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The effectiveness of giving silkworms *Tubifex* sp. enriched with curcumin on the growth and survival of jelawat fish larvae *Leptobarbus hoevenii*

Efektivitas pemberian cacing sutra *Tubifex* sp. diperkaya kurkumin terhadap pertumbuhan dan kelulushidupan larva ikan jelawat *Leptobarbus hoevenii*

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ABSTRACT

Curcumin is a secondary metabolite that enhances fish immunity and functions as an antibacterial and antimicrobial agent. Curcumin acts as a supplement to increase the larvae's appetite. The aim of this study was to evaluate the effect of curcumin-enriched silkworms (*Tubifex* sp.) on the growth and survival of jelawat fish larvae. This research was carried out in June–July 2023 at the Fish Hatchery and Breeding Laboratory, Faculty of Fisheries and Marine Sciences, Riau University. This study applied an experimental method using a completely randomized design (CRD) with three replications. The treatment in this study was P_0 (silkworms without curcumin enrichment), P_1 (silkworms enriched with curcumin 0.2 mg/kg silkworms), P_2 (silkworms enriched with curcumin 0.3 mg/kg silkworms), P_3 (silkworms enriched with 0.4 mg/kg curcumin), and P_4 (silkworms enriched with curcumin 0.5 mg/kg silkworms). The results showed that the treatment of silkworms enriched with curcumin had a significant effect on the growth and survival of jelawat fish larvae ($P<0.05$). The best treatment is P_3 (silkworms enriched with curcumin 0.4 mg/kg silkworms) with absolute weight growth of 2.26 ± 0.04 g, absolute length 5.25 ± 0.03 cm, SGR 11.84 ± 0.04% and survival 100 ± 0.00% respectively. The water quality parameters during the research period were temperature 27.2-29.5°C, pH 6.3-7.5, and dissolved oxygen 4.5-5.8 mg/L still in good condition for jelawat fish.

Keywords: curcumin, jelawat fish larvae, silkworms

ABSTRAK

Kurkumin merupakan salah satu senyawa metabolit sekunder yang dapat meningkatkan daya tahan tubuh ikan dan memiliki manfaat sebagai zat anti bakteri atau mikroba. Kurkumin berperan sebagai suplemen untuk menambah nafsu makan larva. Tujuan penelitian adalah untuk mengetahui pengaruh pemberian cacing sutera (*Tubifex* sp.) yang diperkaya kurkumin terhadap pertumbuhan dan kelulushidupan larva ikan jelawat. Penelitian ini dilaksanakan pada bulan Juni–Juli 2023 di Laboratorium Pembenihan dan Pembibitan Ikan Fakultas Perikanan dan Ilmu Kelautan Universitas Riau. Penelitian ini menggunakan metode eksperimen dengan rancangan acak lengkap faktor dan tiga kali ulangan. Perlakuan pada penelitian ini adalah P_0 (cacing sutera tanpa diperkaya kurkumin), P_1 (cacing sutera yang diperkaya dengan kurkumin 0,2 mg/kg cacing sutera), P2 (cacing sutera yang diperkaya dengan kurkumin 0,3 mg/kg cacing sutera), P_3 (cacing sutera yang diperkaya dengan kurkumin 0,4 mg/kg cacing sutera), dan P_4 (cacing sutera yang diperkaya dengan kurkumin 0,5 mg/kg cacing sutera). Hasil penelitian menunjukkan bahwa pemberian cacing sutera diperkaya kurkumin berpengaruh nyata terhadap pertumbuhan dan kelangsungan hidup larva ikan jelawat ($P<0,05$). Perlakuan terbaik adalah P_3 (cacing sutera yang diperkaya dengan kurkumin 0,4 mg/kg cacing sutera) dengan pertumbuhan bobot mutlak 2,26 ± 0,04 g, panjang mutlak 5,25 ± 0,03 cm, SGR 11,84 ± 0,04% dan kelangsungan hidup 100 ± 0,00%. Parameter kualitas air selama penelitian yaitu suhu 27,2-29,5°C, pH 6,3-7,5, dan oksigen terlarut 4,5-5,8 mg/L, masih dalam kondisi baik untuk ikan jelawat.

