Effect of *Curcuma xanthorrhiza* extract added in feed on the growth and body composition of cobia (*Rachycentron canadum*)

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Abstract. Cobia (*Rachycentron canadum*) have fast growth and adapt quickly to the environment. Giving curcuma (*Curcuma xanthorrhiza*) extract in feed represents an effort to increase feed efficiency, subsequently increasing nutrient metabolism. This study aims to determine cobia's growth performance and nutritional quality and the best ratio of curcuma extract in its feed. This study was an experimental study with four treatments: A - 0 mL kg^{-1} feed, B - 5 mL kg^{-1} feed), C - 10 mL kg^{-1} feed, and D - 15 mL kg^{-1} feed. The cobia used in this study was in stage D-40 (larvae), with an average weight of 4±0.12 g and an average length of 10±0.5 cm. Fish were maintained in nets measuring 40x40x50 cm in a pond of 1x4x0.5 m. The maintenance period was 40 days with 20 fish per net stocking density. The feeding frequency was four times per day using the at-satiation method. The results showed that curcuma extract significantly affected growth. The values of total feed consumption (TFC), biomass, absolute length, specific growth rate (SGR), protein efficiency ratio (PER), feed utilization efficiency (FUE), and feed conversion ratio (FCR) were highest in treatment D, with sequential values of 823.33 g, 36.38 g, 9.98 cm, 2.46% ind/day, 1.84%, 88.46%, 1.13, while the survival rate (SR) value of each treatment was 100%. Treatment D had the highest protein and fat concentration of cobia, with 62.15% and 8.04%, respectively. The essential amino acid with the highest concentration was methionine (11.95%), and the most elevated essential fatty acid was EPA (7.95%). The water quality during the research period was in good conditions for the growth of cobia.
Key Words: *C. xantorrhiza*, feed, nutrition, production.

Introduction. Cobia (*Rachycentron canadum*) has fast growth, can adapt to changes in environmental conditions, has high-quality meat, and can grow to a size of 3-4 kg in one year and 8-10 kg in two years (Gopakumar et al 2012). Cobia meat contains omega-3 fatty acids such as EPA and DHA (Setianingsih et al 2019). In addition, cobia meat is white and has good organoleptic properties, making it suitable for use in the sashimi industry (Nguyen et al 2019). Curcuma (*Curcuma xanthorrhiza*) is a natural ingredient that contains curcumin and essential oils. Fish farming activities and feed affect growth performance (Herawati et al 2019), so the quality and quantity of the aquafeed need to be considered. The addition of supplements is one of the efforts to increase feed efficiency, while the benefits of adding supplements to feed are increased fish endurance, help of the digestive system, increased feed efficiency, and increased fish appetite. From 10 g of turmeric powder, the total curcumin can reach 30.87 mg g^{-1} (Amelinda et al 2018). Curcumin and essential oils increase fish appetite, improve the work of digestive organs, stimulate the bile wall to secrete fluids, and stimulate the release of pancreatic juice, which contains digestive enzymes such as amylase, lipase, and protease in tilapia (*Oreochromis niloticus*) (Ardiansyah & Achmad 2020). Curcumin content in curcuma ranges between 0.95 and 2 g per 100 g dry weight (Susilowati et al 2014; Anggoro et al 2015; Sukaryo 2016).

Several studies have been carried out by adding curcuma to aquafeeds. Prabowo et al (2017) stated that the best dose was 12 g kg^{-1} of feed and produced an average weight of milkfish (*Chanos chanos*) fry of 1.97 g. Adding 15 mL kg^{-1} of curcuma extract to the feed resulted in the best growth *Lates calcalifer* (Pinandoyo et al 2019). This study

aimed to determine the growth performance, body composition, and nutritional quality of cobia after adding curcuma extract to its feed.

Material and Method

Experimental design. The experiment proposed four treatments with three replications: treatment A with no addition of the curcumin extract (0 mL kg^{-1} feed); treatment B with 5 mL of extract per kg of feed (0.77 mg curcumin); treatment C with 10 mL per kg of feed (1.55 mg curcumin) and treatment D with 15 mL per kg of feed (2.33 mg curcumin).

