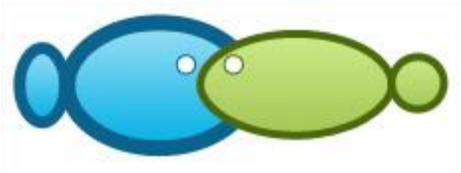

The effect of different doses of curcuma extract (*Curcuma xanthorrhiza*) added to commercial feed on the feed efficiency, growth and survival of the Java barb, *Barbonymus gonionotus* (Bleeker, 1849)

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Abstract. The Java barb (*Barbonymus gonionotus*) is a consumable fish with economic value and is affordable. However, one of the challenges in cultivating Java barb is its slow growth rate. Innovation in feed is necessary. Adding additives to feed helps increase the appetite of fish. One of the materials that can be used is curcuma (*Curcuma xanthorrhiza*) extract. The essential oil and curcumin content in *Curcuma* increases appetite, stimulates the bile walls to release fluid and stimulates the pancreas to secrete enzymes such as amylase, lipase, and protease to enhance digestion. This study aimed to determine the effect of adding curcuma extract to artificial feed on the growth performance and survival rate of Java barb. This study used 5 treatments and 4 replications. The treatments tested were A (0 g kg^{-1}), B (10 g kg^{-1}), C (15 g kg^{-1}), D (20 g kg^{-1}), and E (25 g kg^{-1}). The test fish used was Java barb with a weight of 2.44–2.67 g and a stocking density of 15 fish per container. The fish were maintained in 20 L aquariums. The maintenance was carried out for 42 days with feeding at 07:00, 12:00, and 17:00. The results showed that the addition of curcuma extract had a significant effect ($p<0.05$) on feed conversion ratio (FCR), specific growth rate (SGR), and absolute weight gain. The highest results were found in treatment D, which resulted in a total feed consumption of 54.36±2.47 g, a SGR of 83.04±2.46%, a FCR of 1.11±0.01, an absolute weight gain of 3.64±0.23 g, and a SGR per day of 1.82±0.04%. Meanwhile, the highest survival rate was in treatment B, with 96.67±3.85%.
Key Words: biomass, curcumin, fingerlings, production.

Introduction. The Java barb (*B. gonionotus*) is an indigenous freshwater aquaculture fish of Indonesia and is considered one of the economically viable consumption fish, affordable to the general public (Cahyanti et al 2022). According to Virianita et al (2020), the production of Java barb in Central Java Province in 2010 reached 1538.8 tons, with the highest output in Wonogiri Regency, accounting for 14.98% of the total production. Statistical data shows that Java barb farming production increased from 2016 to 2022, totaling 39100 tons per year (Perikanan 2022). According to Kusmini et al (2022), Java barb can be considered a superior commodity, given its abundance in various regions of Indonesia and its limited use as a consumption commodity. However, there are several challenges in cultivating Java barb, including its relatively slow growth. Safitri et al (2023) stated that a common issue in Java barb farming is slow growth due to the lack of enzymes that can help improve the fish's digestion process.

To improve feed quality, one of the strategies that can be employed is the addition of feed additives, which can increase appetite and feed consumption in cultured fish. Efforts to reduce production costs include applying the use of additives to primary feed (Haser et al 2018). One such additive is curcuma (*Curcuma* spp.) extract. Curcuma contains chemical compounds with active ingredients, such as curcuminoids and essential oils. Curcuminoids in curcuma are antibacterial, anticancer, and antitumor agents and contain antioxidants (Ngodu et al 2021). The essential oils and curcumin enhance appetite, stimulate the

gallbladder to release bile, and trigger the pancreas to secrete enzymes such as amylase, lipase, and protease, which aid in the digestion of carbohydrates, fats, and proteins in feed (Pangestu et al 2016).

