Comparative effects of herbal supplementation in increasing growth and immunity of *Clarias gariepinus* (Burchell, 1822)

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Abstract. Fish farming is the main activity that provides food based on protein. In addition to fish having excellent nutrition for the body, fish farming can reduce fish catches from nature and at the same time maintain its population. However, in fish farming, it is sometimes constrained by water quality and diseases that can reduce quality and productivity in cultivation. To overcome this, herbs that are immunostimulants, attractants, and growth promoters can be given to increase immunity and growth. The study's results proved that fucoidan supplementation was effective in increasing North African catfish, *Clarias gariepinus* (Burchell, 1822) growth significantly compared to squid oil attractant supplementation for 60 days of maintenance. Meanwhile, the combination of herbal supplementation showed that ginger (*Zingiber officinale*) treatment 30% of the optimal dose (2.25 g) + turmeric (*Curcuma longa*) 70% (1.05 g) kg^{-1} feed, resulted in optimal *C. gariepinus* growth compared to other treatments. The combination of herbal feed Javanese turmeric (*Curcuma xanthorrhiza*) 20% of the optimal dose (10 g) + 80% garlic (*Allium sativum*) (24 g) produced an optimal hematocrit, while leukocrit at dose 40% *Z. officinale* (3.0 g) + 60% *C. longa* (0.9 g) was higher than other treatments in *C. gariepinus*. This shows that herbal supplementation from marine organisms (fucoidan) and land (garlic, turmeric, Javanese turmeric, garlic) can be used to improve the immunity and growth of farmed fish.
Keywords: growth, growth-promoter, immunomodulatory, north african catfish, phytopharmaca.

Introduction. In the aquaculture industry, antibiotic use is restricted due to risks to consumers, the environment, and resistance (Milijasevic et al., 2024). Hence, alternative disease control approaches are needed. Herbal applications are preferred over antibiotics or chemicals because they are safer, leave no residues, and do not pollute. Several herbal ingredients, both aquatic and terrestrial, are now used to boost immunity and growth in fisheries. Aquatic herbs that are already known, such as fucoidan, while terrestrial herbs come from spices such as ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), Javanese turmeric (*Curcuma xanthorrhiza*), and garlic (*Allium sativum*). In addition to herbal growth promoters, attractants such as squid oil can also be used to stimulate growth.

Fucoidan is a bioactive compound derived from brown seaweed. Numerous studies have demonstrated its diverse biological activities, particularly its immunomodulatory, anti-inflammatory, and gastroprotective effects. These promising properties have positioned fucoidan as a compelling subject for ongoing scientific investigation. In recent years, its application has expanded significantly, leading to its development as a key ingredient in cosmetics, dietary supplements for health, and functional additives in animal feed, including in fish (Fitton et al., 2015). Currently, the application of fucoidan to livestock and terrestrial animals has been widely carried out, while for aquatic cultivation, it is still limited. Initial research shows that fucoidan can increase immunity and has antioxidant properties in yellow catfish (*Tachysurus fulvidraco*) (Yang et al., 2014).

In the digestive system, microorganisms that inhabit the intestines have an important role in digesting food, balancing intestinal flora and fauna, and regulating the immune system (Nayak, 2010). Epithelial cells and goblet cells along the intestinal mucosa of the digestive tract function as physical and chemical barriers, including mucus produced by goblet cells and leukocytes in the tissue as a defense against pathogens (Birchenough et al., 2015). Recent research results prove that dietary fucoidan can modulate intestinal microbes and have a protective effect against mucosal and epidermal damage in mice (Shi et al., 2017). However, there are still no reports of the negative effects of fucoidan in maintaining the intestinal health status of aquatic animals such as *Carassius auratus*.