Curcuma extract preparation. Fresh curcuma was washed and thinly sliced, and dried in the sun. After drying, it was mashed using a blender and sifted to obtain curcuma powder (Anggoro et al 2015). 500 g of curcuma powder were macerated using 70% ethanol at room temperature for 3x24 h and filtered using filter paper. Cendrianti et al (2014) stated that maceration extraction can be carried out using 70% ethanol solvent for 3x24 h. The filtrate obtained was collected in a bottle using a funnel, then the filtrate was separated from the solvent using a rotatory vacuum evaporator at a temperature of 40°C, at a speed of 100 rpm, and a pressure of 0.7 bar to obtain a pure extract (Amelinda et al 2018). The curcuma extract was mixed with Aquadest according to the treatment and sprayed on the test feed until evenly distributed and aerated.

Maintenance of fish. The containers used for maintenance used 12 nets of 40x40x50 cm. The containers were sterilized and filled with water (70% of the volume). The cultivation container used an aquaculture recirculation system (RAS). Before starting the rearing, the test fish were acclimatized for three days to adapt to the new environment or rearing media. During acclimatization, cobia was fed. The length of maintenance was 40 days, with the frequency of feeding four times a day with the at-satiation method. Cobia juveniles stage D-40 (with a size of 4±0.12 g and a length of approximately 10 cm) originating from the Lampung Marine Aquaculture Center (BBPBL) Hatchery were used. The stocking density of the tested fish was 20 fish per net. The total number of fish used in the study was 240 fish.

Observed parameters. Once every week, sampling was conducted to observe the growth performance parameters, which consist of total feed consumption (TFC), biomass growth, body length growth, specific growth rate (SGR), feed utilization efficiency (FUE), protein efficiency ratio (PER), feed conversion ratio (FCR), 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 total feed consumption can be calculated using the formula:

$$F=C-S$$

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

$$W=W_t-W_o$$

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).

Body length growth. Body length growth is the growth of a fish's body length from the beginning to the end of maintenance. The following formula was used to calculate growth in body length (Zonneveld et al 1991).

$L=L_t-L_o$

Where: L - growth of body length (cm); L_t – total length of fish at the end of rearing (cm); L_o – total length of fish at the beginning of rearing (cm).

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).

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

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

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

Protein efficiency ratio (PER). The following Zonneveld et al (1991) formula was used to calculate PER:

PER=[(Wt-Wo)/Pi]x100

Where: Wt - weight of fish at the end of maintenance (g); Wo - weight of fish at the beginning of maintenance (g); Pi - protein content x amount of feed consumed.

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

SR=Nt/N0x100

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

Water quality parameters. Water quality parameters were measured at the beginning and end of the study. The water quality parameters measured were salinity, dissolved oxygen (DO), temperature, and pH. Salinity was measured using a refractometer. DO and temperature were measured using WQC. The pH was determined in the laboratory, with a pH test. The water quality during the study is presented in Table 1.

Table 1

Water quality during the study

Parameter	*Value*	*Tolerable value*
Dissolved oxygen (mg L^{-1})	4.66-5.39	4*
Temperature (°C)	28.7-29.1	23.4-31.8**
Salinity (ppt)	32	30-34***
pH	7.69-7.76	7-8.5****

Note: * - Fisheries Laboratory and Environmental Health Examination Center for Aquaculture (BBPBL) Lampung; ** - Benetti et al (2008); *** - Chou et al (2004); **** - Nguyen et al (2019).

Proximate analysis. Proximate analysis (AOAC 2005) was used to determine the content in protein, fat, ash, carbohydrates, and water of cobia (100 g dried cobia). The protein analysis was determined using the Kjeldahl method, while the fat content was determined using the Soxhlet method. Analysis of water and ash content was carried out using gravimetric principles. The breakdown of carbohydrates was calculated manually based on the proximate analysis results.

Amino acid analysis. Amino acids were analyzed for feed and cobia using an HPLC type 1100 apparatus with Eurosphere 100-5 C18, 250×4.6 mm column with initial P/N: 1115Y535. The wastes were: A) 0.01 M acetate buffer at pH 5.9; B) 0.01 M MeOH acetate buffer at pH 5.9; THF>80:15:5 Fluorescence: Extra: 340 mm Em: 450 nm. Samples (2.5 g) were placed in a closed glass, and 15 mL of 6 M HCl were added. Furthermore, the mixture was vortexed for homogeneity and hydrolyzed in an autoclave at 110ºC for 12 h before being cooled to room temperature and neutralized with 6 M NaOH. After adding 2.5 mL of 40% lead acetate and 1 mL of 15% oxalic acid, 3 mL of the mixture were filtered off with a 0.45 m Millex-HV filter (Merck KGaA, Darmstadt, Germany). 25 µL of the filtered mixture plus 475 mL of the OPA anhydrase solution were stirred and incubated for 3 min for injection into the HPLC system. Finally, 30 mL of the final mixture were placed into the HPLC system (AOAC 2005).