Kata kunci: cacing sutera, kurkumin, larva ikan jelawat

INTRODUCTION

Jelawat fish is a type of fish native to Indonesia whose living habitat is in fresh water which has the potential to be developed. Jelawat fish can easily be found in several areas of Riau, Jambi, South Sumatra, Central Kalimantan, and West Kalimantan (Silaban, 2022). Jelawat fish has high market demand because it is popular with local and international communities such as Malaysia and Brunei so this fish has the prospect of being cultivated (Riyoma *et al.,* 2020). Cultivation needs are very dependent on seed availability. Therefore, it is necessary to carry out jelawat fish cultivation activities so that the availability of seeds, both quality and quantity, is available continuously.

Recent data from a study in the Jambi region indicates that Hoven's carp fry can be obtained locally for approximately IDR 225 per fish, but resale prices often rise to around IDR 400. In more remote areas such as Riau's Kampar region, prices can escalate to IDR 2,000 to 2,500 per seedling (Taslim *et al.,* 2015). Silkworms have an important role because they can stimulate fish growth faster than other natural foods such as water fleas (*Daphnia* sp. or *Moina* sp.). This is because the nutritional content of silkworms consists of protein 77.42%, fat 14.15%, ash content 5,89% and BETN 0.44% (Asiah *et al.,* 2024).

The problem of silkworms in cultivation activities is not too influential. However, some fish's growth is still less than optimal when only given silkworms. As the research result of Asiah *et al.* (2024) revealed that kelabau fish larvae fed silkworms feed produce a survival rate of 90% and a specific growth rate of 0.022%/day, therefore it is necessary to enrich silkworms with certain nutrients. Several studies have been successfully carried out, such as enriching live food with several nutrients, such as fatty acids, vitamins, and minerals (Samat *et al.,* 2020), and using curcumin (Heltonika *et al.,* 2015) with a 100% survival rate. Based on the description above, it is necessary to carry out feed enrichment studies with natural (*Tubifex* sp.) and curcumin, which is expected to improve the appetite and endurance of fish. So, it is expected to provide accelerated growth and improvement of the fish larvae survival rate.

Curcumin is a secondary metabolite compound that can increase the fish's body's resistance to bacterial attacks and has benefits as an anti-bacterial or microbial substance (Pakpahan *et al.,* 2020). Apart from that, curcumin acts as a supplement to increase the larvae's appetite so that it can fulfill the body's energy metabolism and be used for growth. As stated by Safaryan (2021), curcumin has properties that can influence appetite because it can speed up the emptying of stomach contents so that appetite increases and facilitates the release of bile thereby increasing the activity of the digestive tract. Curcumin in turmeric is also an active compound that can increase fish appetite. This is because curcumin can stimulate the performance of digestive enzymes and can neutralize toxins so that it affects the process of nutrient absorption from the feed consumed optimally (Haetami *et al.,* 2023).

Prihandini and Umami (2022) stated that the growth rate of Tilapia fish (*Oreochromis niloticus*) was higher when turmeric extract was added to the feed, compared to tilapia fish not given additional treatment with turmeric extract in the feed. Based on the results of research conducted by Haetami *et al.* (2023) on the addition of 15 ml/kg turmeric extract/kg feed to dumbo catfish, it gave the best results for the highest absolute length growth of 12.93 ± 0.7 cm, the highest absolute weight growth of 53.62 ± 7 kg, and the highest survival of 98.3 ± 2.8%. In addition, according to Tian *et al.* (2023) curcumin promotes the secretion of digestive hormones and modulates the bile system, which can positively influence the digestion of nutrients, including carbohydrates, fats, and proteins. These physiological effects improve the digestion and absorption of carbohydrates, lipids, and proteins in the diet, which in turn increase feed efficiency and ultimately contribute to better growth performance in fish.

Based on the benefits of curcumin, it is necessary to conduct research on the effect of giving silkworms (*Tubifex* sp.) that are enriched with curcumin on the growth and survival of the jelawat larvae (*Leptobarbus hoevenii*). With the aim of knowing the best enrichment dose of curcumin in silkworms on the growth and survival of jelawat fish larvae (*Leptobarbus hoevenii*).

