The effects of turmeric-enriched feed (*Curcuma longa* Linn.) on the growth, survival rate and profitability of Asian seabass cultivation in freshwater media

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Abstract. Improving the resistance of Asian seabass (*Lates calcarifer*) in aquaculture has an important role in optimizing the production and profits. Turmeric (*Curcuma longa*) is a potential local herbal nutraceutical that has immunostimulant properties. This study was performed to examine the effects of turmeric added in fish feed on the growth, survival rate and profitability of Asian seabass cultivated in freshwater media. A 30-day experimental was performed to Asian seabass of an average size of 5.20 g (±0.09 g) per fish that had been adapted to freshwater media. Fish were reared using fibre tubs with a water volume of 0.5 m^3 and 34 fish per each tube to be given treatments in two replications. Different turmeric concentrations of 5% (treatment A), 3% (treatment B), 1.5% (treatment C), 0.5% (treatment D) and 0% (treatment E as control) were administered. Water quality parameters consisting of dissolved oxygen (DO), salinity, temperature and pH were measured weekly. The results showed that turmeric treatment on Asian seabass feed had a significant effect on absolute biomass growth (W), feed conversion ratio (FCR) and benefit cost ratio (BCR), where treatment C showed the most optimal performance. The modelling results proposed the optimal concentration of turmeric ranged between 0.93 and 1.29%

Key Words: BCR, *Curcuma longa*, FCR, *Lates calcarifer*, SR, SGR.

Introduction. Aquacultural engineering to improve the fish resistance in fish farming has a significant contribution since fish survival affects fish mortality and growth rates, which in turn will affect the production and profitability of fish farming, including Asian seabass (*Lates calcarifer*) cultivation (Hidayati et al 2021; Wijayanto et al 2022a, b, c). Fish growth and fish survival rate (SR) can affect feed efficiency, where feed cost has the largest proportion in intensive aquaculture expense. Therefore, feed efficiency is closely related to profitability in aquaculture (Cheong 1989; Wijayanto et al 2022b). Asian seabass is one of the leading commodities in fish farming in Asia, including Indonesia. At the present, Asian seabass has been intensively cultivated in brackish water and sea water, while the cultivation of Asian seabass in fresh water media has not yet developed in Indonesia. Several studies have shown that Asian seabass can be cultivated in fresh water (Rajkumar et al 2006; Ghosh 2019; Wijayanto et al 2020a; Wijayanto et al 2022a, b, c).

The Food and Drug Administration (FDA) has banned the use of antibiotics as feed supplements since 2017 which then followed by higher interest in conducting research on feed supplementation using herbal ingredients. Herbal nutraceutical ingredients are known to improve feed digestion and increase the fish's resistance to stressors from both biotic and abiotic environmental disturbances (Chowdhury et al 2021; Paray et al 2021; Park et al 2021; Shekarabi et al 2022). Herbal extracts in fish farming can be administered through oral, injection and immersion, yet oral administration remains the most efficient method with minimum stress exposure (Gabriel 2019). The use of additives as immunostimulants in fish feed can increase the fish's immune system. In Indonesia, various local herbal ingredients can be used as immunostimulant ingredients, including turmeric (*Curcuma longa*). Turmeric is known to positively affect the fish health, including in species *Clarias batrachus* (Riauwaty & Windarti 2021), *Sparus aurata* (Ashry et al 2021), *Cyprinus carpio* (Pirani et al 2021), *Pangasionodon hypophthalmus* (Syawal et al 2021), and *Clarias gariepinus* (Anene et al 2022). Turmeric is a local biopharmaceutical product in Indonesia with total production that reaching 203,457,526 kg in 2018, where East Java Province contributed by 57% in the total turmeric production in Indonesia (BPS-Statistics Indonesia 2019). Therefore, turmeric is a potential ingredient to be developed as an immunostimulant for fish farming in Indonesia. In this study, the effects of turmeric on fish feed on the growth, survival rate and profitability of Asian seabass or barramundi cultured in freshwater media were examined.

Material and Method

Research setting. This laboratory-scale experimental research was conducted in the laboratory of the Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Semarang (Indonesia) within 30 days from February to March 2022.

Research material. The test fish in this study were Asian seabass of an average size of 5.20 g (±0.09 g) per fish that had been adapted to fresh water media. Fish were reared using fibre tubs with a water volume of 0.5 m^3 and 34 fish per each tube. There were 10 units of fibre tub used in five treatments and two replications. Feeding was carried out using 4% of fish biomass commercial feed per day containing a minimum of 52% crude protein. The feed was enriched with different turmeric concentrations of 5% (treatment A), 3% (treatment B), 1.5% (treatment C), 0.5% (treatment D) and 0% (treatment E as control). Turmeric was grated and soaked in water to be added in commercial feed. Then, the test feed was aerated to dry. The experiment was carried out in a completely randomized design, where each tank did not relate to the other.

