

Optimization of shallot (*Allium cepa*) liquid addition to fish feed on the growth and profitability of red tilapia (*Oreochromis* sp.)

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Abstract. This study aimed to analyze the effect of adding shallot (*Allium cepa*) liquid into fish feed on the growth performance and profitability of farmed red tilapia (*Oreochromis* sp.). Three different doses of 0.0% (treatment A), 2.5% (treatment B), and 5.0% (treatment C) of feed weight were used in this completely randomized design study done within 30 days. Test fish with an initial size of 2.11 ± 0.03 g were reared in fiberglass tanks at a stocking density of 30 fish per tank and fed 4% of biomass per day. The parameters observed included specific growth rate (SGR), weight gain rate (WGR), survival rate (SR), feed conversion ratio (FCR), and benefit cost ratio (BCR). The results showed that shallot liquid addition to the fish feed significantly affected the growth, feed efficiency, and BCR. Liquid shallot at low doses produced high WGR and SGR values along with a more efficient FCR. In this study, the control treatment (treatment A, 0.0% shallot liquid) resulted in the most optimal performance, while the highest SR and BCR values were obtained in the control treatment. Polynomial regression optimization analysis indicated that the optimal dose ranges low, between 0.131 and 0.694%.

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

Introduction. Red tilapia (*Oreochromis* sp.) farming is developing rapidly in Indonesia because of its economic potential and relatively short production cycle. The market demand for red tilapia is also relatively high at a moderate price, both for domestic needs and for export. Therefore, the production and the sustainability of red tilapia farming need to be improved by applying innovation in feed management. Feed cost makes up the largest proportion, over 60% of total production costs (Mengistu et al., 2020; Stockhausen et al., 2024).

The success of red tilapia farming is strongly influenced by several factors, including seed quality, water quality management, stocking density, and feed (both quality and efficiency). With a fast growth rate and good adaptability, red tilapia needs adequate nutrition intake from the feed, which can boost its resistance to diseases. Meanwhile, it is also necessary to manage cost efficiency by adding feed additives known to improve the growth and feed efficiency of the fish (Rodrigues et al., 2022; Fujaya et al., 2023; Méndez-Martínez et al., 2023; Yuniarti et al., 2024; El-Sayed et al., 2025; Ha et al., 2025; Hew et al., 2025; Al-Sagheer et al., 2026).

Natural and herbal-based feed additives have been widely used as an alternative to synthetic chemicals and synthetic antibiotics. *Allium cepa*, commonly known as shallot, is a potent feed additive for containing various bioactive compounds such as flavonoids, saponins, tannins, and alkaloids, which act as antioxidants, antibacterials, anti-inflammatories, and immunostimulants. The skin of the shallot also contains active compounds that boost the immune system and inhibit the growth of pathogenic bacteria in fish (Akrami et al., 2015; Younes et al., 2021).

Similarly, garlic (*Allium sativum*) has also been widely used as a feed additive that positively affects growth, feed efficiency, and overall fish health. Other members of the *Allium* genus (including shallot) may have potential to be used as nutraceutical ingredients in fish feed. However, the application of shallot as a feed additive in red tilapia remains

insufficiently explored, particularly in the form of a liquid extract (Mahmoud & El-Hais, 2017; Öz et al., 2024; Anggriani et al., 2026).

To address the gap, this study was performed to analyze how shallot liquid can be optimally added to feed to boost the growth performance of red tilapia and improve the farming profitability. The results of this study offer an effective, economical, and sustainable natural feed innovation.

Materials and Method

Time and location of the study. This experimental study was carried out over 30 days from February to March 2025 at the Laboratory of the Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang, Indonesia.

Test fish and rearing media. Red tilapia with an average initial weight of 2.11 ± 0.03 g per fish were reared in 0.5 m^3 fiberglass tanks at a stocking density of 30 fish per tank. Throughout the study, an aeration and water recirculation system was used to keep water quality optimal. The water was changed periodically, and water quality parameters that included temperature, pH, and dissolved oxygen (DO) were monitored throughout the rearing period (Lindholm-Lehto, 2023; Lembang et al., 2025).

Experimental design and feed treatments. This study was performed using a Completely Randomized Design (CRD). A commercial feed containing a minimum of 31% protein, 5% fat, a maximum of 8% fiber, a maximum of 13% moisture, and a maximum of 12% ash was used and enriched with shallot liquid extract. Shallot liquid was added at doses of 0.0% (treatment A, control), 2.5% (treatment B), and 5.0% (treatment C) of feed weight with three replicates for each treatment. To produce the liquid extract, shallot was grated for juice extraction, weighed according to the dose, then diluted with a small amount of water to be sprayed evenly onto the commercial feed. The feed was then air-dried before being fed to the test fish. Feeding was carried out at 4% of fish biomass per day, in three feedings a day (morning, midday, and evening). The test fish were weighed every 10 days to adjust the amount of feed given (Kord et al., 2021; Wijayanto et al., 2022; Al-Sagheer et al., 2026).