Fatty acid analysis. The fatty acid profile of fish and feed were analyzed using the QP-2010 Gas Chromatograph - Mass Spectrophotometer (GCMS) (Shimadzu) and Mass Spectrophotometer, which has a column length of 50 m, with a diameter of 0.22 mm Wall Coat Open Tubular CP-SIL-88 (Agilent, Santa Clara, CA, USA). The analyses were carried out over a column temperature range of 120-200°C. The method used was *in-situ* trans-certification. 100 mg of the sample was homogenized using 4 mL of water. The 100 mL homogenate obtained was transferred into a test tube. 100 µL of methylene chloride were added, along with 1 mL of 0.5 M NaOH in methanol. After adding N and the tubes were tightly closed, they were heated to 90°C for 10 min. The test tube was cooled, and 1 mL of 14% BF3 in methanol was added. After adding N, it was heated at the same temperature for 10 min. After that, the test tube was cooled to ambient temperature, and 1 mL of water and 200-500 mL of hexane were added. The mixture was stirred for 1 min to extract the methyl ester from the fatty acids. After centrifugation, the top layer of the sample was ready for GC analysis (AOAC 2005).

Statistical analysis. SGR, absolute length growth, biomass, SR, proximate composition, amino acid profile, and fatty acid profile were statistically analyzed using the normality, homogeneity, and additivity tests before being tested by Analysis of Variance (ANOVA). Water quality parameters were analyzed descriptively and compared with references. If ANOVA showed differences, Duncan's multiple range test ($p<0.05$) was used to determine the exact pairs of datasets with significant differences.

Results. The proximate analysis of feed with the addition of curcumin extract (dry weight) for cobia is presented in Table 2. The highest nutritional content was found in treatment D, while the lowest nutrient content was found in treatment A.

Table 2

The proximate composition of feed with the addition of curcumin extract

Treatments (mL kg^{-1} feed)	*Dry weight content (%)*				
	Protein	*Carbohydrate*	*Crude fat*	*Ash*	*Crude fiber*
A (0)	44.97±0.01	24.35±0.02	12.99±0.02	10.58±0.06	5.11±0.02
B (5)	46.64±0.02	22.63±0.05	13.39±0.02	10.19±0.01	6.15±0.05
C (10)	46.95±0.09	22.18±0.04	13.57±0.02	10.22±0.02	6.08±0.03
D (15)	47.55±0.03	21.51±0.03	14.23±0.03	9.18±0.03	6.53±0.08

Amino acid profile of the feed. The amino acid profile of the feed with the addition of curcumin extract for cobia is presented in Table 3. Lysine had the highest concentration (10.23%) of essential amino acids, while glutamic acid had the highest concentration (7.87%) among non-essential amino acids, both in treatment D.

