

The effect of ginger supplementation in fish feed on the growth and profitability of red tilapia culture

Dian Wijayanto

Faculty of Fisheries and Marine Science, Universitas Diponegoro, Tembalang, Semarang, Central Java, Indonesia. Corresponding author: D. Wijayanto, dianwijayanto@gmail.com

Abstract. Red tilapia (*Oreochromis* sp.) is an important freshwater aquaculture commodity in Indonesia. Ginger (*Zingiber officinale*) can be used as a feed additive in fish farming due to its various bioactive compounds that can enhance fish immunity and growth. This research analyzed the effects of ginger supplementation in feed on the culture performance of red tilapia (SGR, WGR, FCR, SR, and BCR). The experimental fish weighing approximately 2.69±0.44 g per individual were reared in 0.5 m³ fiberglass tanks at a density of 25 fish per tank. A completely randomized design was used with different doses of ginger supplementation: 0.10% (treatment A), 0.25% (treatment B), and 0.50% (treatment C), each with three replications within 40 days. The results showed that ginger supplementation in feed significantly affected the culture performance of red tilapia, with the most optimal dosage of 0.10% (treatment A). The relationship between ginger dosage and culture performance parameters followed a quadratic pattern, with the optimal dosage ranging between 0.063 and 0.118%. At the right dosages, ginger is a potential natural feed additive that improves the productivity and efficiency in red tilapia aquaculture.

Key Words: benefit-cost ratio, feed conversion ratio, specific growth rate, survival rate, weight gain rate.

Introduction. Red tilapia (*Oreochromis* sp.) is a freshwater aquaculture species widely cultivated in tropical countries, including Indonesia due to its high demand. The production of red tilapia in Indonesia reached 1,172,633 tons in 2020 (KKP 2024). The fish has relatively fast growth, high tolerance to diverse environmental conditions, feed efficiency, and stable market demand (Omasaki et al 2017; Mengistu et al 2020; El-Hack et al 2022; Rossignoli et al 2023), making it a significant and sustainable source of animal protein among Indonesians. In intensive culture systems, tilapia productivity is strongly influenced by feed quality, culture management, and fish health during the farming process (Gullian-Klanian & Arámburu-Adame 2013; Zimmermann et al 2023).

Fish growth and efficiency in aquaculture activities can be measured through several biological parameters: specific growth rate (SGR), weight gain rate (WGR), feed conversion ratio (FCR), and survival rate (SR). These parameters evaluate the success of the culture system and the effectiveness of feed utilization. Optimal growth increases the productivity, while feed efficiency lowers the operational costs which account for more than 60% of the total production cost in fish farming. Improvement to the feed efficiency and fish growth is the main focus of modern aquaculture research (Wijayanto et al 2022; Rossignoli et al 2023; Sriprateep et al 2025).

Natural ingredients are used as feed additives to boost the growth performance of fish. Natural ingredients are considered safer, environmentally friendly, and capable of enhancing metabolism, immune systems, and feed efficiency in fish farming (Kristiana et al 2020; Barducci et al 2022; Syanya et al 2023; Hemat et al 2024; Wijayanto et al 2025). Various herbal plants have been studied and used as feed additives, such as turmeric, garlic, and ginger. The bioactive compounds such as flavonoids, phenols, essential oils, and antioxidants in the plants are known to enhance fish immunity and metabolism. The use of herbal ingredients as feed additives is a potential alternative to the use of chemical substances or synthetic antibiotics in aquaculture (Wei et al 2025; Wijayanto et al 2025). Ginger (*Zingiber officinale*) contains various active compounds such as gingerol, shogaol,

and zingerone, which are known to have antioxidant, antibacterial, and immunostimulant properties. These compounds can help improve fish health, enhance digestive systems, and increase nutrient utilization efficiency in feed (Elabd et al 2019; Barducci et al 2022; Hemat et al 2024; Wijayanto et al 2025).