Observed parameters. The parameters observed included weight gain rate (WGR), specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), and benefit cost ratio (BCR). SGR was calculated from the logarithmic increase in the fish's average weight per day. WGR is expressed as the percentage increase in fish weight over the rearing period. SR is expressed in percentage. FCR describes the amount of feed needed to produce one unit of weight gain, where a lower FCR value shows greater feed use efficiency. BCR is calculated by comparing total revenue with total production costs, in which BCR value greater than 1 indicates positive profitability (Al-Asgah & Ali, 1997; Amira et al., 2021; Wijayanto et al., 2022). The following formulas were used to calculate the parameters observed in this study:

$$\begin{aligned} \text{SGR (\% day}^{-1}\text{)} &= (\text{Ln } W_t - \text{Ln } W_0) / t && [1] \\ \text{WGR (\%)} &= [(W_t - W_0) / W_0] \times 100 && [2] \\ \text{SR (\%)} &= (N_t / N_0) \times 100 && [3] \\ \text{FCR} &= F / W && [4] \\ \text{BCR} &= B / C && [5] \end{aligned}$$

where: W_t = average fish weight (g) at day t ;

W_0 = average fish weight (g) at the beginning of the experiment;

Ln = natural logarithm;

N_t = number of fish surviving at the end of the experiment;

N_0 = initial number of fish stocked;

F = total feed consumption (g);

W = fish weight gain (g);

B = additional revenue generated from fish growth (IDR);

C = feed cost incurred during the experimental period (IDR).

Data analysis. Analysis of variance (ANOVA) was conducted to statistically determine the effects of the treatments on the observed parameters. Significant differences found between treatments were then followed up by performing Duncan's test at a 95% confidence level ($p < 0.05$) to determine the most optimal treatment. Treatment optimization was determined through a mathematical modeling approach (polynomial regression), using the first derivative of the dependent variable with respect to the independent variable set equal to zero (Van Dam, 1990; Wijayanto et al., 2022).

Results. The addition of shallot liquid to the feed affected the growth and farming performance of red tilapia. Zero to moderate dose treatments (0-2.5%) produced relatively high WGR and SGR values, with WGR ranging from 103.52 to 128.85% and SGR from 1.62 to 1.66% day⁻¹. The highest SR reached 90% in the control treatment, while the other treatments ranged from 73.33 to 86.67%. The highest feed efficiency, with the lowest FCR values (1.93-2.14), was obtained from treatments A and B. The highest benefit as shown by a BCR value of 1.55, was obtained in the control treatment, even though low-dose shallot treatments were also profitable (Table 1 and Figure 1).

Table 1

WGR, SGR, SR, FCR and BCR in the research

Variables	A (0%)			B (2.5%)			C (5%)		
	A1	A2	A3	B1	B2	B3	C1	C2	C3
Initial biomass (g)	62.66	64.16	63.56	63.61	64.81	63.91	62.12	62.72	62.42
Final biomass (g)	143.40	140.43	138.39	135.58	138.59	130.07	106.48	107.88	107.76
W0 (g ind ⁻¹)	2.09	2.14	2.12	2.12	2.16	2.13	2.07	2.09	2.08
Wt = 30 (g ind ⁻¹)	5.31	5.40	5.32	5.21	5.33	5.20	4.84	4.90	4.90
Initial number of fish (ind)	30	30	30	30	30	30	30	30	30
Final number of fish (ind)	27	26	26	26	26	25	22	22	22
WGR (%)	128.85	118.88	117.74	113.14	113.84	103.52	71.41	72.01	72.64
SGR (% day ⁻¹)	1.65	1.66	1.65	1.63	1.65	1.62	1.55	1.57	1.56
SR (%)	90.00	86.67	86.67	86.67	86.67	83.33	73.33	73.33	73.33
FCR	1.93	2.08	2.12	2.14	2.15	2.31	2.96	2.85	2.95
BCR*	1.55	1.44	1.42	1.40	1.40	1.30	1.01	1.05	1.02

Assumption: * Fish price of IDR 30,000 per kg and feed price of IDR 10,000 per kg.