Table 3

Amino acid profile of feed with the addition of curcumin extract

Amino acid (%)	*Treatment (mL kg^{-1} feed)*			
	A (0)	*B (5)*	*C (10)*	*D (15)*
Aspartic acid	6.89±0.05^{b}	5.94±0.07^{a}	5.82±0.09^{a}	5.44±0.01^{a}
Proline	3.55±0.09^{a}	4.08±0.07^{b}	3.44±0.04^{a}	4.7±0.09^{c}
Serine	7.56±0.02^{d}	4.76±0.03^{a}	6.63±0.08^{c}	5.62±0.03^{b}
Glutamic acid	7.66±0.02^{c}	6.36±0.02^{a}	7.35±0.02^{b}	7.87±0.07^{b}
Glycine	6.93±0.06^{d}	3.33±0.01^{b}	2.78±0.07^{a}	4.19±0.01^{c}
Histidine	5.78±0.02^{b}	8.25±0.01^{c}	5.50±0.05^{a}	5.7±0.09^{b}
Arginine	4.05±0.01^{a}	5.85±0.05^{c}	4.89±0.08^{b}	7.28±0.08^{d}
Threonine	3.02±0.09^{a}	3.47±0.06^{b}	4.16±0.03^{c}	6.37±0.06^{d}
Alanine	5.22±0.03^{c}	4.51±0.08^{b}	3.98±0.01^{a}	5.51±0.04^{d}
Valine	3.24±0.09^{a}	3.72±0.05^{b}	4.13±0.07^{c}	4.87±0.03^{d}
Methionine	3.11±0.02^{a}	3.89±0.09^{b}	4.4±0.05^{c}	8.4±0.07^{d}
Lysine	3.57±0.07^{a}	4.59±0.03^{b}	6.99±0.02^{c}	10.23±0.01^{d}
Isoleucine	3.99±0.01^{a}	5.87±0.02^{c}	4.5±0.07^{b}	7.27±0.04^{d}
Leucine	4.44±0.05^{a}	4.97±0.02^{b}	5.46±0.09^{c}	5.57±0.05^{d}
Phenylalanine	4.99±0.07^{a}	5.41±0.07^{b}	4.97±0.05^{a}	5.98±0.1^{c}
Tryptophan	7.23±0.06^{c}	6.93±0.01^{b}	7.78±0.07^{d}	4.19±0.01^{a}

Note: Different superscripts indicate significant differences between treatments ($p<0.05$).

Fatty acid profile of the feed. The fatty acid profile of feed with the addition of curcumin extract is presented in Table 4. EPA had the highest concentration (13.13%) of essential fatty acids, while palmitic acid had the highest concentration (8.59%) of non-essential fatty acids, both found in treatment D.

Table 4

Fatty acid profile of feed with the addition of curcumin extract

Fatty acid profile (%)	*Treatment (mL kg^{-1} feed)*			
	A (0)	*B (5)*	*C (10)*	*D (15)*
C14:0 (Myristic)	9.52±0.09^{b}	10.49±0.06^{c}	5.41±0.02^{a}	5.48±0.09^{a}
C15:0 (Pentadecanoic)	6.76±0.08^{b}	7.18±0.03^{c}	6.17±0.04^{a}	6.15±0.08^{a}
C16:0 (Palmitic)	5.14±0.07^{a}	6.29±0.09^{b}	7.97±0.08^{c}	8.59±0.04^{d}
C18:0 (Stearic)	5.71±0.05^{c}	6.65±0.01^{d}	5.52±0.03^{b}	4.91±0.09^{a}
C18:1 n-9 (Oleic/ω9)	8.07±0.03^{c}	4.95±0.03^{a}	4.89±0.08^{a}	6.61±0.01^{b}
C18:2 n-6 (Linoleic/ω6)	4.83±0.09^{a}	5.46±0.07^{b}	6.49±0.07^{c}	8.07±0.02^{d}
C18:3 n-3 (Linolenic/ω3)	3.54±0.02^{a}	4.76±0.08^{b}	4.89±0.03^{c}	7.32±0.01^{d}
C20:0 (Arachidic)	7.3±0.04^{d}	2.83±0.02^{a}	6.02±0.04^{c}	3.05±0.03^{b}
C20:4 n-6 (Arachidonic)	2.71±0.03^{a}	4.15±0.03^{b}	6.15±0.09^{c}	8.23±0.07^{d}
C20:5 n-3 (EPA)	6.19±0.08^{a}	9.64±0.07^{b}	10.88±0.02^{c}	13.13±0.08^{d}
C22:6 n-3 (DHA)	2.23±0.05^{a}	3.08±0.04^{b}	5.07±0.01^{c}	6.17±0.03^{d}

Note: Different superscripts indicate significant differences between treatments ($p<0.05$).

Total feed consumption (TFC). The TFC of cobia during the study is presented in Figure 1. The highest TFC of cobia was observed in treatment D, 823.33±0.8 g, and the lowest in control, of 680±0.2 g.