Several research results indicate that fucoidan exhibits multifunctional activities, including immunomodulatory effects and the enhancement of immunity in zebrafish (*Danio rerio*) (Ikeda-Ohtsubo et al., 2020) as well as being effective in promoting the growth of striped bass (*Morone saxatilis*) (Fazio et al., 2020). The use of fucoidan supplements in aquatic animals is starting to be widely applied to increase immunity, growth, efficiency, and feed conversion, and has antioxidant properties (Pomin, 2015). In certain cases, aquaculture still uses antibiotics and chemical drugs to control and prevent infectious diseases (Assefa & Abunna, 2018). This situation can be dangerous because it can cause microbial resistance, environmental pollution, and consumer health as happened in China with the commercially important fish (*Carassius gibelio*). Intensive cultivation is carried out with high stocking densities, and risks causing poor water environments. This is caused by an accumulation of leftover food and feces at the bottom of the pond. Deteriorating water quality causes outbreaks of infectious diseases that can be transmitted (She et al., 2017). To improve the growth of fish farming, in addition to fucoidan, other attractants, and herbal compounds can also be used.

Growth enhancement can be achieved through the provision of attractants. The results of a study conducted by (Rionaldo et al., 2021) showed that giving squid oil mixed into feed can increase the grouper with a dose of 12 mL kg^{-1} feed, which resulted in a feed consumption rate of 99.23% and a survival rate of 100%. This is because grouper fish like fishy-smelling feed, so their consumption increases, which also causes their growth to increase. Research conducted by Arditya et al. (2019) using squid flour significantly increased ($p < 0.05$) total feed intake, protein efficiency ratio, and daily growth rate in snakehead fish (*Channa striata*) but have not significant effect ($p < 0.05$) on survival. Furthermore, as reported by Hossain et al. (2024) in the fish hatchery industry, mixing squid oil into feed on breeding performance has an impact on fertility, embryo development, and larvae of butter catfish. The best results were achieved in butter catfish (*Ompok pabda*) given squid oil extract containing EPA and DHA in their food. This shows that squid oil supplementation in feed can improve the breeding and reproductive performance of butter catfish. The findings of this study help develop a nutrient-rich diet for the development of better butter catfish larvae at the farm level, which can ultimately reduce mortality and poor survival of offspring of commercially important catfish species.

In addition to squid oil attractants and fucoidan, several herbs have been studied to increase non-specific immunity and growth, such as ginger, turmeric, Javanese turmeric, and garlic. The results showed that optimal growth of catfish supplemented with herbs was obtained at a dose of 7.5 g kg^{-1} ginger powder feed (Habibah, 2020), 1.5 g turmeric powder kg^{-1} feed (Wahyuningtyas, 2020), 50 g kg^{-1} Javanese turmeric powder (Wahyuningtias, 2020), and 30 g kg^{-1} garlic powder (Susiyani, 2020).

In addition to extensive research on the potential of single herbs for non-specific immunity and fish growth, to further develop this potential, the application of using a combination of 2 different herbs is desired. This study aims first to determine the effectiveness of herbal supplementation of fucoidan and squid oil attractants in increasing the growth of North African catfish, *Clarias gariepinus* (Burchell, 1822). Second, to determine the effectiveness of the combination of ginger + turmeric herbs with different percentages on the growth of *C. gariepinus*. Third, to determine the effectiveness of the combination of ginger + turmeric herbs compared to Javanese turmeric + garlic herbs for the non-specific immunity of *C. gariepinus*.

Material and Method

Description of the study. This study used fucoidan, which was extracted from brown seaweed, squid oil as an attractant, and terrestrial herbs including ginger, turmeric, Javanese turmeric, and garlic. The seaweed obtained was washed using fresh water until clean, then dried in the sun. The dried seaweed was then extracted using the acid method (Kim et al., 2007)**.** While squid oil, ginger, turmeric, Javanese turmeric, and garlic were purchased from traditional markets

Experimental design. The study was conducted under laboratory conditions using a completely randomized design (CRD), each with four replications. The experiment consisted of three consecutive experimental phases designed to evaluate the effects of dietary supplementation with functional additives and herbal-based ingredients.

Experiment 1: Evaluation of dietary fucoidan and squid oil attractant supplementation. The first experiment evaluated the effects of two dietary supplements, fucoidan and squid oil attractant, on the experimental fish. Three dietary treatments were established: (1) control diet without supplementation; (2) diet supplemented with fucoidan at 4 g kg^{-1} feed; and (3) diet supplemented with squid oil attractant at 12 mL kg^{-1} feed. Each treatment was performed with four replicates.