In addition to biological aspects, the success of fish farming also needs to be evaluated from an economic perspective through some indicators. One commonly used indicator is the benefit-cost ratio (BCR), which compares the revenue obtained to the total production cost. Feed additives improve fish growth and feed efficiency, eventually increasing both productivity profitability of the business. This research was conducted to analyze the effect of ginger supplementation in feed on the culture performance of red tilapia.

Material and Method

Time and location of research. This experimental research was conducted for 40 days, from June to July 2025 at the Laboratory of the Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Indonesia.

Experimental fish and rearing media. Red tilapia (*Oreochromis* sp.) with an average initial weight of 2.69 ± 0.44 g per individual were taken as samples. The fish were reared in fiberglass tanks with a volume of 0.5 m^3 at a stocking density of 25 fish per tank. Aeration and water recirculation systems were applied to maintain water quality throughout the research. Periodic water exchange and monitoring of water quality parameters, including temperature, pH, and dissolved oxygen, were carried out during the rearing period (Gullian-Klanian & Arámburu-Adame 2013; Siddique et al 2025).

Experimental design and feed treatments. A completely randomized design (CRD) was utilized in this research using commercial feed containing a minimum of 31% protein, a minimum of 5% fat, a maximum of 8% fiber, a maximum of 13% moisture, and a maximum of 12% ash. The feed was enriched with ginger at 0.10% (treatment A), 0.25% (treatment B), and 0.50% (treatment C). Fresh ginger was grated, and the liquid extract was collected and used as the treatment material for feed supplementation. The ginger extract was prepared according to the respective treatment doses and diluted with water at a ratio of 1:10 (ginger liquid extract). The diluted solution was then evenly sprayed onto commercial artificial feed, after which the feed was air-dried before being administered to the fish. Fish were fed the treatment feed at 3% of their biomass per day, with a feeding frequency of three times daily (morning, afternoon, and evening). Fish were weighed every 10 days to adjust the feeding rate (Ahmed et al 2022; Andriani & Aisyah 2025; Wijayanto 2025).

Observed parameters. Several parameters were observed in this research, including fish growth (SGR and WGR), feed efficiency (FCR), survival rate (SR), and the profitability of the culture system that is analyzed through benefit-cost ratio (BCR) (Barducci et al 2022; Islam et al 2024; Wei et al 2025; Wijayanto et al 2025). SGR represents the specific growth rate of fish based on the logarithmic increase in average body weight per day. WGR is the weight gain rate, expressed as the percentage increase in fish weight during the rearing period. SR is the survival rate, expressed as a percentage. FCR is the feed conversion ratio and describes the amount of feed required to produce one unit of weight gain. Lower FCR indicates better feed efficiency. BCR was calculated by comparing total revenue with total production cost. A BCR value greater than 1 indicates that the aquaculture operation is profitable (Al-Asgah & Ali 1997; Amira et al 2021; Wijayanto 2025). The formulas used in the research are as follows:

| | | |
|--|-------|-----|
| WGR (%) = $[(W_t - W_o)/W_o] \times 100$ | | [1] |
| SGR (% day ⁻¹) = $(\ln W_t - \ln W_o) / t$ | | [2] |
| SR (%) = $(N_t/N_o) \times 100$ | | [3] |
| FCR = F / W | | [4] |
| BCR = B / C | | [5] |

Where: W_t is the average fish weight (g) at day t , while W_0 is the average fish weight (g) at the beginning of the experiment. \ln denotes the natural logarithm. SR represents the survival rate (%) of fish at the end of the rearing period, where N_t is the number of fish surviving at the end of the experiment and N_0 is the initial number of fish stocked. F is the total feed consumption (g), W is the weight gain of fish (g), B is the additional revenue generated from fish growth (IDR), and C is the feed cost incurred during the experimental period (IDR).

