The optimization of growth, survival rate, feed efficiency and benefit cost ratio of Asian seabass reared in freshwater media with fish feed enrichment using Javanese turmeric (*Curcuma xanthorrhiza*)

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Abstract. The objective of this research is to investigate the use of Javanese turmeric (*Curcuma xanthorrhiza*) as a supplement in feed for Asian seabass (*Lates calcarifer*) farming to optimize the growth, survival, feed efficiency, and profitability. This research was conducted in 40 days, using Asian seabass seeds with an average size of 12.04 grams per fish. Four different treatments with two replications were conducted. Each group was given different dose of Javanese turmeric in the feed (5% for treatment A, 3% for treatment B, 1.5% for treatment C, and 0.5% for treatment D). Water quality parameters were evaluated every week, including dissolved oxygen (DO), salinity, temperature, and pH. The results indicated that treatment A (5% Javanese turmeric) gained the most optimal specific growth rate (SGR), feed conversion ratio (FCR) and benefit cost ratio (BCR) variables, whereas treatment B (3% Javanese turmeric) showed the best survival rate (SR). Furthermore, optimization modelling indicated the most optimal doses of Javanese turmeric in Asian seabass feed are 3.4% for SR, 4% dose for FCR, 7.4% dose for SGR, and 9.6% dose for BCR.
Key Words: BCR, *Curcuma xanthorrhiza*, FCR, *Lates calcarifer*, SGR, SR.

Introduction. Asian seabass (*Lates calcarifer*) is a leading fishery commodity in Indonesia, with production coming from both capture fisheries and fish farming (Wijayanto et al 2020; KKP 2022). The high demand and high prices for Asian seabass make it a popular target for fishermen, who typically catch it using line and gill nets (Carpenter & Niem 1999). Statistics Indonesia recorded the total production of captured Asian seabass of 21,534 quintals in 2021 (BPS-Statistics Indonesia 2022a). On the other side, overfishing is a global concern, therefore, the development of Asian seabass aquaculture is necessary (Hajirezaee et al 2015; FAO 2020; Shah et al 2020; Wijayanto et al 2020; Marnn et al 2021). In 2020, Asian seabass farming production in Indonesia reached 5,418 tons, which amount decreased from 2018 of 9,583 tonnes (KKP 2022) which could be impacted by the Covid-19 pandemic. Asian seabass culture is common in the Asia Pacific region (Daet 2019; Ghosh 2019; Wijayanto et al 2020; SEAFDEC 2022; Wijayanto et al 2022a, b). Indonesia is one of leading exporters of Asian seabass in the World. According to the Food and Agriculture Organization (FAO), the global production of Asian seabass aquaculture has increased from 18.1 thousand tons in 2000 to 105.8 thousand tons in 2020 (FAO 2022).

The natural habitat of Asian seabass is in marine waters and some are found in rivers (Carpenter & Niem 1999). Fish farming of Asian seabass in Indonesia is typically conducted in brackish water ponds and sea water cages (KKP 2022). Current research have shown that Asian seabass can also be reared in low salinity environments and fresh water (Wijayanto et al 2020, 2022a, 2022b). Therefore, it is opportunity for fish farmers living away from the coast to rear Asian seabass. The growth, feed efficiency, and survival are key factors for the success of fish farming. Growth and survival affect the amount of production, while feed efficiency can reduce production costs, as the cost of procuring feed is the largest operational cost component in intensive aquaculture. Fish resilience can be improved by providing optimal feed and good water quality management (Hidayati et al 2021; Wijayanto et al 2022a, b).