MATERIAL AND METHODS

Time and place

This research was carried out in June-July 2023 at the Fish Hatchery and Breeding Laboratory (PPI), Faculty of Fisheries and Marine Affairs, Riau University.

Material

Jelawat fish larvae

The test fish used in this research were 750 jelawat fish larvae that were 20 days old. Jelawat larvae come from the Freshwater Fisheries Seed Center (BPBAT) Sungai Gelam, Jambi. 10-day-old larvae adapted to be fed with artemia feed for 10 days. Artemia feed is cultured as 1 g of artemia cysts in 1 L of water and 25 g of salt. After that, it is given strong aeration for 24 hours. Artemia is cultured every 07.00, 13.00, 19.00, and 01.00 WIB.

Harvesting artemia is done by lifting the aeration stone from the culture container and leaving it for 5-10 minutes so that the artemia separates from the shell. After that, siphon the artemia that has settled at the bottom of the container, then rinse the artemia with clean water to reduce the salt content. Larvae were treated with a stocking density of 5 individuals/L using plastic containers with a volume of 30 L and filled with 10 L of water (Sunarno & Syamsunarno, 2017).

Test fish meal

The fish meal given during the research was silkworms. Silkworms were obtained from local cultivators (Giez tank, Pekanbaru. 100 g of silkworms per two days is added with half a boiled egg yolk and pro-analyst curcumin according to the dosage. The feed enrichment in this study was carried out by adding boiled egg yolk and pro-analyst curcumin to the Tubifex worms used as the main feed. Tubifex worms (*Tubifex* sp.) sourced from the Giez tank cultivator in Pekanbaru were utilized as a natural protein source with high nutritional value.

Every day, 100 g of Tubifex worms were enriched with half a boiled egg yolk, which is rich in protein, fat, and vitamins to support the growth and immunity of the test organisms. Additionally, the addition of proanalysis curcumin in a specific dosage acts as an antioxidant and anti-inflammatory agent that can enhance health, reduce stress, and improve the physiological condition of the studied organisms. Through this enrichment, the feed is expected to optimize growth efficiency and strengthen the immune system of research subjects, 100 mg of turmeric extract for 100 g of silkworms. The pro-analysis grade curcumin used was a yellow powder (Merck, 100 mg). The administration of curcumin-enriched silkworms was carried out four times daily. The administration interval is every six hours, at 07.00, 13.00, 19.00, and 01.00 WIB.

The first stage is to prepare 100 g of silkworms per treatment, half a boiled chicken egg yolk, and pro-analyst curcumin. Then, half an egg is crushed with a spoon, adding curcumin according to the dosage. After it is crushed, curcumin is added according to the treatment dose, then the boiled egg yolk is ready to be given to the silkworms. Preparation of silkworm feed enriched with curcumin is carried out at intervals of one to two hours before feeding the larvae.

Research methods

The method used in this research was an experimental method with a completely randomized design (CRD), one factorial with five treatment levels, namely 0 mg, 0.2 mg, 0.3 mg, 0.4 mg, and 0.5 mg and three replications. The level of treatment in this study refers to the best research results of 0.3 mg/kg of silkworms conducted by Heltonika *et al.* (2015) on betok fish. The experimental design used in this research is as follows:

P0 = Tubifex without enrichment with curcumin
P1 = Tubifex enriched with curcumin 0.2 mg/kg silkworms
P2 = Tubifex enriched with curcumin 0.3 mg/kg silkworms
P3 = Tubifex enriched with curcumin 0.4 mg/kg silkworms
P4 = Tubifex enriched with curcumin 0.5 mg/kg silkworms

Research procedure

Container preparation

The containers used in this research were 15 plastic boxes with a capacity of 30 L. Before using the containers, wash them thoroughly and dry them. After the container is dry, water is filled and potassium permanganate (PK) solution is added for 24 hours to sterilize it. Then rinse with clean water and fill with 10 L of water/container. Next, randomization of research containers consists of three stages, namely the first stage is determining the initial angle of the research container, then the second stage is determining the direction of numbering the containers and the third stage is randomization of treatments by drawing lots. After preparing the layout of the container and providing a treatment label. Each treatment container was given one unit of aeration stone in each container with the aim of supplying oxygen.