Data analysis. The data collected in this research were statistically analyzed using analysis of variance (ANOVA) to determine the effect of treatments on the measured parameters. If significant differences among treatments were detected, Duncan's multiple range test was applied at a 95% confidence level ($p < 0.05$) to identify the best treatment. Treatment optimization was determined through mathematical modeling using the first derivative approach of the dependent variable with respect to the independent variable with a value of zero (Yossa & Verdegem 2015; Wijayanto 2025).

Results. Table 1 and Table 2 show the results of this research. As seen in the tables, ginger supplementation in feed affected growth performance, feed efficiency, survival rate, and profitability of red tilapia culture. Treatment A (0.1%) produced the most optimal WGR, SGR, SR, FCR, and BCR. On the other hand, higher ginger doses in treatments B (0.25%) and C (0.50%) reduced the values of the parameters. It concludes that excessive ginger doses may decrease feed palatability or disrupt the metabolic balance of the fish.

Table 1
WGR, SGR, SR, FCR and BCR of the research

| Variables | A (0.1%) | | | B (0.25%) | | | C (0.50%) | | |
|-----------------------------------|----------|--------|--------|-----------|--------|--------|-----------|--------|--------|
| | A_1 | A_2 | A_3 | B_1 | B_2 | B_3 | C_1 | C_2 | C_3 |
| Initial biomass (g) | 74.53 | 74.13 | 73.93 | 74.73 | 73.74 | 73.28 | 72.79 | 73.08 | 72.64 |
| Final biomass (g) | 202.79 | 194.80 | 195.81 | 192.06 | 188.79 | 186.87 | 150.02 | 144.00 | 158.08 |
| W_0 (g ind ⁻¹) | 2.98 | 2.97 | 2.96 | 2.99 | 2.95 | 2.93 | 2.91 | 2.92 | 2.91 |
| $W_{t=40}$ (g ind ⁻¹) | 8.45 | 8.47 | 8.51 | 8.35 | 8.21 | 8.12 | 7.14 | 7.20 | 7.19 |
| Initial number of fish (ind) | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Final number of fish (ind) | 24 | 23 | 23 | 23 | 23 | 23 | 21 | 20 | 22 |
| WGR (%) | 172 | 163 | 165 | 157 | 156 | 155 | 106 | 97 | 118 |
| SGR (% day ⁻¹) | 2.60 | 2.62 | 2.64 | 2.57 | 2.56 | 2.55 | 2.24 | 2.25 | 2.26 |
| SR (%) | 96 | 92 | 92 | 92 | 92 | 92 | 84 | 80 | 88 |
| FCR | 1.07 | 1.14 | 1.13 | 1.17 | 1.18 | 1.18 | 1.63 | 1.79 | 1.48 |
| BCR* | 3.26 | 3.07 | 3.10 | 2.99 | 2.98 | 2.96 | 2.14 | 1.96 | 2.37 |

Assumption: * The price of fish is IDR 35,000 per kg and the price of feed is IDR 10,000 per kg.

Table 2
Statistical analysis

| Variables | Average values | | | F values | Sig values | Notes | Duncan test |
|----------------------------|----------------|------|------|----------|------------|-------------|-------------------|
| | A | B | C | | | | |
| SR (%) | 93 | 92 | 84 | 10.74 | 0.01038 | Significant | $A^1 = B^1 > C^2$ |
| WGR (%) | 167 | 156 | 107 | 69.65 | 0.00007 | Significant | $A^1 = B^1 > C^2$ |
| SGR (% day ⁻¹) | 2.62 | 2.56 | 2.26 | 616.91 | 0.0000001 | Significant | $A^1 > B^2 > C^3$ |
| FCR | 1.12 | 1.18 | 1.63 | 28.63 | 0.0008 | Significant | $A^1 = B^1 < C^2$ |
| BCR | 3.14 | 2.98 | 2.15 | 47.84 | 0.0002 | Significant | $A^1 = B^1 > C^2$ |

Note: 1, 2, 3 represent subsets.