Ardiansyah & Achmad (2020) conducted research using curcuma extract, showing that adding 12 g kg^{-1} curcumin extract resulted in the highest growth and survival rates for Tilapia fry (*Oreochromis niloticus*). Prabowo et al (2017) demonstrated that the highest growth was achieved with a 12 g kg^{-1} feed dosage, yielding an average fry weight of 1.97 g for milkfish (*Chanos chanos*). In a study by Astuti et al (2017), it was shown that the addition of curcumin extract to the feed had a significant effect on the feed consumption rate of Java barb. Additionally, a study by Herawati et al (2023) stated that the addition of curcumin extract at a dose of 12 g kg^{-1} produced the best results in the growth performance of cobia (*Rachycentron canadum*). Based on this research, the authors intend to study the effect of adding curcuma extract (*Curcuma xanthorrhiza*) to commercial feed on the feed efficiency, growth, and survival of Java barb.

Material and Method

Description of the study. The research activities were conducted from April to June 2024, at the Sawangan Fish Hatchery, Magelang, Central Java. The curcuma extract was obtained from an extraction process conducted at the Research and Integrated Testing Laboratory (LPPT) of Gadjah Mada University. The ginger was cleaned, then sliced thinly and dried in the sun. Once dry, the ginger was crushed using a blender and filtered to produce ginger powder. 500 g of ginger powder were macerated with 70% ethanol solution at room temperature for 3 days, then filtered through filter paper. Extraction was carried out with 70% ethanol solvent. The resulting filtrate was collected in a bottle using a funnel, then the solvent was separated using a rotating vacuum evaporator at a temperature of 40°C, speed of 100 rpm, and pressure of 0.7 bar, so that a pure extract was obtained (Amelinda et al 2018). The extract was then mixed with Aquadest according to the desired treatment, then sprayed evenly on the test feed and allowed to dry.

The test subjects were Java barb fry with an average weight of 2.44–2.67 g and an average length of 5.95 cm per fish. The stocking density for the test fish was 15 fish per maintenance container. The fish fry was obtained from the Freshwater Fish Hatchery and Aquaculture Ngrajek, Magelang, Central Java. The test feed used was commercial feed PF 500, mixing the feed with curcuma extract using a spraying method according to the given dosage. Maintenance was carried out for 42 days (Yuniarti et al 2022), with feeding done to satiation three times a day at 07:00, 12:00, and 17:00 WIB (Utami et al 2018).

Experimental design. The experiment proposed five treatments with four replications: treatment A with no addition of curcumin extract (0 g kg^{-1} feed), treatment B, with 10 g kg^{-1} feed, treatment C with 15 g kg^{-1} feed, treatment D, with 20 g kg^{-1} feed and treatment E with 25 g kg^{-1} feed.

Based on the proximate analysis results, the nutritional content of each treatment was as follows: treatment A (0 g kg^{-1}) contained 40.66% protein, 9.76% fat, 4.05% fiber, 9.35% ash, and 6.73% moisture; treatment B (10 g kg^{-1}) contained 40.56% protein, 9.02% fat, 3.76% fiber, 9.29% ash, and 6.89% moisture; treatment C (15 g kg^{-1}) contained 40.29% protein, 9.64% fat, 4.39% fiber, 9.36% ash, and 5.64% moisture; treatment D (20 g kg^{-1}) contained 40.07% protein, 3.96% fat, 3.82% fiber, 9.26% ash, and 5.41% moisture; treatment E (25 g kg^{-1}) contained 40.01% protein, 3.90% fat, 5.51% fiber, 9.27% ash, and 6.17% moisture.

Observed parameters. Every week, sampling was conducted to observe the growth performance parameters, which include total feed consumption (TFC), feed utilization efficiency (FUE), feed conversion ratio (FCR), biomass growth, specific growth rate (SGR), and survival rate (SR).

Total feed consumption (TFC). TFC represents the total quantity of feed consumed by the fish. According to Zonneveld et al (1991), the TFC can be calculated using the formula:

F=C-S

Where: F - feed consumption (g); C - administered feed (g); S - remaining feed (g).

The efficiency of feed utilization (FUE). FUE was calculated using the formula of Zonneveld et al (1991):

FUE=[(Wt-Wo)/F]x100

Where: Wt - final biomass at the end of the study (g); Wo - baseline biomass at the start (g); F - the amount of feed consumed during the study.

Feed conversion ratio (FCR). The formula of Zonneveld et al (1991) for FCR is:

FCR=F/[(Wt+D)-Wo]

Where: F - the amount of feed given (g); Wt - the weight of fish at the end of maintenance (g); Wo - the weight of fish at the beginning of maintenance (g); D - the weight of dead fish during maintenance (g).