Experiment 2: Evaluation of ginger and turmeric supplementation. The second experiment investigated the effects of different dietary combinations of ginger and turmeric at different inclusion ratios. The supplementation levels were established based on the previously determined optimal inclusion doses of ginger (7.5 g kg^{-1} feed) and turmeric (1.5 g kg^{-1} feed). The proportion of ginger and turmeric was progressively adjusted among treatments while maintaining the experimental inclusion framework. The dietary treatments consisted of three unsupplemented control group and nine herbal supplementation treatments (T1-T9), as presented in Table 1.

Experiment 3: Evaluation of combined herbal supplementation. The third experiment evaluated additional herbal combinations using different inclusion levels. Two herbal combinations were tested: (1) ginger combined with turmeric and (2) Javanese turmeric combined with garlic. The treatments were formulated based on the optimal inclusion doses of ginger (7.5 g kg^{-1} feed), turmeric (1.5 g kg^{-1} feed), Javanese turmeric (50 g kg^{-1} feed), and garlic (30 g kg^{-1} feed). Each combination was evaluated at different ratios, including an unsupplemented control treatment, as shown in Table 2 and 3.

Treatments. This study used a laboratory experimental method with a completely randomized design by providing treatments and replications. This research consists of three experiment.

The experiment 1:
Control: without treatment
Fucoidan: pellet feed mixed with 4 g fucoidan kg^{-1} feed
Attractant: pellet feed mixed with 12 mL feed squid oil attractant kg^{-1} feed

The experiment 2:
This research uses a combination treatment of 2 different herbs, namely ginger and turmeric, with different percentages. The research design is as follows (Table 1):

Table 1

Dietary treatments containing different ratios of ginger and turmeric supplementation

Treatment	*Ginger (% of total herbal supplementation)*	*Ginger (g kg⁻¹ feed)*	*Turmeric (% of total herbal supplementation)*	*Turmeric (g kg⁻¹ feed)*
Control	0	0	0	0
T1	10	0.75	90	1.35
T2	20	1.50	80	1.20
T3	30	2.25	70	1.05
Control	0	0	0	0
T4	40	3.00	60	0.90
T5	50	3.75	50	0.75
T6	60	4.50	40	0.60
Control	0	0	0	0
T7	70	5.25	30	0.45
T8	80	6.00	20	0.30
T9	90	6.75	10	0.15

Note: Ginger and turmeric inclusion levels were calculated based on the reference doses of 7.5 g kg^{-1} feed and 1.5 g kg^{-1} feed, respectively.

The experiment 3:

The research uses a combination of treatment with 4 different types of herbs, namely ginger + turmeric and Javanese turmeric + garlic, with different doses. The research design is as follows (Tables 2 and 3).

Table 2

Dietary treatments containing different ratios of ginger and turmeric supplementation

Treatment	*Ginger (%)*	*Ginger (g kg⁻¹ feed)*	*Turmeric (%)*	*Turmeric (g kg⁻¹ feed)*
Control	0	0	0	0
T1	40	3.0	60	0.9
T2	50	3.75	50	0.75
T3	60	4.5	40	0.6

Table 3

Dietary treatments containing different ratios of Javanese turmeric and garlic supplementation

Treatment	*Javanese turmeric (%)*	*Javanese turmeric (g kg⁻¹ feed)*	*Garlic (%)*	*Garlic (g kg⁻¹ feed)*
Control	0	0	0	0
T4	10	5	90	27
T5	20	10	80	24
T6	30	15	70	21

The parameters observed included weight and length gain, daily growth rate, feed conversion ratio, and feed efficiency.

$$WG = FW - IW$$

Where:
WG - weight gain (g);
FW - final weight (g);
IW - initial weight (g).

$$LG = FL - IL$$

Where:
LG - length gain (cm);
FL - final length (cm);
IL - initial length (cm).

$$SGR = [(LnWt\text{-}LnWo):t] \times 100\%$$

Where:
SGR - specific growth rate (%);
Wt - final weight (g);
Wo - initial weight (g);
t - time (day).

$$FCR = F: (Wt\text{-}Wo)$$

Where:
FCR - feed conversion rate;
F - feed intake (g);
Wt - final weight (g);
Wo - initial weight (g).

$$FE = [\ (Wt - Wo): F] \times 100\%$$

Where:
FE - feed efficiency (%);
F - feed intake;
Wt - final weight (g);
Wo - initial weight (g).

