumin's anti-inflammatory properties, mediated through NF-κB pathway inhibition, combined with gingerol's prostaglandin E2 suppression, create an optimal intestinal environment for nutrient absorption [19].

Furthermore, both compounds exhibit prebiotic effects, promoting beneficial gut microbiota (*Lactobacillus* and *Bifidobacterium*) while suppressing pathogenic bacteria, leading to improved intestinal villus morphology and barrier function [20]. The enhanced antioxidant enzyme activities (superoxide dismutase, catalase, and glutathione peroxidase) observed with herbal supplementation reduce oxidative stress, allowing more energy allocation toward growth rather than cellular repair processes, which explains the significant improvements in weight gain and specific growth rate.

Our findings are consistent with previous reports on the beneficial effects of ginger supplementation in aquaculture species. For instance, dietary inclusion of ginger rhizome powder at levels of 0.5-1.5% was shown to significantly improve growth performance, digestive enzyme activities, and antioxidative responses in striped catfish (*Pangasianodon hypophthalmus*) reared under outdoor conditions (Ashry et al., 2023) [3]. Notably, fish fed a 1% ginger-supplemented diet exhibited the highest growth rate, lowest feed conversion ratio, and elevated growth hormone levels ($P < 0.05$). Similarly, our results demonstrated that 0.5% dietary supplementation with turmeric and ginger (TG0.5) significantly enhanced the growth performance of Nile tilapia, indicating that low to moderate inclusion levels of these phytogenic additives can stimulate growth. These parallel outcomes further support the potential of ginger and turmeric as natural feed additives to promote fish health and productivity in intensive or environmentally variable aquaculture systems.

The absence of statistically significant differences in both RBC counts and WBC counts across all dietary treatments represents a positive finding indicating that turmeric and ginger supplementation did not induce hematological stress or pathological changes in Nile tilapia. RBC counts remained within the normal physiological range for healthy tilapia across all treatments, confirming that oxygen-carrying capacity and erythropoiesis were not compromised by herbal supplementation. This stability is particularly important in aquaculture systems where environmental stressors can readily alter hematological parameters as stress responses. WBC counts, while showing numerical variation (9.00-14.67 $\times 10^4$/mL), remained well within normal ranges with no statistical significance (P = 0.289). The moderate numerical increase observed in the TG2.0 group (57% higher than control) may suggest enhanced immune readiness rather than inflammatory response, as all values remained within healthy physiological limits. This finding is consistent with previous studies demonstrating

pISSN 1859-1388
eISSN 2615-9678

that moderate levels of bioactive compounds can stimulate immune cell production without inducing systemic inflammation [5].

The absence of significant changes in the hepatosomatic, gallbladder somatic, and visceral somatic indices across treatments indicates that turmeric and ginger supplementation improved growth without disrupting internal organ balance or causing physiological stress. Liver size remained stable, suggesting efficient metabolism without structural strain. Likewise, consistent gallbladder and visceral indices show that digestion and organ development stayed proportional to body growth.

The absence of statistical significance in hematological parameters or somatic indices should therefore be interpreted as positive evidence of physiological safety and homeostatic maintenance, rather than a limitation of the study. In aquaculture nutrition research, the maintenance of normal physiological parameters during enhanced growth performance represents an ideal outcome, demonstrating that the dietary intervention improves biological efficiency without compromising fish health. This supports the immunomodulatory role of phytogenics without causing stress or organ hypertrophy, which agrees with previous studies in common carp and other aquaculture species [1,16,21].

The survival rate remained high across all treatments (95-100%), indicating that turmeric and ginger supplementation did not have any toxic effects at the tested inclusion levels.

A key strength of this study is its controlled experimental design and the dual use of turmeric and ginger, which reflects a more practical dietary strategy. The findings provide clear evidence that a moderate level (0.5%) of combined turmeric and ginger improves growth without adverse effects. However, the study has several limitations, including a relatively short duration (90 days), the absence of digestive enzyme activity measurements, and the lack of gut histological analysis. Future studies should extend the trial period, incorporate larger sample sizes, assess digestive enzymes and gut microbiota, and examine intestinal morphology. Additional work should also evaluate different turmeric-ginger ratios, conduct pathogen challenge tests, and assess economic feasibility for commercial application.

5 Conclusion

The present study demonstrated that dietary supplementation with turmeric and ginger powders, particularly at a combined level of 0.5% each (TG0.5), significantly enhanced the growth performance and feed conversion efficiency of Nile tilapia (*O. niloticus*) without negatively affecting survival, hematological indices, or somatic indices. These findings suggest that moderate inclusion of turmeric and ginger can serve as an effective phytogenic feed additive strategy to improve aquaculture productivity in a safe and natural manner. Further studies with larger sample sizes, longer durations, and detailed biochemical analyses are recommended to elucidate the underlying physiological mechanisms and confirm long-term benefits.

Acknowledgement

The authors would like to thank the Faculty of Biology, Hanoi National University of Education, for providing facilities and support throughout the experiment.

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