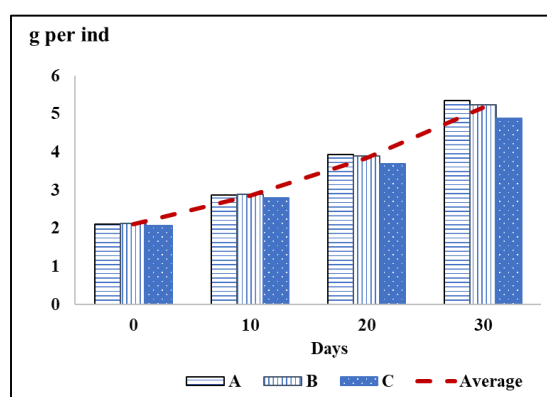


Figure 1. Fish growth progress.

The results of the statistical analysis shown in Table 2 present the significant effect of the shallot liquid addition on the SR, WGR, SGR, FCR, and BCR parameters. In general, treatment A obtained the most optimal results. The results of the regression analysis (Figure 2) indicate a significant relationship between shallot dose and growth response. A relatively low dose of shallot liquid (0.131-0.694%) could improve performance efficiently

(Table 3). Table 4 presents a comparison of the addition of shallot into fish feed for several fish species.

Statistical analysis

Table 2

Variables	Average values			F values	Sig. values	Notes	Duncan test
	A	B	C				
SR (%)	88	86	73	73.5	0.00006	Significant	A ^a > B ^b = C ^b
WGR (%)	122	110	72	86.0	0.00004	Significant	A ^a > B ^b > C ^c
SGR (% day ⁻¹)	1.65	1.63	1.56	68.4	0.00007	Significant	A ^a > B ^b = C ^b
FCR	2.04	2.20	2.92	87.6	0.00004	Significant	A ^a < B ^b = C ^c
BCR	1.47	1.37	1.03	53.1	0.00015	Significant	A ^a > B ^b = C ^b

Note: a, b, c represent subsets.

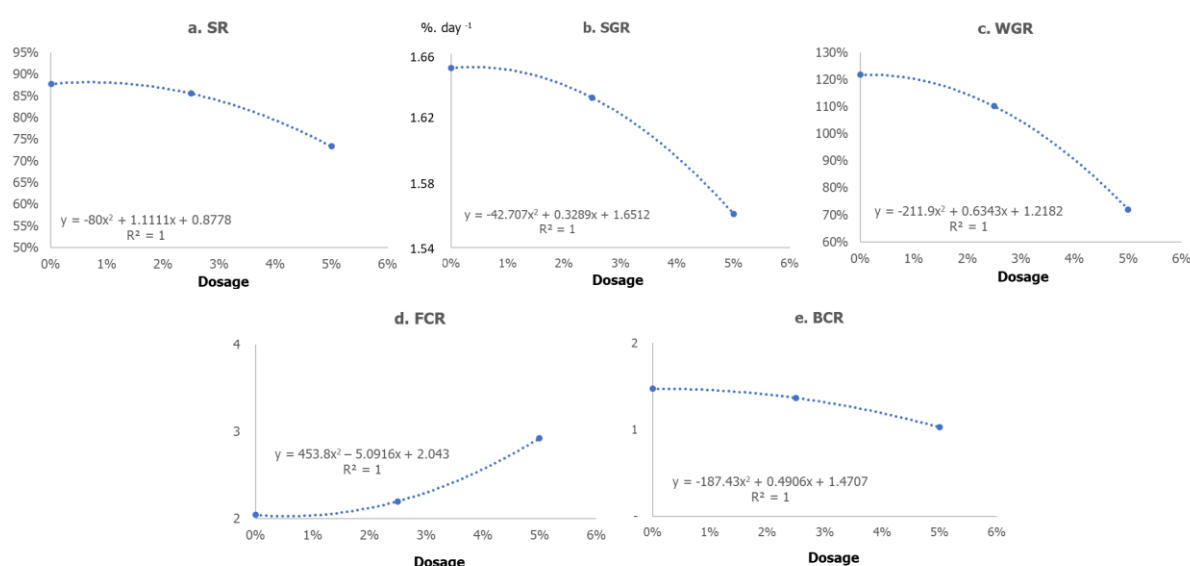


Figure 3. The relationship between SR, SGR, WGR, FCR, and BCR with different shallot doses.