For immunity parameters:
Hematocrit = (erythrocyte volume length: total blood volume length) x 100%
Leukocrit = (leukocyte volume length: total blood volume length) x 100%

Statistical analysis*.* The research data obtained were presented as mean ± SD (standard deviation). To determine whether the treatment affected immunity, the data were analyzed using Analysis of Variance (ANOVA) with an F-test at the 95% confidence level by software Statistics version 21. If a significant difference was found, the Duncan Multiple Range Test (DMRT) was performed at the 95% confidence level.

Results. Table 4 shows the growth of catfish treated with attractant and fucoidan supplementation for 60 days. On the 60th day, the growth was measured by the increase in weight (WG) and length (LG) obtained at the end of the study, which was calculated and compared with the control group in this study. Fucoidan supplementation significantly increased weight gain (41.47±0.54 g) compared to both control and attractant treatments ($p < 0.05$), representing a 2.8-fold improvement over control.

Table 4

Growth of *Clarias gariepinus* supplemented with attractant and fucoidan

Growth parameter	*Treatment (mg kg^{-1})*		
	Control	*Fucoidan*	*Attractant*
Weight gain	14.99±0.41^{a}	41.47±0.54^{b}	28.61±0.27^{c}
Length gain	8.15±0.23^{a}	14.59±0.28^{b}	10.91±0.35^{c}
Survival growth rate	3.12±0.06^{a}	4.33±0.14^{b}	3.94±0.16^{c}
Feed conversion rate	1.40±0.04^{a}	1.18±0.01^{b}	1.33±0.01^{b}
Feed efficiency	71.27±1.95^{a}	85.01±0,95^{b}	75.22±0.68^{b}

Note: Fucoidan and attractant inclusion levels were calculated based on the reference doses of 4 g kg^{-1} feed and 12 mL kg^{-1} feed, respectively.

Fucoidan supplementation resulted in the highest growth performance among treatments, with significantly greater weight gain and length gain compared to both the control and squid oil groups ($p < 0.05$). Although squid oil improved growth relative to the control, its effect was markedly lower than that of fucoidan. Feed conversion ratio (FCR) was also significantly reduced in the fucoidan group, indicating improved feed utilization efficiency (Table 4).

A combination of herbs. The results of the research on the combination of herbal supplements ginger + turmeric resulted in growth, as indicated by the increase in weight and length (WG & LG), and optimal specific growth rate (SGR) are listed in Table 5. The herbal combination resulted in significant growth.

Table 5

Growth of *Clarias gariepinus* supplemented with a combination of ginger and turmeric

Treatments (g kg^{-1})	*Parameters*		
	Weight gain (g)	*Length gain (cm)*	*Survival growth rate*
Control	12.66±0.48^{a}	3.41±0.20^{a}	3.57±0.10^{a}
T1: ginger 0.75 g + turmeric 1.35g	27.03±2.52^{b}	6.97±0.67^{b}	4.81±0.11^{b}
T2: ginger 1.50 g + turmeric 1.20 g	28.30±3.91^{bc}	7.98±0.54^{bc}	4.90±0.28^{bc}
T3: ginger 2.25 g + turmeric 1.05g	32.54±1.16^{c}	8.75±0.41^{c}	5.22±0.11^{c}
Control	18.09±0.88^{a}	5.89±0.24^{a}	4.51±0.05^{a}
T4: ginger 3.0 g + turmeric 0.9 g	17.72±0.79^{a}	5.99±0.34^{a}	4.47±0.11^{a}
T5: ginger 3.75 g + turmeric 0.75 g	20.24±0.48^{b}	7.47±0.19^{b}	4.69±0.09^{b}
T6: ginger 4.5 g + turmeric 0.6 g	20.63±0.31^{b}	7.56±0.18^{b}	4.74±0.08^{b}
Control	6.45±0.37^{a}	3.87±0.27^{a}	2.54±0.09^{a}
T7: ginger 5.25 g + turmeric 0.45 g	9.36±0.39^{c}	5.53±0.08^{b}	3.17±0.07^{c}
T8: ginger 6 g + turmeric 0.3 g	8.30±0.44^{b}	5.19±0.42^{b}	2.95±0.09^{b}
T9: ginger 6.75 g + turmeric 0.15 g	8.79±0.76^{bc}	5.26±0.48^{b}	3.03±0.19^{bc}