All treatments showed relatively high SR values (above 80%), with treatment A obtaining the highest score. The average weight development of the experimental fish is shown in Figure 1, while the estimated optimal dosage is presented in Figure 2 and Table 3. It is confirmed that increasing ginger dosage in feed produces different responses across each

culture performance parameter. The relationship between ginger dosage and SR, SGR, WGR, FCR, as well as BCR tends to follow a quadratic pattern, indicating the presence of an optimal dosage point before performance declines again.

It can be inferred that ginger supplementation in feed does provide benefits to aquaculture performance, but only within a certain dosage range. Excessively high doses tend to reduce growth, survival, and feed efficiency parameters.

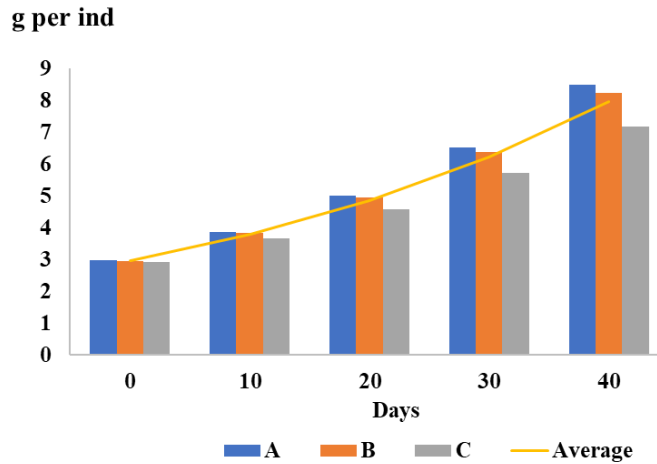


Figure 1. Fish growth progress.

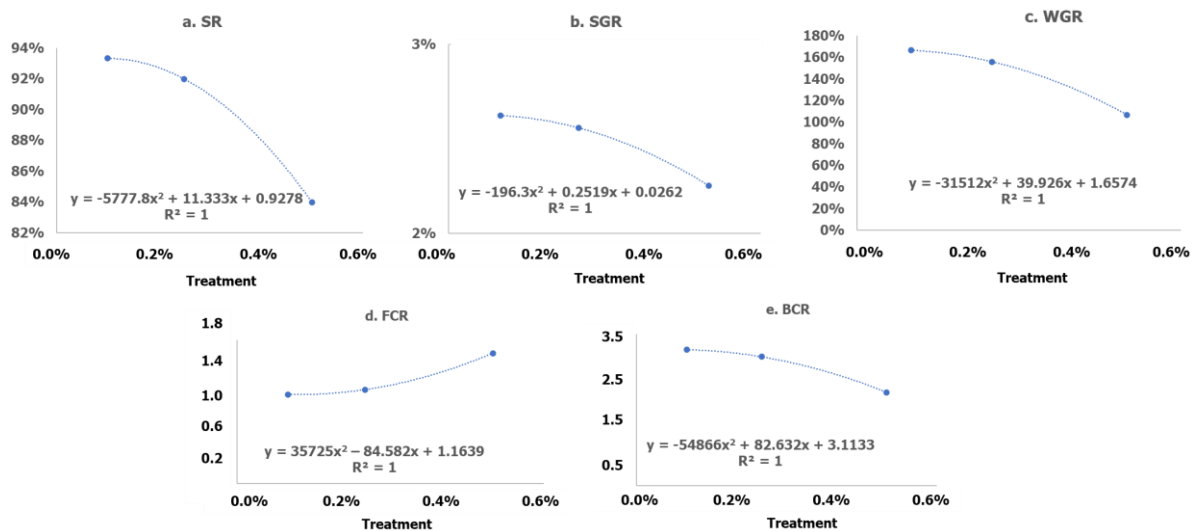


Figure 2. The correlation between SR, SGR, WGR, FCR and BCR with ginger dosage treatment.