Maintenance water preparation

The water used for larval rearing research is water that comes from a drilled well, then settled for three days in a reservoir so that dirt and metal particles can settle to the bottom of the reservoir container. Each research container was filled with 10 L of water. After all the containers were filled with water, 1 unit of aeration stone was installed per container with the aim of increasing the oxygen level in the container.

Larval rearing

Jelawat fish larvae were reared for 40 days given natural food in the form of silkworms enriched with curcumin according to at-satiation treatment. The curcumin used is curcumin with the trademark curcumin pro analyst produced by Merck. During the rearing period, siphoning is carried out to clean up leftover food and feces at the bottom of the aquarium and a 30% water change is carried out.

Test parameter measurement

Sampling was carried out five times, namely sampling on day one (beginning of research), day 10, day 20, day 30, and day 40 (end of research). Fish larvae were taken for sampling in the afternoon as much as 50% of the total fish population in one research container by weighing the body weight and measuring the length of the fish.

Parameters measured

The formula used to measure absolute weight, length growth, SGR (%), and SR (%) according to Seenivasan *et al.* (2014) is:

Average absolute weight gain (g)

$$Wm = \text{Average weight at the end of the study (g)} - \text{Average weight the start of the study (g)}$$

Average absolute length growth (cm)

$$Lm = \text{Average length at the end of the study (cm)} - \text{Average length the start of the study (cm)}$$

$$SGR\ (\%/day) = \left(\frac{(\text{Ln } W2 - \text{Ln } W1)}{t}\right) \times 100$$

Note:

W1 = Average initial weight (g)
W2 = Average final weight (g)
T = Total number of experimental days

$$\text{Survival rate } (\%) = \frac{\text{Total No. if live animals}}{\text{Total No, initial animal}} \times 100$$

Fish behavior towards feed

The feeding behavior of fish which involved observed swimming patterns, swimming positions, group activity, and response to food, was observed to examine how to the larvae consumed the food, the attraction to it, and the amount of uneaten feed (Heltonika, 2022). Observations of fish behavior towards the food provided were made during the 40 days of the study.

Water quality measurement

The water quality parameters measured during research activities were physical and chemical parameters (temperature, pH, and dissolved oxygen), carried out three times during the research, namely at the beginning, middle, and end of the research.

RESULT AND DISCUSSION

The effect of giving curcumin-enriched silkworms on the growth of absolute weight (g), absolute length (cm), specific growth rate (%/day), and survival (%) of jelawat fish larvae

The results of research on giving silkworms enriched with curcumin on growth in absolute weight (g), absolute length (cm), specific growth rate (%/day), and survival (%) of jelawat fish larvae reared for 40 days are presented in Table 1. Based on Table 1, it shows that the growth in absolute weight (g) of jelawat fish larvae is between 1.77 ± 0.04-2.26 ± 0.04 g, to absolute length (cm) ranging from 4.67 ± 0.15-5.25 ± 0.03, specific growth rate (%/day) between 11.24 ± 0.06-11.84 ± 0.04, and survival rate of 100%.

Behavior of fish larvae on feed

Based on the results obtained from observing the behavior of fish larvae towards feed that have been carried out, they are presented in Table 2.

Water quality

Water quality parameters for rearing jelawat fish larvae were measured three times, namely at the beginning, middle, and end of the study. The results of water quality measurements are presented in Table 3.