Biomass growth. The growth of fish biomass is the difference between fish biomass at the end of rearing and fish biomass at the beginning of rearing, expressed in grams. According to Zonneveld et al (1991), the growth of biomass can be calculated using the formula:

W=Wt-Wo

Where: W - growth of biomass (g); W_t - fish biomass at the end of rearing (g); W_o - fish biomass at the start of rearing (g).

Specific growth rate (SGR). SGR is the daily growth expressed in % per day. According to Zonneveld et al (1991), the SGR can be calculated using the formula:

SGR=[(LnWt-LnWo)/t]x100

Where: SGR - specific growth rate (% day); Wo - fish biomass at the beginning of the study (g); Wt - fish biomass at the end of the study (g); t - time of the study (days).

Survival rate (SR). The SR of Java Barb was calculated using the following formula (Zonneveld et al 1991):

SR=Nt/N0x100

Where: SR - survival rate of Java Barb (%); Nt - the number of Java Barb at the end of the study; N0 - the number of java Barb at the beginning of the study.

Water quality parameters. Observations of the aquaculture water quality parameters during the study included temperature, pH, and dissolved oxygen (DO). The water quality measurements were taken before feeding. Water quality parameters were measured twice daily, in the morning and in the afternoon. The water quality was measured using a pH meter and a DO meter***.*** The water quality during the study is presented in Table 1.

Table 1

Water quality during the study

Parameter	*Value*	*Tolerable value*
DO (mg L^{-1})	4.2–6.6	>4[a]
Temperature (^{0}C)	26.4–28.1	25–29[b]
pH	6.85–7.01	6–9[c]

Note: [a] - Sipayung et al (2023); [b] - Fekri et al (2018); [c] - Harmilia et al (2020).

Proximate analysis. The feed's proximate analysis was conducted at the Agricultural Instrument Standard Application Center (BPSIP) testing laboratory in Central Java. Table 2 presents the proximate feed analysis with the addition of curcumin extract.

Table 2

The proximate composition of feed with the addition of curcumin extract

Treatments (mL kg-1 feed)	*Wet weight (%)*				
	protein	*moisture*	*Ash content*	*Fat*	*Fiber*
A (0)	40.66	6.73	9.35	9.76	4.05
B (10)	40.56	6.89	9.29	9.02	3.76
C (15)	40.29	5.64	9.36	9.64	4.39
D (20)	40.07	5.41	9.26	3.96	3.82
E (25)	40.01	6.17	9.27	3.90	5.51

Statistical analysis. The data were tested for normality, homogeneity, and additivity. If the data were normally distributed and homogeneous, an analysis of variance (ANOVA) was conducted (all data were normally distributed). ANOVA is performed to determine whether the treatments have an effect. If ANOVA shows significant differences ($p<0.05$), Duncan's multiple range test is conducted. Water quality data are analyzed descriptively. In this study the data obtained was normally distributed. Therefore, further tests were carried out using the Duncan test to compare the averages between treatments.

Results

Total feed consumption (TFC). The TFC of Java Barb during the study is presented in Figure 1. The highest TFC of Java Barb was observed in treatment D, 54.36±2.47 g, and the lowest in A, 38.19±1.09 g.

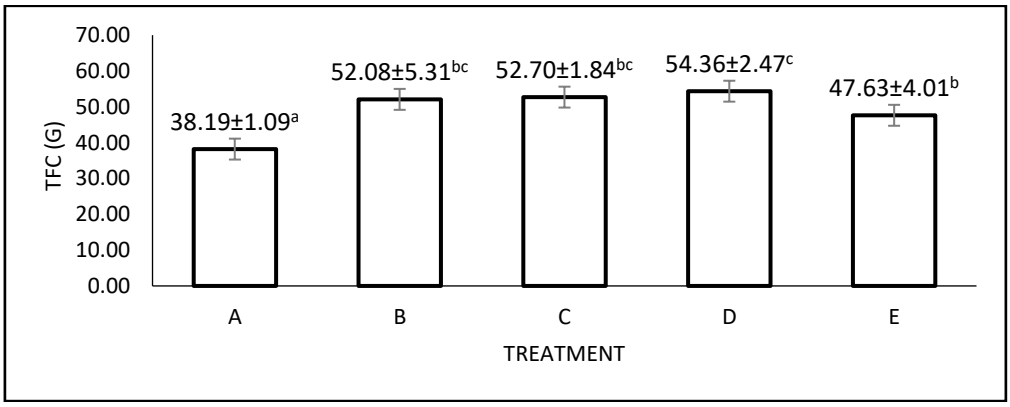

Figure 1. Total feed consumption (TFC) of Java barb (*Barbonymus gonionotus*); different superscripts indicate significant differences ($p<0.05$).