Table 3

Estimated optimal dosage

| <i>Variables</i> | <i>Optimal treatment (% ginger)</i> | <i>Estimated optimal value</i> |
|------------------|-------------------------------------|--------------------------------|
| SR | 0.098% | 93% |
| WGR | 0.063% | 167.0% |
| SGR | 0.064% | 2.628 % day ⁻¹ |
| FCR | 0.118% | 1.114 |
| BCR | 0.075% | 3.144 |

As found in actual research, the addition of ginger in feed affects fish growth. Ginger at low doses has been effective in improving WGR, SGR, FCR, SR, and BCR. Whereas, higher doses may reduce aquaculture performance (Table 4).

Table 4

Research on the addition of ginger in fish feed

| Type of fish | Optimal dose | Research |
|---|--------------------------------|-----------------------|
| Nile tilapia (<i>Oreochromis niloticus</i>) | 1% (ginger powder) | Hassanin et al (2014) |
| Nile tilapia (<i>Oreochromis niloticus</i>) | 0.5% (essential oil of ginger) | Brum et al (2017) |
| Nile tilapia (<i>Oreochromis niloticus</i>) | 4.1-5.8% (ginger powder) | Naliato et al (2021) |
| Crucian carp (<i>Carassius auratus</i>) | 0.4% (ginger polysaccharides) | Luo et al (2024) |
| Giant gourami (<i>Osphronemus goramy</i>) | 0.3% (ginger extract) | Wijayanto (2025) |
| Red tilapia (<i>Oreochromis sp.</i>) | 0.063-0.118% (ginger extract) | This research |

Regarding water quality, all treatments were relatively within acceptable standards for tilapia (Table 5). The pH in this research ranged from 7.90 to 8.03, and the temperature was around 25°C. According to BSN (2009), red tilapia can be reared at temperatures of 25-30°C and within a pH range of 6.5-8.5, with dissolved oxygen (DO) of least 5 ppm. In this research, the DO was still within the tolerable range from 3.93 to 4.57 ppm for red tilapia (Li et al 2020).

The gaps in the water quality among treatments (A, B, and C) were not significant, where variations in treatment dosage did not have a major impact on water quality. The gaps in the growth performance and feed efficiency observed in this research were rather influenced by the feed treatment (ginger dosage) than by water quality parameters.

Table 5

Water quality

| Parameters | A | | | B | | | C | | |
|------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | A ₁ | A ₂ | A ₃ | B ₁ | B ₂ | B ₃ | C ₁ | C ₂ | C ₃ |
| pH | 8.03± 0.15 | 8.00± 0.20 | 7.93± 0.15 | 7.97± 0.21 | 7.90± 0.10 | 7.97± 0.19 | 7.90± 0.17 | 7.91± 0.17 | 8.00± 0.26 |
| Temp. (°C) | 25.27± 0.23 | 25.27± 0.25 | 25.07± 0.12 | 25.07± 0.15 | 25.13± 0.12 | 25.10± 0.20 | 25.13± 0.21 | 25.13± 0.15 | 25.17± 0.21 |
| DO (ppm) | 4.57± 0.70 | 4.20± 0.20 | 4.13± 0.21 | 4.23± 0.31 | 3.97± 0.06 | 4.00± 0.40 | 4.23± 0.12 | 4.00± 0.40 | 3.93± 0.29 |

Discussion. Ginger supplementation in feed significantly affects the performance of red tilapia as reflected from the growth, feed efficiency, SR, and economic profitability. Table 1 and Table 2 show that treatment A (0.1%) was the most effective among other treatments, as seen in higher WGR, SGR, and SR values, as well as lower FCR and higher BCR. On the other side, higher ginger dosages in treatments B (0.25%) and C (0.50%) reduced the aquaculture performance parameters. At the right dose, ginger acts as an appetite enhancer, growth promoter, and immunostimulant. The bioactive compounds such as phenols, alkaloids, flavonoids, steroids, and tannins in ginger have antibacterial, antifungal, antioxidant, and anti-inflammatory properties. These compounds contribute to improved fish health and digestive function (Al-Radadi et al 2022; Anjur & Ahmad 2022; Zhang et al 2023; Febriani et al 2023; Purbomartono et al 2024).