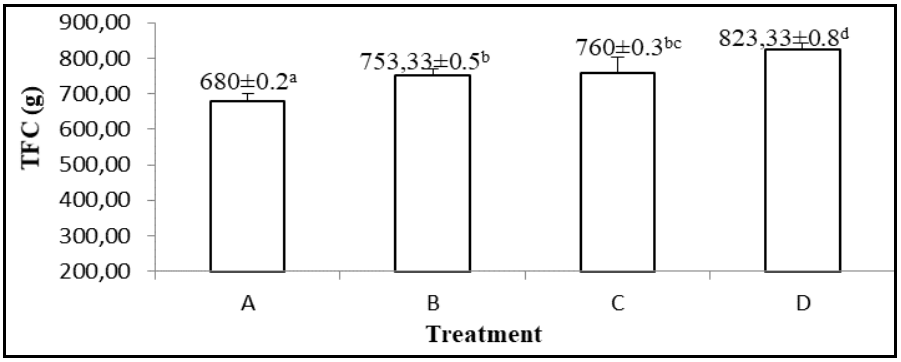

Figure 1. Total feed consumption (TFC) of cobia (*Rachycentron canadum*); different superscripts indicate significant differences ($p<0.05$).

Biomass growth. Figure 2 presents the growth of cobia during the study. The highest biomass growth of cobia was in feeding treatment D, namely 36.38±0.89 g and the lowest biomass growth was in the feeding treatment A, 25.57±0.81 g.

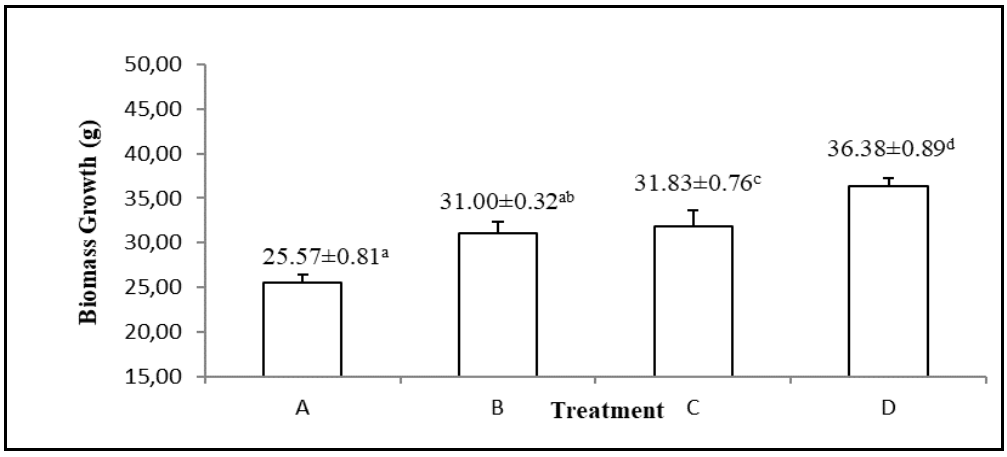

Figure 2. Biomass of cobia (*Rachycentron canadum*); different superscripts indicate significant differences ($p<0.05$).

Absolute length growth. Figure 3 presents the absolute length growth of cobia during the study. The highest absolute length growth of cobia was in treatment D (9.98±0.38 cm), and the lowest was in the control treatment (7.7±0.5 cm).

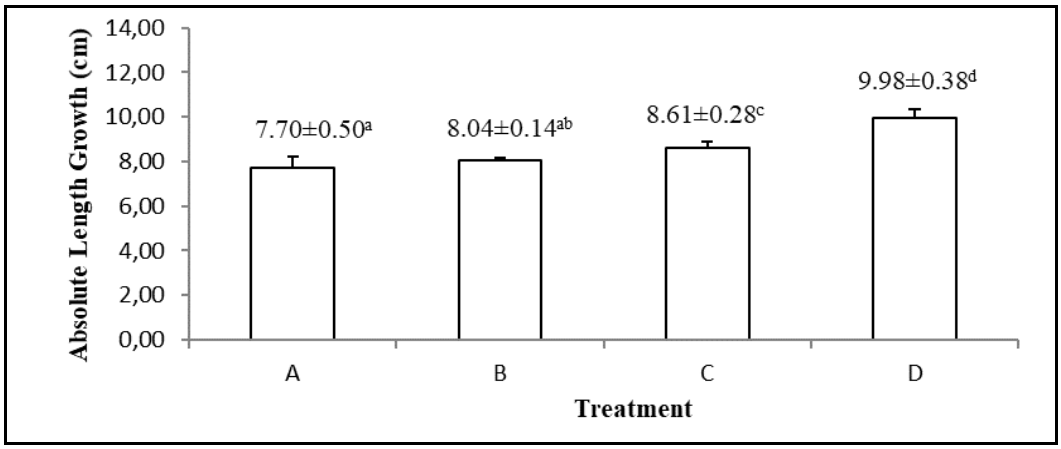

Figure 3. The absolute length growth rate of cobia (*Rachycentron canadum*); different superscripts indicate significant differences ($p<0.05$).