Note: Ginger and turmeric inclusion levels were calculated based on the reference doses of 7.5 g kg^{-1} feed and 1.5 g kg^{-1} feed, respectively.

Among all treatments, the combination of 2.25 g kg^{-1} ginger and 1.05 g kg^{-1} turmeric (T3) produced the highest growth performance, with significantly higher weight gain, length gain, and SGR compared to other treatments ($p < 0.05$). Increasing the ginger proportion beyond this level did not further improve growth, suggesting a dose-dependent effect and possible saturation.

Immunity. The results of a study of a combination of four different herbs, namely ginger + turmeric and Javanese turmeric + garlic, with different doses on the immune response in *C. gariepinus*, are listed in Tables 6 and 7. While hematocrit values were highest in the temulawak + garlic combination, leukocrit, considered a more direct indicator of immune response, was significantly enhanced in the ginger + turmeric treatments.

Table 6

Hematological parameters of hematocrit and leukocrit of *Clarias gariepinus* supplemented with a combination of ginger + turmeric

Treatment	*Parameters*	
	Hematocrite	*Leucocrite*
Control	54.60±0.56^{a}	1.97±0.23^{a}
T-1: ginger 3.0 g + turmeric 0.9 g	57.24±0.65^{bc}	3.95±0.46^{b}
T-2: ginger 3.75 g + turmeric 0.75 g	57.52±0.57^{bc}	3.92±0.75^{b}
T-3: ginger 4.5 g + turmeric 0.6 g	58.96±0.58^{c}	3.82±1.85^{b}

Note: Ginger and turmeric inclusion levels were calculated based on the reference doses of 7.5 g kg^{-1} feed and 1.5 g kg^{-1} feed, respectively.

Table 7

Hematological parameters of hematocrit and leukocrit of *Clarias gariepinus* supplemented with a combination of Javanese turmeric + garlic

Treatment	*Parameters*	
	Hematocrite	*Leucocrite*
Control	57.83±10.65^{a}	2.16±1.66^{a}
T-4: Javanese turmeric 5 g + garlic 27 g	62.25±7.11^{a}	1.83±1.28^{a}
T-5: Javanese turmeric 10 g + garlic 24 g	63.25±15.48^{a}	1.91±1.26^{a}
T-6: Javanese turmeric 15 g+ garlic 21 g	58.41±7.75^{a}	2.16±1.01^{a}

Note: Javanese turmeric and garlic inclusion levels were calculated based on the reference doses of 50 g kg^{-1} feed and 30 g kg^{-1} feed, respectively.

The effects of herbal supplementation on hematological parameters are presented in Table 6 and Table 7. Hematocrit values ranged from 54.60±0.56% to 63.25±15.48% across treatments. The highest hematocrit values were observed in the combination of Javanese turmeric (10 g kg^{-1}) and garlic (24 g kg^{-1}), although no statistically significant differences were detected among several treatments ($p > 0.05$).

Leukocrit values varied between 1.83±1.28% and 3.95±0.46%. The highest leukocrit values were recorded in treatments containing ginger and turmeric, particularly at intermediate inclusion levels. However, variability among replicates was relatively high, and differences between some treatments were not statistically significant ($p > 0.05$).