Discussion

Growth in absolute length, weight, and specific growth rate of larvae

Based on Table 1, the treatment of silkworms enriched with curcumin significantly influenced the growth performance of jelawat fish larvae,

including absolute weight, length, and specific growth rate. The best results were consistently obtained at treatment P3 (0.4 mg/kg curcumin), where the average absolute weight growth reached 2.26 ± 0.04 g, the average length was 5.25 ± 0.03 cm, and the specific growth rate was 11.84 ± 0.04%/day. In contrast, the lowest values were observed at P0 (silkworms without curcumin enrichment), with weight growth of 1.77 ± 0.04 g, length of 4.67 ± 0.15 cm, and a specific growth rate of 11.24 ± 0.06%/day. These findings indicate that the enrichment of silkworms feed with curcumin has a positive impact on fish growth, with 0.4 mg/kg being the optimal dose compared to both lower and higher doses. This result aligns with the statement of Fatchurochman *et al.* (2017) that inappropriate doses, whether excessive or insufficient, may inhibit growth and cause physiological problems in fish.

The enhanced growth observed in P3 can be attributed to the bioactive functions of curcumin in improving digestive and metabolic processes. Curcumin has been reported to increase digestive enzyme activities such as trypsin, lipase, and amylase in the hepatopancreas and intestine, thereby enhancing nutrient absorption and growth performance (Mahmoud *et al.,* 2017). In giant gourami (*Osphronemus goramy*), dietary inclusion of turmeric (*Curcuma longa*) extract has been reported to stimulate bile release from the gallbladder. The increased bile secretion facilitates the breakdown of dietary lipids and improves the activity of digestive enzymes, which in turn enhances nutrient absorption and supports improved growth in the fish (Arifin *et al.,* 2016). The antioxidant properties of curcumin, partly due to its Vitamin C content, further act as catalysts for metabolic processes, counteracting free radicals,

Table 1. Effect of giving silkworms enriched with curcumin on growth in absolute weight (g), absolute length (cm), specific growth rate (%/day), and survival (%) of jelawat fish larvae.

Treatment curcumin (mg)	Absolute Weight (g)	Absolute Length (cm)	SGR (%/day)	Survival (%)
$P_{0\ (without\ curcumin\ administration)}$	1.77 ± 0.04^{a}	4.67 ± 0.15^{a}	11.24 ± 0.06^{a}	100 ± 0.00^{a}
$P_{1\ (0,2)}$	2.05 ± 0.04^{b}	4.98 ± 0.03^{b}	11.59 ± 0.04^{b}	100 ± 0.00^{a}
$P_{2\ (0,3)}$	2.12 ± 0.03^{c}	5.07 ± 0.03^{b}	11.68 ± 0.03^{c}	100 ± 0.00^{a}
$P_{3\ (0,4)}$	2.26 ± 0.04^{d}	5.25 ± 0.03^{c}	11.84 ± 0.04^{d}	100 ± 0.00^{a}
$P_{4\ (0,5)}$	2.18 ± 0.02^{c}	5.12 ± 0.04^{bc}	11.75 ± 0.02^{c}	100 ± 0.00^{a}

Note: Uppercase letters behind the mean (±standard deviation) in the same row indicate a significant difference (P<0.05).

Table 2. Observation of fish larvae behavior.

Observation	Giving Curcumin			
	Without the administration of curcumin	Score	Giving curcumin	Score
Fish swimming patterns	Move swiftly and accumulate at one point	1	Move swiftly and accumulate more than one point	2
Fish swimming position	The fish is in the middle of the media	2	The fish is in the middle of the media	2
Group activities	Two groups were formed	2	Three groups were formed	3
Response to feed	Less aggressive in taking food	2	Very aggressive in taking food	3

(Source: Heltonika (2022)).

Table 3. Water quality measurements.

NO	Parameters Measured	Number Range				
		P_0	P_1	P_2	P_3	P_4
1	Temperature (°C)	27.2-29.5	27.3-29.1	27.2-29.0	27.4-29.5	27.3-29.2
2	pH	6.5-7.5	6.3-7.2	6.2-7.5	6.5-7.2	6.3-7.5
3	DO (mg/L)	4.5-5.5	4.9-5.6	4.7-5.8	4.7-5.7	4.8-5.5

preventing disease, improving immunity, and ultimately supporting growth (Pujiasmanto *et al.,* 2021). Furthermore, curcumin functions as an appetite stimulant by enhancing digestive enzyme activity and neutralizing toxins, which maximizes nutrient absorption (Arifin *et al.,* 2016). Ulum *et al.* (2018) also demonstrated that curcumin increases fish appetite and stimulates the secretion of bile and pancreatic enzymes such as amylase, lipase, and protease, thereby improving the digestion of carbohydrates, lipids, and proteins.