Specific growth rate (SGR). Figure 4 presents the SGR of cobia during the study. The SGR of cobia was highest in treatment D (2.46±0.17% day^{-1}), and the lowest in treatment B (1.97±0.20% day^{-1}).

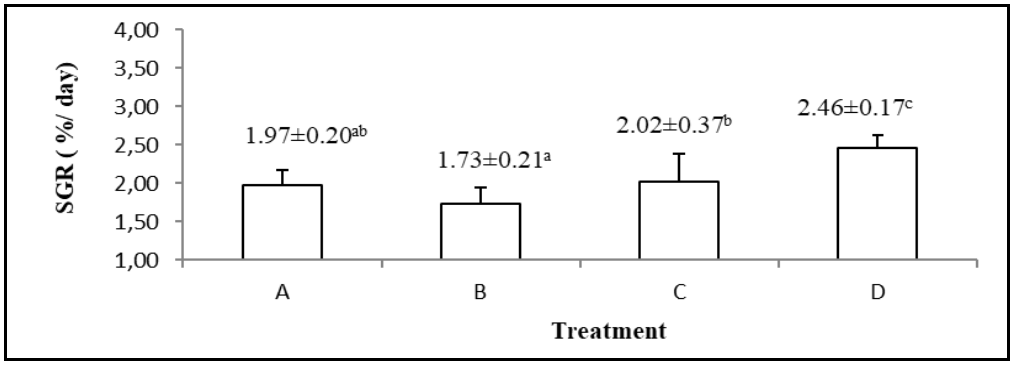

Figure 4. The specific growth rate (SGR) of cobia (*Rachycentron canadum*); different superscripts indicate significant differences (p<0.05).

Feed conversion ratio (SGR). The FCR of cobia during the study is presented in Figure 5. The best FCR of cobia was in treatment D (1.13±0.05), and the highest FCR value was in treatment A (1.35±0.09).

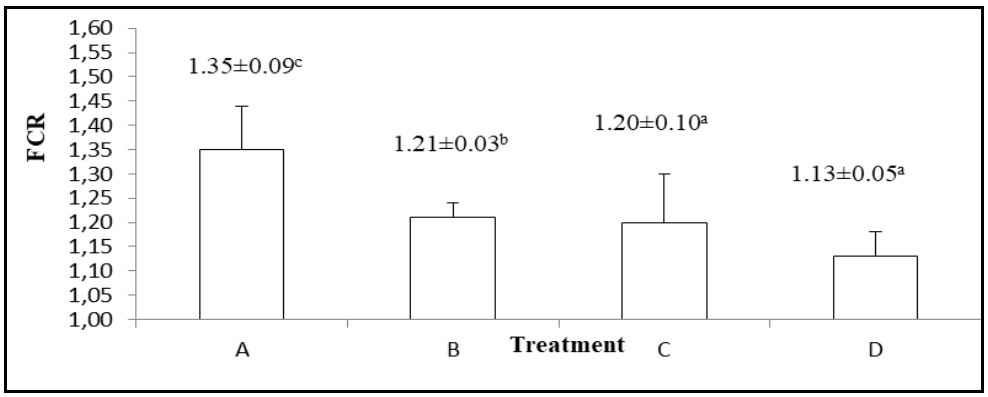

Figure 5. The feed conversion ratio (FCR) of cobia (*Rachycentron canadum*); different superscripts indicate significant differences (p<0.05).

Feed Utilization Efficiency (FUE). The FUE of cobia during the study is presented in Figure 6. The highest FUE of cobia was in treatment D (88.46±4.32%) and the lowest in treatment A (74.61 ± 5.23%).