Optimal dosage estimation

Table 3

Variables	Optimal treatment (% shallot)	Optimal value estimation
SR (%)	0.694	88
WGR (%)	0.150	122
SGR (% day ⁻¹)	0.385	1.652
FCR	0.561	2.029
BCR	0.131	1.471

Prior studies on the application of shallot in fish feed

Table 4

Type of fish	Optimal dose	Study
<i>Oreochromis niloticus</i>	0.5-1% shallot powder	Younes et al. (2021)
<i>Lates calcarifer</i>	3.617 to 4.164% shallot extract liquid	Wijayanto et al. (2022)
TGGG hybrid grouper	2.4-2.6% shallot extract liquid	Wijayanto et al. (2024)
<i>Oreochromis niloticus</i>	500 mg kg ⁻¹ shallot peel extract	Al-Sagheer et al. (2026)
<i>Oreochromis</i> sp.	0.13-0.69% shallot extract liquid	This study

The path analysis (Figure 3) indicates that BCR, SR, FCR, SGR, and WGR are interrelated through a series of direct effects that determine fish farming performance. SR and SGR positively affect WGR, whereas FCR negatively affects BCR. Thus, survival and growth contribute to biomass gain, while feed efficiency directly influences farm profitability. The model uses standardized coefficients (β) to indicate the strength and direction of relationships, with larger absolute β values representing stronger effects. The error term (e) represents variation in the dependent variable not explained by the model; lower e values indicate greater explanatory power (Asaad et al., 2015; Wijayanto et al., 2026).

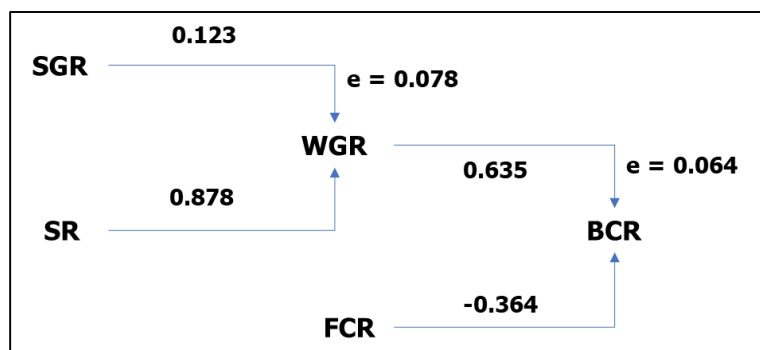


Figure 3. Relation between SR, SGR, WGR, FCR, and BCR in path analysis

BSN (2009) has set the optimal water quality parameters for red tilapia farming, including water temperature of 25-30°C, pH between 6.5 and 8.5, and a minimum DO of 5 ppm. Table 5 presents the results of the water quality parameter measurements in this study. The pH, temperature, and DO remained relatively stable across all treatments (A, B, and C). The pH ranged from 7.83 to 7.97 within the neutral range that supports organism life. Water temperature ranged from 25.80 to 25.97°C, indicating optimal and uniform environmental conditions. The water also contained sufficient oxygen that support optimal metabolic activity, as shown by the DO level within 5.97-6.10 ppm. The environment was kept stable, as shown by insignificant variation between replicates. The well-maintained water quality ensured that differences in growth results were driven mainly by treatment rather than environmental factors.

Table 5

Water quality

Treatment		Parameters		
		pH	Temperature (°C)	DO (ppm)
A	A1	7.97±0.06	25.97±0.55	5.97±0.15
	A2	7.93±0.06	25.87±1.07	6.07±0.21
	A3	7.93±0.12	25.80±0.92	6.07±0.15
B	B1	7.97±0.06	25.80±0.82	6.07±0.25
	B2	7.90±0.10	25.87±0.78	6.07±0.12
	B3	7.90±0.11	25.90±0.75	6.10±0.26
C	C1	7.90±0.17	25.90±0.75	6.03±0.25
	C2	7.87±0.15	25.90±0.66	6.00±0.26
	C3	7.83±0.21	25.10±0.75	6.03±0.15

Discussion. The growth of red tilapia is affected by internal factors (genetics, physiology, and age) and external factors (feed quality, environment, and rearing management) (Nazarudin et al., 2025; Rodriguez-Hernandez et al., 2025; Sallam et al., 2025; Siddique et al., 2025). Performance parameters such as WGR, SGR, SR, FCR, and BCR can be used in assessing the productivity of fish farming.

Prior studies showed that phytogetic additives could be used to improve growth, survival, feed efficiency, and immune response of some fish species (Younes et al., 2021; Wijayanto et al., 2024; Gruber et al., 2025; Al-Sagheer et al., 2026). This study used shallot that contained phytogetic materials as a relatively safe and sustainable natural feed additive to enhance the performance and profitability of red tilapia farming.