The use of herbal nutraceutical ingredients in fish feed to improve fish health is gaining attention as the use of antibiotics in fish feed has been discouraged by the United States-Food and Drug Administration (US-FDA) since 2017 (US-FDA 2018). Herbal ingredients have been proven to improve feed digestion and increase fish resistance to stressors from both biotic and abiotic environmental factors (Paray et al 2021; Park et al 2021; Varghese et al 2021; Wijayanto et al 2022a, b). In Indonesia, there are several nutraceutical herbal ingredients with potential for use in fish feed enrichment, including Javanese turmeric (*Curcuma xanthorrhiza*), also known as 'temulawak'. Javanese turmeric production in Indonesia reached 32.28 thousand tonnes in 2021 (BPS-Statistics Indonesia 2022b) and contains compounds such as xanthorrhizol, which has been found to have antimicrobial, anticancer, anti-inflammatory, and antioxidant properties (Nurcholis et al 2018; Rahmat et al 2021; Setiawan et al 2022). Additionally, Javanese turmeric has been traditionally used as a herbal medicine in Indonesia and contains compounds such as xanthorrhizol, ɑ-curcumene, tetracycline, IPMP (isopropyl methylphenol), catechin and ascorbic acid (Batubara et al 2015). This research analyzed the effect of Javanese turmeric added to fish feed on the growth, survival, feed efficiency, and profitability of Asian seabass cultured in fresh water.

Material and Method

Location and time of research. This experimental research was conducted in a laboratory scale. The research was conducted for 40 days from April to May 2022 at the laboratory of the Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Semarang (Indonesia).

Research materials. Asian seabass seeds with an average size of 12.04 g (±0.08 g) per fish were first adapted to fresh water media in fiber tubs containing 0.5 m^3 water with 33 fish in each tub. Four treatments were performed with 2 replications each. Commercial feed specific for Asian seabass containing minimum crude protein of 52% and 4% of fish biomass per day was used in feeding. The feed was added with different doses of Javanese turmeric; namely 5% (treatment A), 3% (treatment B), 1.5% (treatment C), and 0.5% (treatment D). Javanese turmeric was grated, added with water and soaked in commercial feed before being aerated to dry. This research used a completely randomized design.

Water quality monitoring. The water quality was maintained using water recirculation (filters consisting of charcoal, coral, sand and synthetic fibers). The media water was changed every 10 days by changing 30% of the water. Parameters of water quality were tested every week, including water salinity, dissolved oxygen (DO), pH and water temperature using a multi-parameter water quality checker (Horiba U-50).

Data analysis. Fish weighing was conducted every 10 days. The parameters being measured were specific growth rate (SGR), feed conversion ratio (FCR), survival rate (SR), and benefit cost ratio (BCR). ANOVA statistical test was conducted and followed by Duncan's test if significant differences from effect of the treatment were identified. Some formulae were used in this research (Daet 2019; Hassan et al 2021; Wijayanto et al 2022a, b):

$$SGR = (Ln\ Wt - Ln\ Wo) / t \quad [1]$$

$$FCR = F / W \quad [2]$$

$$BCR = B / C \quad [3]$$

$$SR = (Nt/No) \times 100\% \quad [4]$$

where: SGR is the specific growth rate of fish in % day^{-1}; Ln is the logarithm of a natural; Wt is the fish biomass in g at t days; Wo is the initial fish biomass in g; FCR is feed conversion ratio for feed efficiency indicator; F is the total feed in g; BCR is the benefit cost ratio; B is the increase in income due to fish growth (IDR); C is the feed cost (IDR) (Asian seabass cultivation is regarded profitable if BC ratio is greater than 1.0); SR is the survival rate of fish in %; Nt is the number of fish at the end of the period; while No is the number of fish at the beginning of research.

Treatment optimization modeling was carried out using the procedure for deriving the SR, SGR, FCR and BCR equations for T (treatment) equal to zero.

Results. The results of the research are presented in Table 1, while the results of the statistical analysis can be seen in Table 2. Treatment A (5%) gave the best results for the SGR, FCR and BCR variables, while treatment B (3%) showed the best results for the SR variable. Since the statistical analysis indicated no significant differences between treatments at the 95% level of confidence, Duncan's test was not carried out.