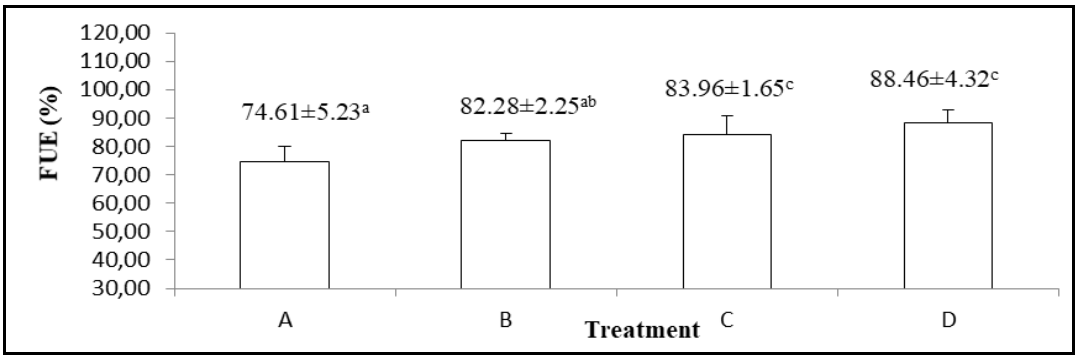

Figure 6. The feed utilization efficiency of cobia (*Rachycentron canadum*); different superscripts indicate significant differences (p<0.05).

Protein Efficiency Ratio (PER). The PER of cobia during the study is presented in Figure 7. The highest PER of cobia was in treatment D (1.84±0.07) and the lowest in the control (1.55±0.11%).

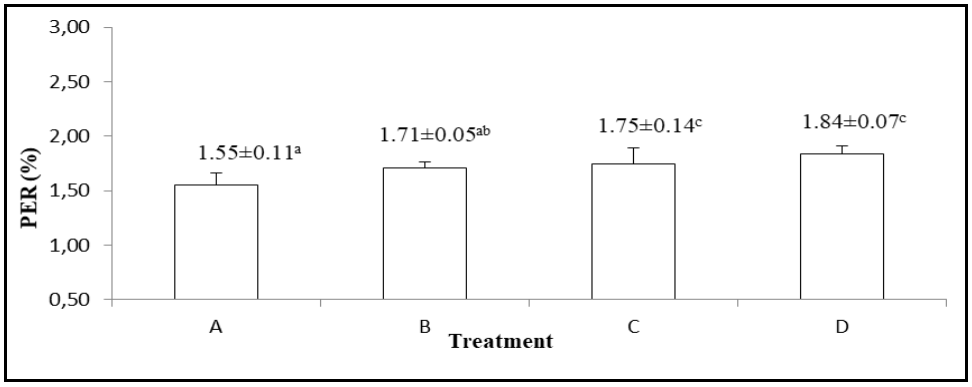

Figure 7. The protein efficiency ratio (PER) of cobia (*Rachycentron canadum*); different superscripts indicate significant differences ($p<0.05$).

Survival rate (SR). The SR of cobia during the study is presented in Figure 8. Cobia did not die during rearing. The SR was the same in each treatment (100%).

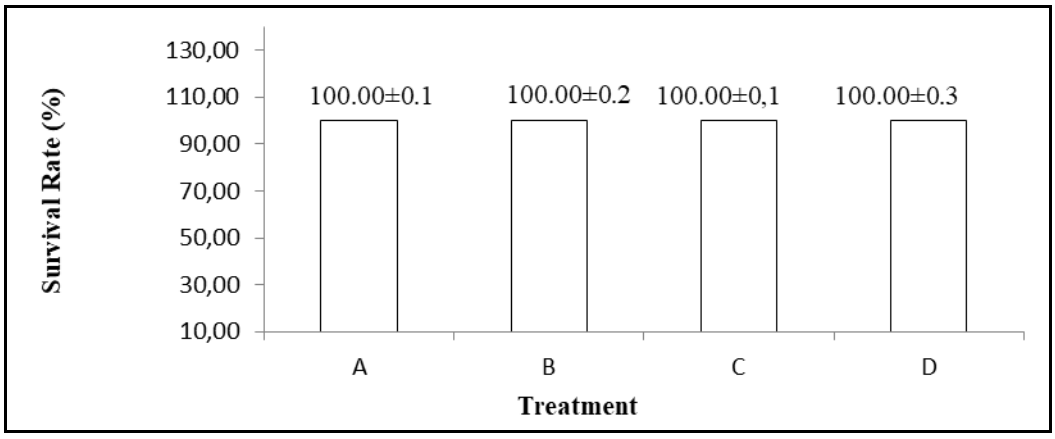

Figure 8. The survival rate of cobia (*Rachycentron canadum*); different superscripts indicate significant differences ($p<0.05$).