Feed utilization efficiency (FUE). The FUE of Java Barb during the study is presented in Figure 2. The highest FUE of java Barb was in treatment D, 83.04±2.46% and the lowest in treatment A, 46.86±3.57%.

Food conversion ratio (FCR). The FCR of Java Barb during the study is presented in Figure 3. The lowest FCR of Java Barb was in treatment D, 1.11±0.01 g and the highest in treatment A, 1.68±0.05 g.

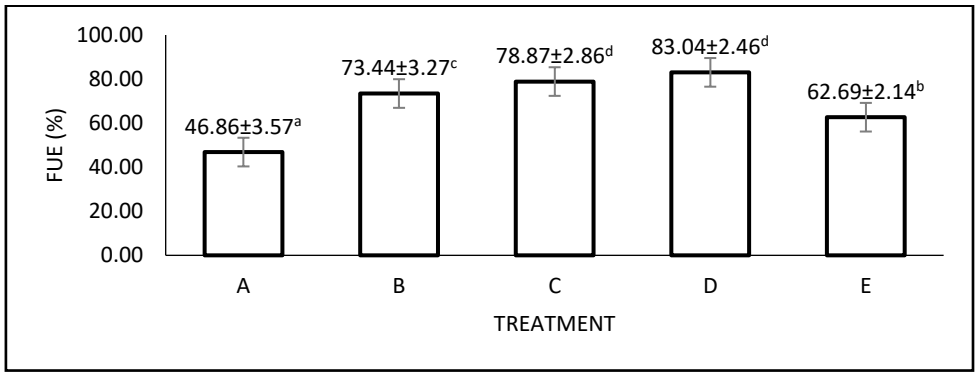

Figure 2. Feed utilization efficiency (FUE) of Java barb (*Barbonymus gonionotus*); different superscripts indicate significant differences ($p<0.05$).

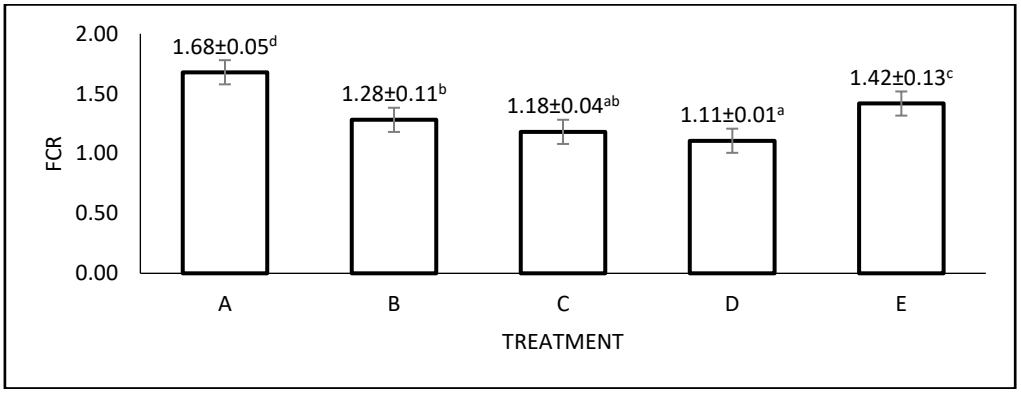

Figure 3. Food conversion ratio (FCR) of Java barb (*Barbonymus gonionotus*); different superscripts indicate significant differences ($p<0.05$).

Growth. The growth of Java barb during the study is presented in Figure 4. The highest growth was in treatment D, 3.64±0.23 g and the lowest in treatment A, 1.39±0.02 g.