Discussion. Based on the research results as listed in Table 4, the effectiveness of fucoidan is better than that of squid oil. Functional compounds can be mixed into food as supplements that can improve health. The supplementation of natural immunostimulants and probiotics is becoming increasingly attractive as an effective alternative for the prevention of disease outbreaks in intensive aquaculture systems. Recently, research on fucoidan has become increasingly interesting because of its potential as an immunomodulator and functional nutrient (Tuller et al., 2014; Yang et al., 2014). Therefore, the superior immunomodulatory activity of fucoidan compared to squid oil not only supports it as a functional feed additive, but also indicates that polysaccharides from seaweed may offer a sustainable approach to improving disease resistance and functional feed.

Research reports show that fucoidan has proven effective in growth dynamics and regulating the quality of digestive system function (Liu et al., 2020). Fucoidan can also be a feed additive that can improve the growth process and performance of Red Seabream (*Pagrus major*) (Sony et al., 2019), and Crucian carp (*Carassius gibelio*) (Cui et al., 2020). Meanwhile, shrimp fucoidan supplementation from the extraction of various seaweed species has been proven to improve weight gain, and daily growth rate and can reduce the feed conversion ratio (Traifalgar et al., 2010; Sivagnanavelmurugan et al., 2014). The decrease in feed conversion ratio indicates that fucoidan can improve digestion and absorption which supports growth. The digestive tract has a function to digest incoming food, but also to protect against pathogen exposure, and is important in maintaining the health of aquatic animals. Fucoidan supplementation functions in maintaining intestinal health by modulating nutrient digestibility, maintaining intestinal microflora, and modulating gastrointestinal architecture (Heim et al., 2014). Research on the effects of fucoidan in maintaining the health status of the digestive tract in aquatic animals such as fish is still rare. Brown seaweed extract supplementation can modulate the balance of the digestive tract environment, antibacterial properties, strong immunomodulators, and improve growth performance through increased digestive function and intestinal absorption (McDonnell et al., 2010). Fucoidan possesses free radical scavenging activity due to its sulfate group. The reduction in reactive oxygen species (ROS) levels in intestinal tissue by fucoidan protects enterocytes from oxidative damage during the feed intake period. This cytoprotective effect maintains mitochondrial function and cell turnover, supporting continuous intestinal epithelial renewal.

A report from (Dawood et al., 2018), shows that the application of supplements containing immunostimulants significantly results in increased growth performance and health quality. Polysaccharide compounds extracted from brown seaweed such as fucoidan can be used as immunostimulants which can increase immunity and then function as growth promoters (Ikeda-Ohtsubo et al., 2020). Supplements containing fucoidan result in increased growth performance, efficient use of feed, as well as resistance to the threat of microbial infections, both bacterial and viral (Saeed et al., 2021). Fucoidan supplementation through food causes an increase in height of the villi so that the area for digestion and absorption of nutrients becomes wider (Mahgoub et al., 2020). Sargassum, a genus of brown seaweed (Phaeophyceae), is known to contain various bioactive compounds that are widely used as supplements to increase growth. Fucoidan can increase immunity (Prabu et al., 2016), which then supports shrimp growth (Traifalgar et al., 2010).

Juvenile barramundi fish (*Lates calcarifer*) fed a diet containing 1% fucoidan inclusion showed increased growth characterized by a significant increase in length, weight, and area of muscle fibers (hypertrophy) compared to a diet containing 0.5% fucoidan inclusion and control feed. This research shows that adding fucoidan to fish food can increase growth (Tuller et al., 2014). Similar results were reported by (Prabu et al., 2016), fucoidan supplementation has shown a significant increase in the growth performance of aquatic animals. Cui et al., (2022) reported similarly, fucoidan supplementation through feed can increase the activity of intestinal digestive enzymes, modulate the intestinal microbial community, and improve immune readiness, which can ultimately improve the growth performance and intestinal health status of *Carassius auratus gibelio*. While in shrimp fucoidan diet is known to increase the growth of *Penaeus monodon* shrimp as a result of increased immunity after being challenged by *Vibrio harveyi* infection in shrimp cultivation (Traifalgar et al., 2010). The increase in immunity as a result of dieting has a positive impact on growth by reducing the conversion ratio and automatically increasing efficiency. This is confirmed by (Azad et al., 2005), that the increased growth of tiger shrimp *Penaeus monodon* postlarvae was caused by the effect of adding immunostimulants through feed, so that digestion and absorption of nutrients become more efficient, which is caused by the activation of phagocytic cells in the hepatopancreas, which produce lytic enzymes upon stimulation. High efficiency in nutrient absorption in the digestive tract results in smaller conversion values.