Table 1

SR, SGR, FCR and BCR in this study

Variables	*A (5%)*		*B (3%)*		*C (1.5%)*		*D (0.5%)*	
	A_1	A_2	B_1	B_2	C_1	C_2	D_1	D_2
SR (%)	93.9	90.9	90.9	97.0	93.9	90.9	87.9	81.8
SGR (% day^{-1})	1.81	2.40	2.15	1.92	1.72	2.13	2.36	1.38
FCR	2.09	1.41	1.63	1.91	2.20	1.68	1.45	3,03
BCR	2.68	3.97	3.43	2.93	2.54	3.34	3.87	1.85

Table 2

Statistical analysis

Variables	*Average values*				*F values*	*Sig values*	*Notes (level of confidence, α = 5%)*
	A (5%)	*B (3%)*	*C (1.5%)*	*D (0.5%)*			
SR (%)	92.42	93.9	92.4	84.8	2.909	0.082	Not significant
SGR (%)	2.11	2.04	1.92	1.87	0.118	0.945	Not significant
FCR	1.75	1.77	1.94	2.24	0.248	0.859	Not significant
BCR	3.33	3.18	2.94	2.86	0.111	0.949	Not significant

The results of treatment optimization modelling for feed enrichment with Javanese turmeric on Asian seabass are presented in Figure 1 and Table 3. The results suggest that the appropriate dosage of Javanese turmeric in feed can increase the survival rate (SR) of Asian seabass, with a 3.4% dose achieving a SR of 95.1%. Additionally, the highest daily growth rate of 2.1% per day was achieved at a dose of 7.4%. FCR was found to be the best at a 4% dose with a value of 1.72, indicating that for every gram of weight gained, 1.72 grams of feed are required. The BCR was found to be the best at a 9.6% dose with a value of 3.5, indicating that for every IDR 1 spent on feed, IDR 3.5 in income is generated. As feed is the largest operational cost in intensive Asian seabass farming, the results of this research suggest that the use of Javanese turmeric in feed may increase the profitability of the fish farming. Table 4 shows the results of monitoring water quality throughout the research.

Table 3

Optimal treatment doses estimation for Asian seabass cultivation

Variables	*Optimal treatment (% Javanese turmeric)*	*Optimal value estimation*
SR	3.4%	95.1%
SGR	7.4%	2.1%
FCR	4.%	1.71
BCR	9.6%	3.50