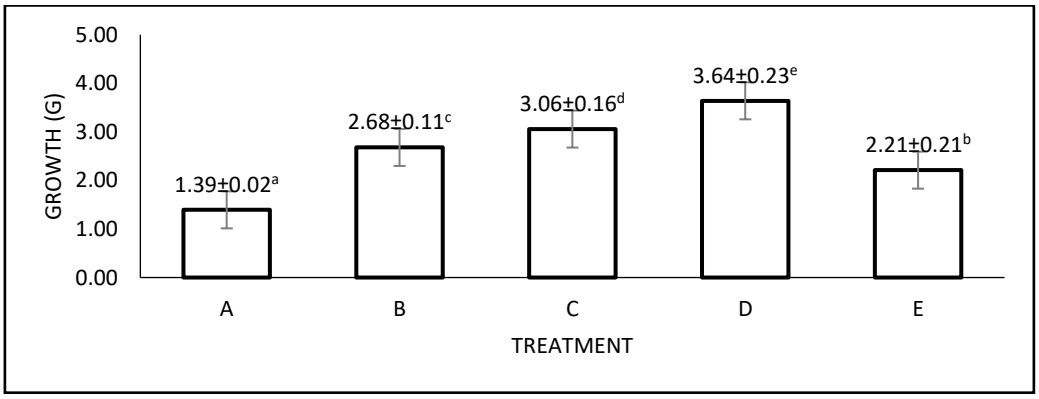

Figure 4. Growth of Java barb (*Barbonymus gonionotus*); different superscripts indicate significant differences ($p<0.05$).

Specific growth rate (SGR). The SGR of Java barb (*Barbonymus gonionotus*) during the study is presented in Figure 5. Java barb's highest SGR was in treatment D, 1.82±0.04%, and the lowest was in treatment A, 0.97±0.08%.

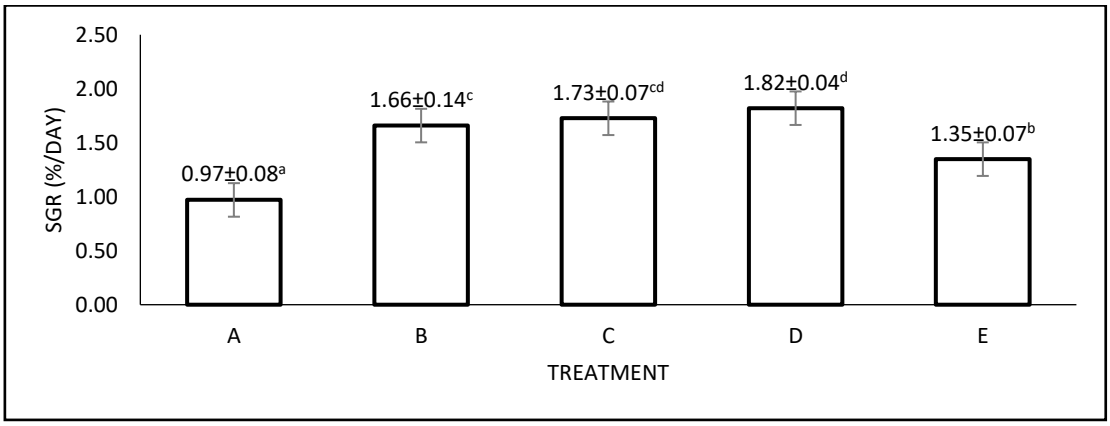

Figure 4. Specific growth rate (SGR) of Java barb (*Barbonymus gonionotus*); different superscripts indicate significant differences ($p<0.05$).

Survival rate (SR). The SR of Java barb during the study is presented in Figure 5. The highest SR of Java barb was in treatment B, 96.67±3.85% and the lowest in treatment A, 90.00±3.85%.