However, excessive ginger dosage resulted in lower values of the parameters. The reduced feed palatability or disruption of the fish's metabolic balance could lead to this decline. Nevertheless, the SR across all treatments remained relatively high (> 80%), indicating that ginger was not toxic within the tested dosage range. The relationship between ginger dosage and performance parameters (SR, SGR, WGR, FCR, and BCR) followed a quadratic pattern. The optimal dosage is found within low range of dosage from 0.063 to 0.118%, depending on the parameter observed. The use of ginger in limited amounts is sufficient in enhancing aquaculture performance (Febriani et al 2023; Wijayanto

2025). In addition, each herbal nutraceutical has a different optimal dosage range depending on the ingredients and fish species being cultured (Wijayanto et al 2022, 2025).

In terms of feed efficiency, ginger supplementation improved the ability of fish to utilize nutrients. Higher BCR values reflect higher economic profitability. In addition to biological benefits, ginger also enhances the efficiency of aquaculture operations. The high SR value in treatments with ginger supplementation is also likely related to the immunostimulant and antibacterial properties of ginger's bioactive compounds, which enhance the fish immune system and increase resistance to stress and disease during rearing. In aquaculture, optimization of growth, feed efficiency, and disease control are central in improving productivity and profitability (Hajirezaee et al 2015; Omasaki et al 2017; Satriawan et al 2020; Mengistu et al 2020; Hidayati et al 2021; Wei et al 2025).

As found by previous researchers, ginger addition to the feed can improve growth and feed efficiency in cultured fish. However, the effectiveness of ginger depends on the dosage, where low doses tend to produce more optimal results than high doses (Hassanin et al 2014; Brum et al 2017; Naliato et al 2021; Luo et al 2024; Wijayanto 2025).

The water quality parameters during the research remained habitable for fish, with relatively stable pH, temperature, and dissolved oxygen values. Water quality is an important factor in supporting fish growth and survival (El-Hack et al 2022; Anjur & Ahmad 2022; Rossignoli et al 2023; Zimmermann et al 2023; Wijayanto 2025). No significant differences were observed among treatments. Variations in fish performance in this research were rather influenced by feed treatment than water quality factors.

Ginger has strong potential as an effective natural feed additive to improve growth, feed efficiency, and economic profitability in red tilapia aquaculture. However, its application must consider the optimal dosage to avoid reduced performance.

Conclusions. The ginger supplementation in fish feed has a significant effect on the performance of red tilapia aquaculture, as seen from the values of growth (WGR and SGR), feed efficiency (FCR), survival rate (SR), and economic profitability (BCR). The most optimal treatment was obtained at a dosage of 0.10%, which resulted in the high growth, strong feed efficiency, high survival rate, and the most optimal profit value. Increasing the ginger dosage beyond this level (0.25% and 0.50%) tended to reduce aquaculture performance, likely due to decreased feed palatability or disruption of fish metabolism. A quadratic pattern was found, with the optimal dosage range between 0.063 and 0.118%. Water quality parameters remained within acceptable ranges for tilapia culture and did not act as a limiting factor. Hence, the gaps in the fish performance were primarily influenced by feed treatment. To conclude, ginger supplementation at the right dosage has strong potential as an effective natural feed additive to enhance productivity and efficiency in red tilapia aquaculture.

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Conflicts of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Author:

Dian Wijayanto (DW), Faculty of Fisheries and Marine Science, Universitas Diponegoro, Tembalang, Prof. Jacob Rais Street, Semarang, Central Java, Indonesia, e-mail: dianwijayanto@gmail.com; dianwijayanto@lecturer.undip.ac.id

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