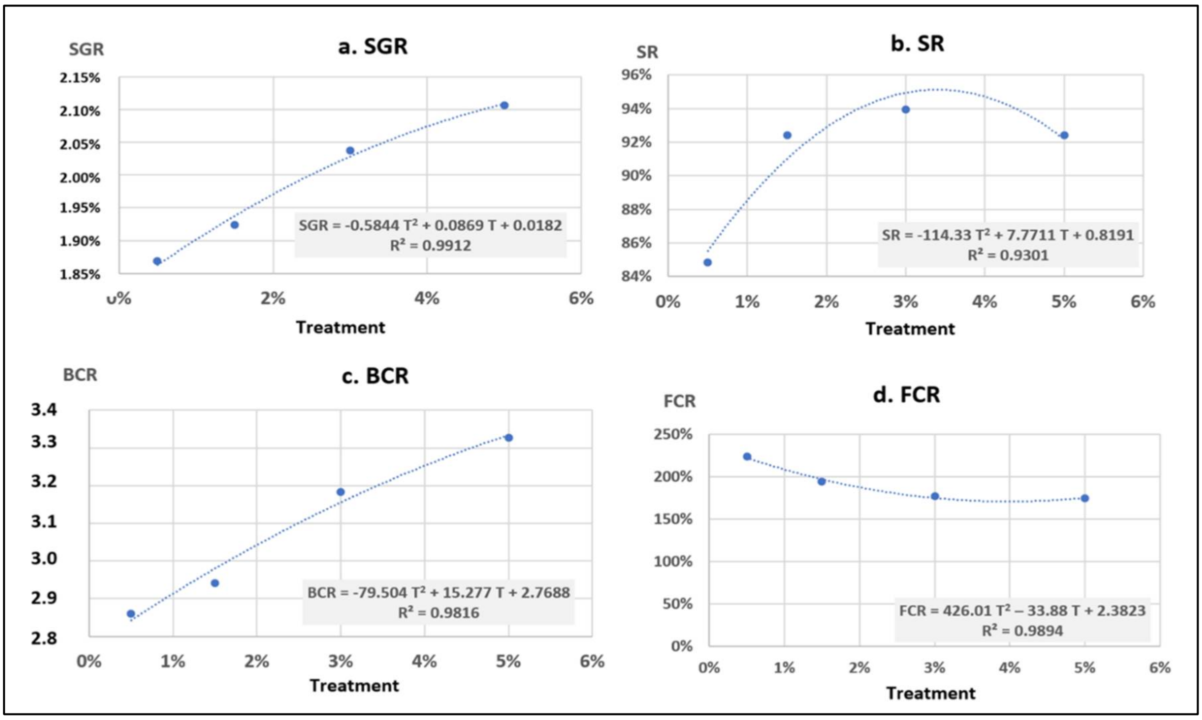

Figure 1. SGR, SR, BCR and FCR model in this study.

Table 4

Water quality during experiment

Variables	*A (5%)*		*B (3%)*		*C (1.5%)*		*D (0.5%)*	
	A_1	A_2	B_1	B_2	C_1	C_2	D_1	D_2
Morning								
pH	8.36± 0.44	8.15± 0.52	8.01± 0.45	7.90± 0.38	7.91± 0.34	7.78± 0.30	7.80± 0.28	7.77± 0.32
Temperature (^{O}C)	24.40± 0.70	24.30± 0.63	24.24± 0.63	24.22± 0.67	24.20± 0.62	24.34± 0.63	24.26± 0.66	24.30± 0.70
DO (ppm)	5.62± 0.38	5.30± 0.21	5.38± 0,18	5.20± 0.12	5.24± 0.26	5.18± 0.18	5.22± 0.23	5.22± 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
Evening								
pH	7.99± 0.32	7.67± 0.24	7.64± 0.37	7.57± 0.31	7.61± 0.23	7.54± 0.28	7.56± 0.29	7.53± 0.28
Temperature (^{O}C)	25.28± 0.13	24.84± 0.31	24.76± 0.26	24.70± 0.21	24.54± 0.17	24.64± 0.15	24.68± 0.19	24.68± 0.18
DO (ppm)	5.78± 0.48	5.28± 0.13	5.48± 0.13	5.32± 0.16	5.38± 0.33	5.30± 0.24	5.32± 0.28	5.32± 0.26
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

Discussion. Asian seabass can be found in a variety of habitats, including the coast, estuaries, and freshwater environments. Adult Asian seabass are typically found in estuary waters and mangroves, while juvenile fish may migrate up rivers before returning to estuaries to spawn. Asian seabass has the ability to change sex, transitioning from male to female at the age of 3-5 years. Their natural diet primarily consists of shrimp (Carpenter & Niem 1999; Hajirezaee et al 2015; Marnn et al 2021). In Indonesian fish farming practices, Asian seabass are typically fed either artificial feed or trash fish. Although trash fish is cheaper, it has a higher FCR than artificial feed (Ignatius 2009).

Javanese turmeric is a medicinal plant native to Indonesia which contains curcuminoid and xanthorrhizol compounds that promote the health of both for humans and fish. Javanese turmeric belongs to the species belonging to Zingiberaceae family which have been used as traditional medicine to cure kidney stones, hepatitis, treat microbial infections, and lower cholesterol levels. Javanese turmeric is also used in treating arthritis, bloody diarrhea, constipation, child fever, dysentery, gastric disorders, hypotriglyceridemia, hemorrhoids, liver disease, rheumatism, skin eruptions and vaginal discharge. Javanese turmeric (including curcuminoids and xanthorrhizol) have anti-bacterial, anti-cancer, anti-fungal, anti-inflammatory, anti-lipidemic, and anti-oxidant properties (Batubara et al 2015; Nurcholis et al 2018; Darmawan & Pramono 2017; Atun et al 2020; Rahmat et al 2021; Setiawan et al 2022). Ashry et al (2021) found that curcumin could increase fish growth rate, fish resistance and feed efficiency.