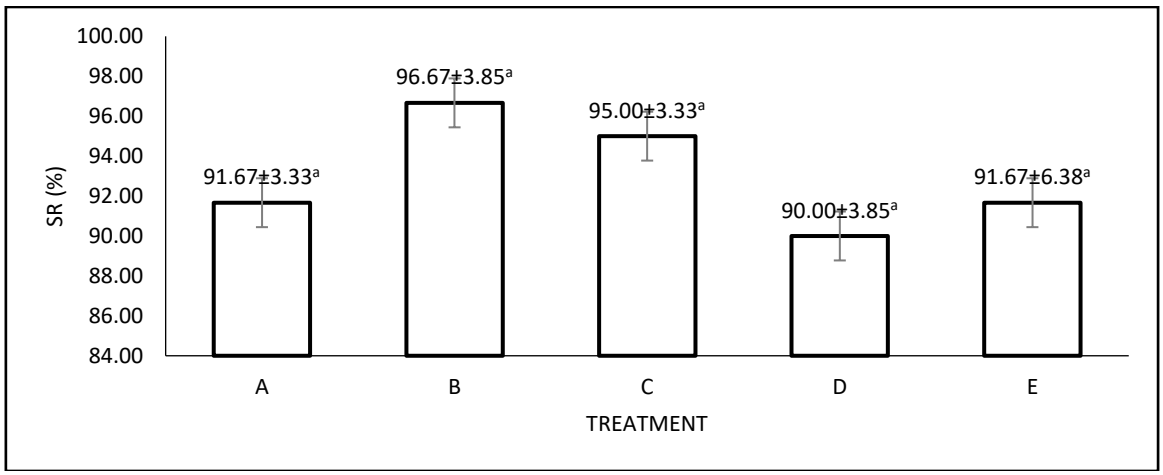

Figure 5. Survival rate (SR) of Java barb (*Barbonymus gonionotus*); different superscripts indicate significant differences ($p<0.05$).

Discussion. Feed consumption in fish increased from treatments A to D, likely due to the curcumin content from the curcuma extract. The curcumin can stimulate increased appetite in the reared fish. Curcumin promotes growth by enhancing the appetite of fish (Yandini et al 2023). This is supported by Mainassy et al (2022), who state that curcumin stimulates the gallbladder wall to release bile into the small intestine, thus improving the digestion of fats, proteins, and carbohydrates, which enhances nutrient absorption. Additionally, essential oils in curcumin may stimulate liver cells and bile secretion. Essential oils stimulate liver cells to increase bile production and facilitate bile secretion, increasing bile fluid (Farzaei et al 2018). Additionally, curcumin stimulates the gallbladder wall to release bile into the small intestine, improving the digestion of fats, proteins, and carbohydrates, and increasing nutrient absorption (Santika et al 2021). Feed consumption decreased in treatment E, likely due to the essential oil content in the curcuma extract, which made the feed taste bitter (Halawa et al 2023). The bitterness of the feed could have reduced the

fish's appetite. Moreover, the fish's response to the feed mixed with curcumin extract was somewhat slow, possibly due to the diminished characteristic odor of the feed after mixing.

The lower TFC compared to previous studies is suspected to be due to fish stress from the sampling process. Stressed fish experience reduced appetite. Stressors in fish trigger the hypothalamus to inhibit appetite. According to Mulyanti et al (2018), stressors stimulate the hypothalamus to secrete specific hormones to suppress fish appetite. This hormonal secretion stops when the stressor is removed or when the fish is in optimal conditions. The hypothalamus regulates feeding activity through orexigenic and anorexigenic centers, stimulating and inhibiting appetite and eating habits. Reduced appetite leads to a loss of energy sources for metabolic activities. Stressed fish require more energy to maintain balance in their bodies.

High-quality feed supports efficient fish growth. This is indicated by high FUE and low FCR. Adding curcuma extract improves FUE and FCR in the reared fish. The curcumin content is believed to enhance feed digestibility, thus maximizing growth rates in fish. Curcumin and essential oils also act as growth stimulants by stimulating the release of pancreatic juices containing amylase, lipase, and protease, which enhance digestion of carbohydrates, fats, and proteins (Halija et al 2019). Liang et al (2022) state that digestive enzymes in fish can enhance feed digestibility and promote growth. High feed efficiency indicates good feed quality. Good-quality feed also signifies efficient feed use, with minimal nutrients wasted for energy needs and growth. The results suggest that the feed provided during the observation period was of good quality. A low FCR value shows good feed quality. A high FCR indicates the feed quality is poor or inadequate for fish weight gain. Feed is considered good if its efficiency is above 50% (Ahmadi et al 2012).