A similar opinion was reported by (Cruz-suárez et al., 2000), that the supplementation of polysaccharides from the seaweed *Macrocytis pyrifera* into the feed ration resulted in increased nutrient digestibility, efficiency in protein utilization and better feed conversion so that the growth of *L. vannamei* shrimp juveniles increased.

In the last few decades, several studies have shown that increasing immunocompetence through the addition of immunostimulants is a promising prophylactic approach to control bacterial diseases in shrimp farming (Raa, 2000). Although the prophylactic potential of immunostimulants has been well documented, their efficacy varies widely and appears to depend on many interacting factors, including the route of administration. All treatment groups that received fucoidan supplementation through feed showed much more optimal survival, feed utilization, and conversion values after receiving *V. harveyi* challenge compared to controls. The way fucoidan increases immunocompetence is by activating hemocytes and phagocytic cells through the activation of phagocytosis-activating proteins. Increased growth and survival after being challenged with *Vibrio harveyi* could be caused by activation of the cellular immune response through increased phagocytic activity after administration of fucoidan.

Herbal growth-promoter. Consumer health is the main consideration and priority in providing food sources. The demand for fishery products continues to increase, causing fish farmers to try to increase their production. To increase productivity, immunostimulants and growth promoters such as ginger, turmeric, Javanese turmeric, and garlic can be used, which are quite widely available on the market. Based on the results of the study in Table 5, the combination of herbal supplements of ginger 2.25 g + turmeric 1.05 g produced the best growth as indicated by the increase in weight and length and optimal daily growth (SGR). The combination of herbs that produced optimal growth was the percentage of ginger 20% + turmeric 70% of its optimal dose. This shows that turmeric supplements are more dominant in producing growth in the combination of ginger and turmeric.

Research conducted by Gholian et al. (2022) proved that the use of 2% turmeric powder through feed can induce growth gene expression in young Starry sturgeon (*Husso stellatus*). The results of the same study conducted by Wijayanto et al. (2023) on grouper fish showed that turmeric supplementation had a significant effect on absolute biomass growth, feed conversion ratio (FCR), and benefit-cost ratio (BCR) with an optimal dose ranging from 0.93-1.29%. Furthermore, the addition of turmeric through a feed of 2% kg^{-1} provided higher growth in red tilapia compared to controls, with a survival rate of 85.67% (Cahyani et al., 2021). Fish receiving the turmeric-enriched feed showed significantly higher growth rates compared to the control group. This is likely due to turmeric's curcumin content, which can improve nutrient utilization and stimulate appetite, leading to increased growth.

Turmeric, commonly known as turmeric contains the bioactive compound curcumin around 0.3-5.4% of raw turmeric (Akram et al., 2010). Turmeric extract (TE) has also been reported as a good herbal feed additive to modulate oxidative status and stress response in fish (Xavier et al., 2021). Herbal medicine, especially turmeric or curcumin, is a promising substitute for antibiotics in Aquaculture (Liu et al., 2019). The use of turmeric powder has shown positive effects on growth and feed utilization parameters (FCR and feed intake) in South American catfish (*Rhamdia quelen*) and Nile tilapia Nil (Baldissera et al., 2018). In several other studies, significant increases in body weight gain and decreases in FCR were found in rainbow trout and carp when given curcumin extract (Ming et al., 2020). The reduction in FCR and weight gain were also associated with improved nutrient absorption. Curcumin acts as a prebiotic, modulating the gut microbial community. In species such as koi and golden pompano, curcumin supplementation has increased the abundance of beneficial bacteria in the gut.