Measurement of water quality. Water was recirculated using filters (charcoal, coral, sand, and synthetic fibres) to maintain the water quality. The water was changed every 10 days, by replacing 30% of the water. Water quality measurements were conducted weekly to observe water quality parameters consisting of dissolved oxygen (DO), salinity, temperature, and pH using Horiba U-50 (water quality multiparameter).

Data analysis. Fish weight was measured every 10 days. Several formulae used in this study were adapted from Ali et al (2016), Venkatachalam et al (2018), Chowdhury et al (2021), Hassan et al (2021), Wijayanto et al (2022a, b, c), and Shekarabi et al (2022) as follows:

$$W = Wt - Wo \quad [1]$$

$$SGR = (Ln\ Wt - Ln\ Wo) / t \quad [2]$$

$$FCR = F / W \quad [3]$$

$$BCR = B / C \quad [4]$$

$$SR = Nt / No \quad [5]$$

where: W is the fish absolute growth (g); Wt is fish biomass (g) on day t; Wo is fish biomass in g at first day; SGR is the specific growth rate of fish biomass (% day^{-1}); FCR is the feed conversion ratio; F is the accumulation of feed in g that has been given to the test fish; BCR is benefit cost ratio; B is additional income due to fish growth (IDR); C is the cost of feed (IDR) (the Asian seabass cultivation is considered profitable if the BC ratio is greater than 1.0); SR is survival rate (%); Nt is the number of fish at the end of the period; No is the number of fish at the initial period.

Statistical analysis using Anova test was performed and followed with Duncan's test. The treatment optimization modelling was developed based on the first derivation procedure of the SR, SGR, FCR and BCR equations for T (treatment) equal to zero (Wijayanto et al 2022b, c).

Results. The results showed that turmeric supplementation in feed could increase fish growth, reduce the feed cost (lower FCR) and increase the profitability (BCR) as presented in Table 1. Statistically, the treatment had a significant effect on W, FCR and BCR, where treatment B generated the most optimal W, FCR and BCR (Table 2). As for SR and SGR, the treatment did not produce a significant difference. Duncan test results showed treatments C and D were not significantly different on either W, FCR or BCR.

Table 1

SR, W, SGR, FCR and BCR during the experiment

Variables	*A (5%)*		*B (3%)*		*C (1.5%)*		*D (0.5%)*		*E (0%)*	
	A_1	A_2	B_1	B_2	C_1	C_2	D_2	D_2	E_1	E_2
SR (%)	91.2	94.1	91.2	97.1	100.0	97,1	100,0	100,0	91,2	94,1
Average of SR (%)	92.6		94.1		98.5		100.0		92.6	
W (g)	223.37	222.77	207.26	210.49	227.33	236.24	225.07	228.99	230.43	216.20
Average of W (g)	223.07		208.88		232.33		227.03		223.31	
SGR (% day^{-1})	2.64	2.62	2.47	2.58	2.69	2.76	2.68	2.70	2.69	2.54
Average of SGR (% day^{-1})	2.63		2.52		2.73		2.69		2.61	
FCR	1.36	1.40	1.41	1.40	1.28	1.26	1.28	1.30	1.40	1.44
Average of FCR	1.35		1.40		1.27		1.29		1.42	
BCR	4.12	4.17	3.97	4.00	4.38	4.45	4.37	4.32	4.00	3.89
Average of BCR	4.15		3.99		4.41		4.34		3.94	

Table 2

Statistical analysis

Variables	*F value*	*Sig value*	*Duncan test*
SR	3.962	0.082	$D^a > C^{a,b} > B^{a,b} > A^b = E^b$
W	6.371	0.034*	$C^a > D^a > E^a > A^a > E^b$
SGR	2.834	0.142	$C^a > D^a > A^a > E^{a,b} > B^b$
FCR	33.122	0.001**	$E^a > B^a > A^b > D^c > C^c$
BCR	36.043	0.001**	$C^a > D^a > A^b > B^c > E^a$

Note: sign * shows the treatment has a significant effect with α = 5%; sign ** shows the treatment has a significant effect with α = 1%; a, and b show the subset group.

The modelling results (Figure 1 and Table 3) show that the optimal concentration of turmeric ranges between 0.93 and 1.29%. This result can be used as a reference in the aquaculture engineering of Asian seabass feed added with turmeric to increase body resistance that subsequently affects the growth, FCR and profitability. This study also confirmed that excessive amount of turmeric can actually reduce fish growth, lead to inefficient feeding and reduce the profits.