The consistent increases in both weight and length observed at P3 further confirm the statement of Shasia (2021) that body weight in fish increases proportionally with body length. The improved length growth in curcumin-fed larvae is likely associated with enhanced digestive performance and nutrient absorption, which increased feed intake. Putri *et al.* (2017) stated that curcumin stimulates bile release into the small intestine, thereby improving digestion and energy availability for growth. Similarly, Monoarfa *et al.* (2020) reported that curcumin can lyse toxins bound to the intestinal wall, resulting in better nutrient absorption and enhanced growth. Pengestu *et al.* (2016) also found that supplementation with Vitamin C and ginger containing curcumin in commercial feed produced optimal length growth in papuyu fish.

Specific growth rate in this study was also highest at P3, likely due to the optimal dose of curcumin that maximized both nutrient absorption and metabolic activity. This is supported by Elabd *et al.* (2021), who reported that curcumin supplementation improved growth performance and antioxidant status in Nile tilapia (*Oreochromis niloticus*) by increasing the activities of antioxidant enzymes such as superoxide dismutase, glutathione peroxidase, and catalase. Good health conditions are also critical in supporting growth performance, as they increase the efficiency of nutrient absorption and optimize metabolic activity (Pribadi *et al.,* 2021). Similar findings were reported by Li *et al.* (2022), who showed that dietary curcumin improved growth performance, immune response, antioxidant capacity, and inhibited apoptosis in snakehead fish (*Channa argus*). In tawes fish, feeding curcuma extract containing curcumin resulted in the best relative growth rate of 3.84%/day (Astuti *et al.,* 2017), while in seabream, the addition of curcumin increased the specific growth rate by 1.24%/day (Ashry *et al.,* 2021). Moreover, Rahmadani and Diniariwisan (2024) highlighted that curcumin supplementation enhances digestive enzyme activity, increases feed intake, promotes bile secretion, and supports more efficient nutrient absorption, all of which positively affect growth performance.

In summary, the results of this study clearly demonstrate that enrichment of silkworms with curcumin, particularly at a dose of 0.4 mg/kg, significantly improved the absolute weight, length, and specific growth rate of jelawat fish larvae. These improvements are attributed to the synergistic effects of curcumin, including stimulation of digestive enzymes, enhancement of bile secretion, regulation of metabolic activity, antioxidant protection, appetite stimulation, and improved nutrient absorption. Therefore, curcumin supplementation through silkworms enrichment can be considered an effective strategy to optimize fish growth and health.

Survival rate

Table 1 shows that the survival rate in this study reached 100%. This value shows that the survival rate of jelawat fish larvae is very good. Based on research conducted by Heltonika *et al.* (2015) studied the provision of curcumin in silkworms feed to obtain a survival rate of 100% in betok fish for each treatment. This research produces the same survival values as in previous research, it is suspected that natural food in the form of silkworms is the best food for jelawat fish larvae, while curcumin enrichment treatment helps in improving the quality of feed, so that it can increase growth as described by Syahendra *et al.* (2016) silkworms (*Tubifex* sp.) is a natural food that is widely used or exploited by farmers as food for fish larvae, including jelawat fish.

Choosing the right food to give to larval stage fish is also a factor in fish survival. Silkworms food has a high nutritional content and is a size that fits the mouth openings of fish larvae so that fish can consume it directly. Apart from that, silkworms are live animals which, when placed in a rearing container, will move, making the larvae interested in eating them (Pamulu *et al.,* 2017). The choice of silkworms food is also because this food does not damage the water quality in the rearing container. Proper nutrition and feed management play a vital role in ensuring fish health and preventing nutritional deficiencies that can lead to disease (Manam, 2023).