Fish farming success is significantly affected by growth, survival, feed efficiency, and profitability. Growth and survival significantly affect production, while production and selling price determine the revenue and profit obtained from the business. Meanwhile, feed cost is the largest component of the total cost in intensive fish farming (Wijayanto et al., 2022, 2024, 2026). Hence, efficient feed use in fish farming greatly affects the business profitability. Shekarabi et al. (2022) found that shallot supplementation in feed significantly increased the final weight, weight gain, and SGR in rainbow trout. Feed selection and management also determine feed efficiency and profitability in intensive farming of several species, including grouper farming, where feed costs can account for around 85% of total variable costs (Dennis, 2021).

Many practitioners have used feed additives to improve the growth of the fish and the profitability of the business. Plants within the Alliaceae family are known to contain antioxidant, anti-inflammatory, antibacterial, antifungal, and antiparasitic properties, which can support the digestion and the health of many fish species (Talpur & Ikhwanuddin, 2012; Asimi et al., 2013; Shang et al., 2019; Chowdhury et al., 2021; Wijayanto et al., 2024). Shallot contains allicin (diallyl thiosulfinate) that acts as a strong antibacterial and antipathogenic agent. Shallot supplementation can increase the activity of digestive enzymes such as amylase, lipase, and protease in the fish's gut. *Allium* sp. is also rich in bioactive compounds such as phenolics, flavonoids, polyphenols, terpenoids, lectins, and alkaloids, as well as various minerals, vitamins, and fatty acids. The inulin content in *Allium* sp. has likewise been shown to increase SGR and lower FCR (Ali et al., 2016; Gabriel, 2019; Aisara et al., 2021; Shekarabi et al., 2022).

Although shallot offers various benefits in fish feed, its effectiveness is determined by the optimal dosing. At the optimal dose, bioactive compounds work synergistically to improve metabolism, digestive efficiency, and the fish's immune system. On the contrary, excessive dosing might bring adverse effects, since organosulfur compounds may be irritating or even toxic to fish tissue. High doses can also reduce feed palatability from the strong odor and taste, leading to decreased feed intake, slower growth, and lower feed efficiency. The optimal dose of shallot is species-specific since each species has different digestive physiology, nutritional needs, fish size and age, and rearing conditions. In Nile tilapia, dietary onion supplementation has been reported to improve growth, antioxidant status, anti-inflammatory responses, and disease resistance, indicating that the response to onion-derived additives is related to both dose and biological condition of the fish (Younes et al., 2021). Similarly, the positive effects of red onion peel polyphenol-rich extract on growth, feed utilization, antioxidant status, and immune responses were observed in Nile tilapia cultured under high stocking density (Al-Sagheer et al., 2026). Meanwhile, the effectiveness of red onion supplementation in Asian seabass was associated with dose-dependent changes in growth, survival, FCR, and profitability (Wijayanto et al., 2022). Feed additives can be formulated as powders, liquid extracts, ferments, or encapsulated preparations, each with distinct advantages and limitations. At the industrial scale, their application is constrained by variability in active compounds, limited stability, high production costs, and strong odors.

BCR reflects the economic feasibility of fish farming, calculated from the ratio of total revenue to total production costs. BCR value greater than 1 indicates a profitable business. BCR is formed by several interrelated factors on both the revenue and cost sides. Fish selling price is the main determinant of revenue, where a price increase directly raises BCR. Feed cost, as the largest component of variable costs, is also a major determinant of business efficiency. FCR is a key indicator of feed efficiency, with lower values indicating more efficient feed utilization and higher BCR. Productivity is influenced by growth, SR, and farm management, while high mortality reduces production and BCR. Other factors affecting production efficiency include input costs, such as seed, labor, energy, and medication, as well as farm scale and production systems (Yassien et al., 2022; Wijayanto

et al., 2022; Acharjee et al., 2023; Syliver et al., 2025). In this study, SGR and SR influenced WGR, while WGR and FCR influenced BCR.

Conclusions. The results of this study showed that the zero-dose treatments, particularly the control, produced the best overall performance, whereas the highest dose (5%) resulted in the poorest performance. The highest BCR (1.55) was recorded in the control group, although treatments B and C are also considered profitable. Statistical analysis indicated that shallot supplementation significantly affected SR, WGR, SGR, FCR, and BCR. Polynomial regression revealed a nonlinear relationship between dose and performance, with the estimated optimum dose ranging from 0.131 to 0.694%. Within this range, shallot supplementation may improve growth and economic efficiency, indicating its potential as a feed additive when appropriately dosed.

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Authors Contributions. DW designed the study, conducted the data analysis, and prepared the manuscript; RAN and DJK contributed to the preparation and writing of the manuscript.

Conflict 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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