The water quality monitoring results are shown in Table 4. Seen from the pH, DO, and temperature, the quality of the water was regarded ideal for Asian seabass cultivation (Cheong 1989; WWF Indonesia 2015; Yudhiyanto et al 2017). Meanwhile, the salinity was made uniform at 0 ppt which proved that Asian seabass could be reared in fresh water media, even though the fingerlings were gained from hatcheries that used seawater (Rajkumar et al 2006; Ghosh 2019; Wijayanto et al 2020a; Wijayanto et al 2022a, b, c).

Table 3

Optimal treatment estimation

Variables	*Optimal treatment (% turmeric)*
SR	0.93
SGR	1.29
FCR	1.06
BCR	1.07

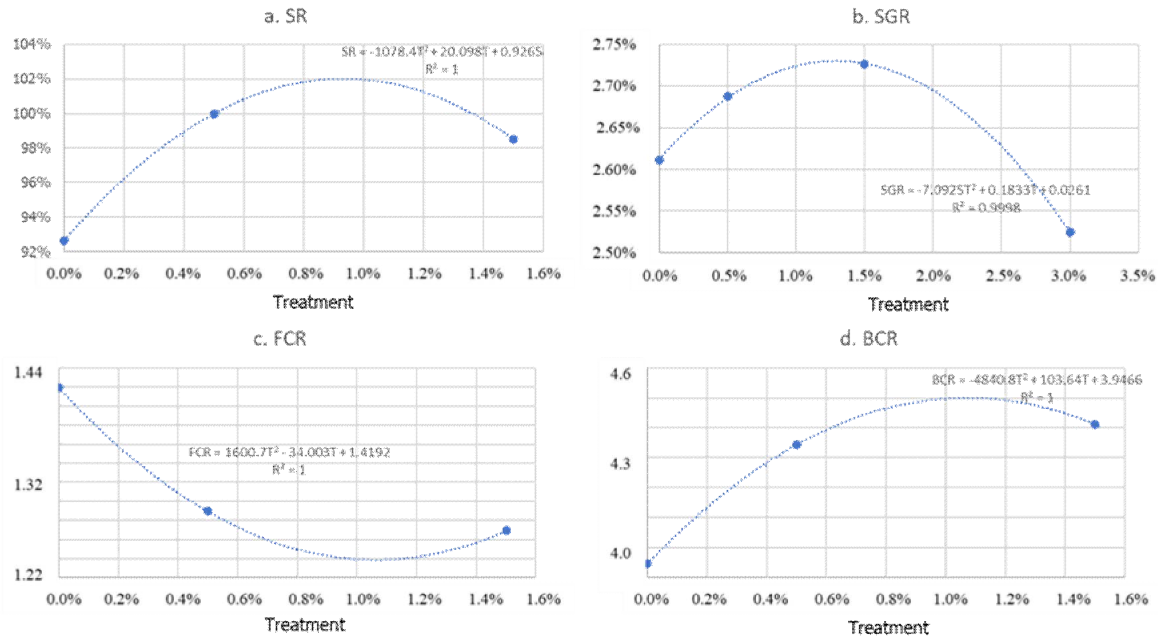

Figure 1. The relationship between SR, SGR, FCR, BCR and different treatments.

Table 4

The results of water quality measurement

Parameters	*A (5%)*		*B (3%)*		*C (1.5%)*		*D (0.5%)*		*E (0%)*	
	A_1	*A_2*	*B_1*	*C_1*	*C_1*	*C_2*	*D_2*	*D_2*	*E_1*	*E_2*
In the morning										
pH	7.84± 0.11	7.71± 0.07	7.63± 0.12	7.68± 0.08	7.61± 0.06	7.58± 0.09	7.55± 0.09	7.56± 0.10	7.56± 0.10	7.43± 0.13
Temperature (^{o}C)	24.50± 0.37	24.28± 0.43	24.26± 0.40	24.32± 0.40	24.34± 0.34	24.38± 0.41	24.38± 0.41	24.40± 0.41	24.56± 0.61	24.48± 0.44
DO (ppm)	5.62± 0.16	5.66± 0.24	5.48± 0.22	5.54± 0.21	5.48± 0.25	5.54± 0.19	5.56± 0.13	5.54± 0.09	5.56± 0.18	5.30± 0.16
Salinity (ppt)	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0
In the afternoon										
pH	7.62± 0.12	7.53± 0.06	7.45± 0.08	7.52± 0.06	7.45± 0.03	7.46± 0.11	7.39± 0.07	7.41± 0.05	7.26± 0.10	7.27± 0.10
Temperature (^{o}C)	25.34± 0.47	24.96± 0.52	24.82± 0.53	24.82± 0.55	24.84± 0.55	24.88± 0.58	24.90± 0.57	24.86± 0.57	24.88± 0.56	24.90± 0.58
DO (ppm)	5.62± 0.39	5.66± 0.34	5.48± 0.30	5.54± 0.18	5.48± 0.26	5.54± 0.18	5.60± 0.26	5.54± 0.29	5.56± 0.12	5.30± 0.20
Salinity (ppt)	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0	0.00± 0.0