The combination of high-quality natural feed like *Tubifex sp.* and curcumin enrichment helps improve feed quality, contributing to the

high survival and optimal growth of jelawat fish larvae. Additionally, Rawung and Saruan (2020) found that curcumin supplementation in feed enhances liver productivity and reproductive performance in female common carp (*Cyprinus carpio* L.), leading to increased vitellogenin production, larger egg diameter, and higher larval survival rates. This suggests that curcumin plays a significant role in improving feed quality and overall fish health, which may also contribute to the high survival rate.

Behavior of fish larvae on feed

Based on Table 2, it can be seen that the results of observing the behavior of jelawat fish larvae for 40 days indicate the influence of silkworms enrichment on larval behavior. In the container with curcumin, the larvae moved wildly and were in the middle of the media, forming three groups but tended to spread out and the larvae were very aggressive when taking food. Briñez-Gallego *et al.* (2023) stated that curcumin can alleviate motor behavior impairments and reduce oxidative stress, suggesting its neuroprotective potential. Curcumin can protect against neurotoxic substances, improving motor behavior and reducing oxidative stress in zebrafish larvae. According to Filosa *et al.* (2016) feeding in fish follows a sequential process that begins with appetite, which drives responsiveness to sensory stimuli such as visual or olfactory cues, leading to food-searching and orientation behavior. Once the food source is located, fish determine its position and type before executing prey capture and ingestion, as demonstrated in studies on zebrafish and sablefish.

Based on observations of the behavior of larvae given silkworms with curcumin, on the fifth day of the study the larvae began to show active movement and response to the food provided and utilized the food for growth. According to Selvi *et al.* (2016) clinical symptoms of fish after giving curcumin showed that the fish had agile movements, the fish had good appetite and the fish's body color was bright, characterized by a shiny and clean body surface. Giving curcumin could also increase the fish's body strength. The curcumin compound functions as an immunostimulant capable of providing fish's immune response directly against antigens that enter the body fish (Dama *et al.,* 2021). According to Manoppo and Kolopita (2016), immunostimulants have a role as guardians of the immune system so that they can stimulate increased feed consumption in fish. The behavior of fish given curcumin shows that giving curcumin to fish does not have a negative effect, seen from the fish's agile movements and response to the feed given.

The larvae moved actively and accumulated in one spot in the larval treatment container without curcumin. The fish were in the middle of the media, formed two groups and were less aggressive in taking food. This is thought to be due to the absence of curcumin in the feed which functions to increase the fish's appetite. Curcumin has the property of stimulating liver cells to increase bile production and facilitate bile secretion/expulsion so that bile fluid increases. In this way, hunger will arise and stimulate appetite (Insana & Wahyu, 2015).

Water quality

Based on the data from water quality measurements during the research period in Table 3 can be seen that in general it is good enough to support the growth of jelawat fish. Temperatures during the study ranged from 27.2-29.5°C. This temperature range is still suitable for the growth and survival of jelawat fish larvae during the cultivation process. This is because jelawat fish can grow well at temperatures of 28,5-29°C (Putri *et al.,* 2021). The results of pH measurements during the research were 6.2-7.5.

In accordance with Mohamad *et al.* (2024) under the control condition of pH 7.0 and 28 °C, the fish exhibited normal feeding performance, a more stable metabolic state, and no significant gill damage was observed. This shows that the pH range during the study was optimal. pH conditions greatly influence the ability to grow, reproduce and live microorganisms in the rearing container (Inawati *et al.,* 2022). Dissolved oxygen (DO) during the study was 4.5-5.8. According to Putri *et al.* (2021), the normal dissolved oxygen (DO) value for living jelawat fish is between 3.4-5.8 mg/L. This shows that the DO value during the research was optimal in the growth and survival of jelawat fish larvae.

CONCLUSION

The results showed that treatment of silkworms enriched with curcumin at different doses had a significant effect ($P<0.05$) on the growth and survival of jelawat fish larvae. The best results are found in P_3 (curcumin 0.4 mg/kg silkworms) resulted in absolute weight growth of 2.26 ± 0.04 g, absolute length growth of 5.25 ± 0.03cm,

specific growth rate of 11.84 ± 0.04%, and survival of 100 ± 0.00%. Enrichment of silkworms with curcumin at different doses enhanced the growth performance and survival of jelawat fish larvae).

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