The results of the study showed that snakehead fish *Channa argus* given curcumin supplementation could increase growth with an optimal dose of 388.125 mg kg^{-1}. The increased growth included final weight, weight gain, protein efficiency ratio, daily growth rate, and feed conversion ratio significantly. However, it should be noted that the curcumin supplement diet at doses of 200 and 400 mg kg^{-1} was better than the doses of 100 and 800 mg kg^{-1} (Li et al., 2022). The results of the same study were reported by (Yonar et al., 2019), *Oncorhynchus mykiss* fish given a curcumin supplement diet for 8 weeks were known to increase weight gain, growth rate, and feed conversion value which decreased significantly. Likewise, it was reported that the addition of a curcumin supplement diet of 393.67 mg kg^{-1} can significantly increase weight gain, daily growth rate, and feed conversion ratio in grass carp *Ctenopharyngodon idella* (Ming et al., 2020), Nile tilapia (*Oreochromis niloticus*) (Mohamed et al., 2020), and in Nile tilapia at a dose of 200 mg kg^{-1} (Abd El-Hakim et al., 2020).

Herbal immunostimulant. In the aquaculture industry, there are restrictions on the use of antibiotics because they can harm consumers, and the environment and cause resistance. Therefore, another approach is needed to prevent and control diseases in aquatic animals. The results of the study showed that supplementation of immunostimulant herbs can increase immunity (Gasmi et al., 2023). Immunity is an important defense that organisms have to be free from disease. Even though fish have specific immunity, because they are lower vertebratas, the function of non-specific immunity is also important, as is specific immunity in vertebrates in general. Non-specific immunity is very important in aquatic animals because the environment in which they live is diverse. Non-specific immunity is needed as the first defense that mobilizes cells or tissues that are threatened by disease. The first movement is carried out by white blood cells (leukocytes) such as phagocytosis. Leukocyte measurements can be carried out in percentages (leukocrit) of the volume of whole blood cells. The importance of these leukocytes is that they are used as the main parameter in non-specific immunity.

Based on Table 7. the optimal dose that can produce the best hematocrit is obtained in the combination of Javanese turmeric 10 g + garlic 24 g supplements with a percentage of 20% Javanese turmeric and 80% garlic. As for leukocrit, the optimal dose is in the combination of ginger 3.0 g + turmeric 0.9 g, namely 40% ginger and 60% turmeric. In this study, the main parameter that indicates non-specific immunity is leukocrit. In increasing the percentage of leukocrit, turmeric is more dominant (60%) than ginger (40%). Therefore, in terms of producing non-specific immunity, the role and function of turmeric are more dominant than ginger in the combination of turmeric and ginger dietary supplements. Turmeric contains curcumin, which functions as a growth promoter and is also an immunomodulator (Ming et al., 2020). The results of a study conducted by Xia et al. (2015) on juvenile Wuchang bream (*Megalobrama amblycephala*) fish showed that curcumin can increase the number of leukocytes, and respiratory burst activity up to a dose of 60 mg kg^{-1} and then decrease. Other studies have shown that curcumin in food produces various pharmacological effects such as immunomodulation (Ganguly et al., 2010) and fish immune responses (Xavier et al., 2022).

Research by Xia et al. (2015) showed that the number of white blood cells increased significantly in fish fed with 60 mg kg^{-1} curcumin, indicating that curcumin may be involved in the inflammatory response. White blood cells are the first line of defense and play an important role in non-specific immunity against microbial infections. Studies have shown that immunostimulants derived from herbal plants can increase fish immunity by increasing the capacity and number of immune responses as indicated by an increase in the number of white blood cells, including the number of red blood cells and hemoglobin, and white blood cells (Talpur et al., 2013; Talpur & Ikhwanuddin, 2013).

Conclusions. The study demonstrated that dietary supplementation significantly enhanced growth and physiological performance in *C. gariepinus* over 60 days. Fucoidan supplementation resulted in superior growth performance compared with the squid oil attractant. Among herbal formulations, combinations of ginger, turmeric, Javanese turmeric, and garlic exhibited variable but beneficial effects on growth and hematological parameters, with specific mixtures optimizing either growth, hematocrit, or leukocrit levels. Overall, the findings indicate that both marine-derived compounds and herbal plant-based supplements can effectively improve growth performance and immune-related blood parameters in farmed catfish, suggesting their potential as functional feed additives in aquaculture." is more appropriate.

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