Discussion. The research results showed that turmeric supplementation in feed could increase fish growth, streamline FCR and increase profitability (BCR). However, excessive turmeric concentration can harm the fish. Turmeric contains curcumin which according to Ashry et al (2021) can increase fish growth rate and fish resistance. Curcumin can also increase feed efficiency. Curcumin made from turmeric extract contains polyphenols that are natural compounds derived from plants which have antioxidant properties. Curcumin can also act as antibacterial, immunostimulant and anti-inflammation agents for humans, animals and fish (Pirani et al 2021).

According to Pirani et al (2021), 5% turmeric supplementation in feed could increase the growth of *C. carpio* and it also affected the fatty acid composition of *C. carpio*, where the fat content of the fish significantly decreased. Meanwhile, Ashry et al (2021) suggested the optimal level of curcumin of 2-3% in feed for *S. aurata* fish. In addition, Anene et al (2022) proved that the optimal use of turmeric flour in feed for *C.*

gariepinus was 1%. Whilst, in this study, the most optimal concentration of turmeric for Asian seabass was found ranging from 0.93 to 1.29%. These different findings indicate that the optimal response on the growth and survival rate from turmeric supplementation in feed can differ based on the fish species.

A study done by Riauwaty & Windarti (2021) proved that turmeric supplementation could reduce gill damage in *C. batrachus* infected with *Aeromonas hydrophila* bacteria, showing that turmeric could act as an anti-bacterial. *A. hydrophila* infection increases the production of toxins (aerolysin) which can damage fish body tissues. *A. hydrophila* bacteria produce aero and hyla genes which in turn produce aerolysis and hemolysin toxins, while turmeric improves the digestion and nutrient metabolism. Meanwhile, Syawal et al (2021) found that turmeric was able to improve the hematological and physiological profile of *P. hypophthalmus* fish, including the total erythrocytes, hematocrit, hemoglobin, total leukocytes, blood glucose, and total serum protein. The addition of turmeric to *P. hypophthalmus* can also increase the growth rate, feed efficiency, and survival rate of *P. hypophthalmus*.

The water quality of the fish rearing media should be taken into consideration as it affects the survival rate and the growth of Asian seabass (WWF Indonesia 2015; Yudhiyanto et al 2017; Venkatachalam et al 2018). Water pollution from anthropogenic activities can harm the fish. Furthermore, water contamination from feed residues and fish faeces can lower the fish resistance (Ghazala et al 2014; Hamed et al 2021). In this study, the water quality during the experiment was relatively supportive for the Asian seabass cultivation, both for DO (> 4 ppm), temperature (26-32^{o}C) and pH (7.0-8.5) (WWF Indonesia 2015; Yudhiyanto et al 2017).

The results of this study indicate that turmeric has the potential to be developed as an herbal immunostimulant ingredient in fish feed. Herbal nutraceutical-based feed administration (including turmeric) tends to be increasingly acknowledged in fish farming businesses, where oral administration is considered the most efficient and effective method (Gabriel 2019). Herbal nutraceutical ingredients can increase fish body resistance, preventing them from easily getting stressed out from environmental disturbances (Chowdhury et al 2021; Paray et al 2021; Shekarabi et al 2022). Good resistance supports the fish growth, metabolism and survival rate which in turn affects the production and profits of fish farming (Cheong 1989; Hidayati et al 2021; Wijayanto et al 2022a, b, c). According to Wijayanto et al (2022b), FCR and profitability share strong correlation. The cost of feed in intensive fish farming is relatively large, reaching up to 40% of the total cost in the cultivation of Asian seabass (Cheong 1989). Efficient use of feed can increase productivity and profits (Wijayanto et al 2022a, b).

Conclusions. Turmeric supplementation significantly affected the W, FCR and BCR. Treatment C demonstrated the most optimal effect on fish growth (W and SGR), feed conversion (FCR) and profit (BCR). Meanwhile, treatment D had the highest contribution on SR. The model proposed in this study suggested the most optimal concentration of turmeric of between 0.93 and 1.29%.

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Conflict of interest. The authors declare that there is no conflict of interest.

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