Both internal and external factors can influence weight growth. Low curcuma dosage results in low performance and slower fish growth rates (Ulum et al 2018). Curcuma contains curcumin and essential oils that can affect the growth of Java barb (Ananda et al 2021). Weight increased in treatments A to D, but decreased in treatment E. This is suspected to be due to the excessive addition of curcuma extract, which reduced the characteristic odor of the fish. Good-quality feed should be easily digestible, free of toxins, and high in nutrients (Susantie & Manurung 2021). Assan et al (2021) add that body weight gain is also determined by the energy content in the feed that exceeds the requirements for maintenance and other bodily activities.

The values of absolute weight gain are closely related to the SGR in fish. The high FUE increases the reared fish's daily growth rate. The SGR is an essential parameter that describes how quickly fish grow over a particular period. Several factors affect the growth rate, including the feed quality. Fish prefer high-quality feed, as it promotes growth (Sepang et al 2021). Proper utilization of feed by fish results in energy for growth, metabolism, movement, and other activities (Nursihan et al 2020).

Protein in feed plays a crucial role in fish growth. Fish growth is closely related to the availability of protein in feed because protein is a tertiary energy source for fish and is very important in developing fish structure. Good growth is highly influenced by the amount of feed and the nutritional content provided (Purwati et al 2015). Good feed should be easily digestible, readily available, relatively inexpensive, and highly protein to ensure optimal individual growth. Protein is a crucial nutrient influencing fish growth (Ratnasari et al 2020).

Survival rate (SR). The highest mortality occurred during the early weeks of rearing, which is suspected to be due to the manipulation for measurements at the start of rearing. Prolonged sampling caused some fish to sustain injuries and become stressed, leading to death. Mulqan et al (2017) stated that various factors influence fish survival, including water quality, feed, fish age, environment, and health. Environmental factors play a significant role in determining the SR of fish larvae. Lower temperatures can reduce the appetite of fish larvae.

Overall, the SR of Java barb during the observation period was considered good. Curcumin can enhance the fish's immune system, helping to prevent disease outbreaks (Haetami et al 2023). Curcumin is a phenolic compound with antibacterial properties that

can boost the immune system against diseases (Pane et al 2018). Ahmadifar et al (2021) state that herbal supplements can improve fish immunity.

Water quality. The temperature range during the study, between 26.4 and 28.1°C, was considered suitable for the survival of Java barb. The optimal temperature range for fish in tropical waters is between 28°C and 32°C (Sianipar et al 2021). This aligns with Fekri et al (2018), who stated that the optimal temperature for fish is between 25°C and 29°C, and the ideal pH value for fish is between 6.0 and 7.1. Temperature conditions significantly affect fish life. Fish lose their appetite at low temperatures and become more susceptible to disease. Conversely, if the temperature is too high, fish experience respiratory stress and may even suffer gill damage (Harmilia et al 2020). The pH range during the study was between 6.85 and 7.01. The ideal pH for aquatic organisms is between 6.5 and 8.5. A pH level below 6 or above 8.5 should be monitored as it may indicate pollution, which can also cause disruptions in fish metabolism and respiration. According to Harmilia et al (2020), a pH range of 6-9 is ideal for fish production.

The range of DO used during the study was between 4.2 and 6.6 mg L^{-1}, very good for the growth of Java barb. This is consistent with the statement by Sipayung et al (2023), which notes that during the fry rearing phase, DO levels should be >4 mg L^{-1}, as fish in this phase have high metabolic rates and oxygen requirements. If the DO concentration is low, the appetite of the cultivated organisms decreases, affecting their growth and disease resistance. If low DO levels persist, the cultivated organisms will die due to oxygen deficiency. Oxygen deficiency (hypoxia) in water can disrupt the life and growth of the organisms living in it.

Conclusions. The addition of 20 mL of curcuma extract per kg of feed resulted in the highest TFC, FUE, FCR, absolute weight, and SGR in Java barb, with respective values of 54.36±2.47 g, 83.04±2.46%, 1.11±0.01, 3.64±0.23 g, and 1.82±0.04% day^{-1}. Meanwhile, the highest SR value was observed in the 10 g kg^{-1} addition treatment, reaching 96.67±3.85%.

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

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