According to Darmawan & Pramono (2017), *C. xanthorrhiza* essential oil lowers LDL-C (low density lipoprotein-cholesterol) and can inhibit weight gain. Therefore, excessive dose of Javanese turmeric can actually inhibit the increase in biomass growth of Asian seabass. The results of this research showed that the optimal doses of Javanese turmeric for Asian seabass that ranged between 3.4 and 9.6%. Fish growth (SGR), survival (SR), selling price of fish, feed efficiency (FCR), and production costs affect the net profit of Asian seabass fish farming.

Javanese turmeric at a dose of 7.4% can generate SGR of 2.1% per day. Meanwhile, the results of Daet's research (2019) show that the SGR of Asian seabass is between 1.51 and 1.65 where this fish is kept in pond. In this research, SR was at a minimum percentage of 81.8% (40 days). Meanwhile, research by Hajirezaee et al (2015) showed that the SR of Asian seabass cultivation was 66% (6 months of cultivation). Daet's research (2019) showed showed that the SR of Asian seabass during a 90-day cultivation was range of 47 to 87%. The SR of Asian seabass is influenced by seed quality, stocking density, feed and quality of the aquatic environment. Cannibalism is a factor that needs to be taken into serious account in Asian seabass farming. This research show that 4% Javanese turmeric added to the feed showed a FCR of 1.71. Meanwhile, Hajirezaee et al (2015) found FCR value of 2.5. Ignatius (2009) found the FCR of Asian seabass using pelleted feed of 1.5 to 2.1, while it reached to 4 to 9 using trash fish.

The water quality is one of factors that promote fish health, which in turn affects SR, feed efficiency and fish growth. The water quality of the water tubs was ensured to support the growth and survival of the test fish (WWF Indonesia 2015; Venkatachalam et al 2018; Wijayanto et al 2022a, b). Asian seabass can tolerate a wide range of water temperature from 15 to 40^{o}C, with optimal growth occurring at temperature between 22 and 35^{o}C. Poor water conditions can cause lower feed consumption, higher FCR and lower SR (Hassan et al 2021).

The results of this research indicate the potentials of Javanese turmeric as immunostimulant that can be added to Asian seabass fish feed. Nutraceutical herbal ingredients (including Javanese turmeric) can improve fish health and boost fish immune system. Herbal nutraceuticals are best consumed orally by adding them into the feed. Strong immunity allows fish to develop optimal growth, metabolism and survival rates which eventually affect the production and profits of fish farming business (Cheong 1989; Gabriel 2019; Hidayati et al 2021; Paray et al 2021; Wijayanto et al 2022a, b).

Conclusions. In this research, treatment A (5%) resulted in the most optimal SGR, FCR and BCR variables, while SR variable was found the best in treatment B (3%). Although statistical analysis did not show a significant difference between the treatments at the confidence level of 95%, the results of the optimization modelling showed that 3.4% of Javanese turmeric added in Asian seabass feed produced the highest SR, while 4% dose produced the most efficient FCR, 7.4% dose produced the highest SGR, and 9.6% dose produced the highest BCR.

Acknowledgement. Gratitude is expressed to the Faculty of Fisheries and Marine Science-Universitas Diponegoro for facilitating this study.

Conflict of interest. The author declares that there is no conflict of interest.

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Received: 29 January 2023. Accepted: 11 March 2023. Published online: 10 April 2023.
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How to cite this article:
Wijayanto D., 2023 The optimization of growth, survival rate, feed efficiency and benefit cost ratio of Asian seabass reared in freshwater media with fish feed enrichment using Javanese turmeric (*Curcuma xanthorrhiza*). AACL Bioflux 16(2):1000-1006.