Body chemical composition. The proximate analysis results for cobia fed with the addition of curcumin extract are presented in Table 5.

Table 5

The proximate analysis results for cobia (*Rachycentron canadum*) fed with the addition of curcumin extract

Treatments (mL curcumin kg^{-1} feed)	*Wet weight (%)*				
	Protein (%)	*Moisture (%)*	*Crude fat (%)*	*Ash (%)*	*Carbohydrate (%)*
A (0)	48.16±0.01^{a}	16.37±0.02	18.59±0.02^{a}	8.83±0.06	8.05±0.02
B (5)	50.65±0.02^{b}	13.61±0.05	19.84±0.02^{b}	7.18±0.01	8.72±0.05
C (10)	51.12±0.09^{b}	12.57±0.04	19.82±0.02^{b}	8.83±0.02	7.66±0.03
D (15)	54.04±0.03^{c}	12.57±0.03	20.04±0.03^{b}	6.99±0.03	6.36±0.08

Note: different superscripts indicate significant differences ($p<0.05$).

The highest nutritional content was found in fish from treatment D, with 54.04% protein and 20.04% fat. The lowest nutrient content was found in fish from treatment A (protein content of 48.16% and fat content of 18.59%). The amino acid profile of cobia fed with curcumin extract is presented in Table 6.

Table 6

The amino acid profile of cobia (*Rachycentron canadum*) fed with curcumin extract

Amino acid (%)	*Treatment (mL kg^{-1} feed)*			
	A (0)	*B (5)*	*C (10)*	*D (15)*
Aspartic acid	5.63±0.05^{b}	6.06±0.06^{c}	6.18±0.09^{d}	5.19±0.09^{a}
Proline	5.08±0.09^{c}	5.75±0.09^{d}	2.84±0.03^{a}	4.87±0.07^{b}
Serine	6.06±0.02^{c}	6.1±0.01^{a}	4.46±0.09^{b}	4.75±0.03^{b}
Glutamic acid	4.36±0.07^{c}	5.35±0.05^{a}	6.16±0.08^{b}	7.81±0.03^{a}
Glycine	6.23±0.02^{c}	6.26±0.07^{c}	5.98±0.05^{b}	5.3±0.06^{a}
Histidine	4.65±0.03^{a}	5.8±0.05^{b}	6.79±0.11^{a}	5.9±0.09^{b}
Arginine	7.85±0.07^{a}	6.28±0.07^{b}	6.27±0.02^{b}	6.36±0.08^{b}
Threonine	6.47±0.07^{a}	5.89±0.09^{b}	6.67±0.04^{c}	7.28±0.06^{d}
Alanine	6.51±0.01^{d}	4.95±0.08^{a}	5.17±0.03^{b}	6.2±0.09^{c}
Valine	4.89±0.03^{a}	6.09±0.04^{b}	6.98±0.08^{c}	6.1±0.03^{d}
Methionine	4.72±0.06^{a}	4.9±0.03^{b}	7.88±0.03^{c}	11.95±0.05^{d}
Lysine	6.7±0.06^{a}	7.75±0.04^{b}	8.8±0.03^{c}	8.33±0.03^{d}
Isoleucine	5.97±0.02^{c}	4.09±0.02^{a}	4.95±0.08^{b}	5.23±0.02^{c}
Phenylalanine	4.51±0.07^{a}	4.98±0.09^{b}	4.8±0.07^{b}	5.48±0.01^{c}
Leucine	5.47±0.05^{d}	3.38±0.01^{a}	5.07±0.02^{c}	4.75±0.03^{b}
Tryptophan	6.23±0.06^{b}	6.93±0.01^{c}	5.78±0.07^{c}	4.19±0.01^{a}

Note: different superscripts indicate significant differences ($p<0.05$).

Methionine is the essential amino acid with the highest concentration in fish from treatment D (11.95%), while glutamic acid was the non-essential amino acid with the highest concentration, also in cobia from treatment D (7.81%). The fatty acid profile of cobia fed with curcumin extract is presented in Table 7.

Table 7

The fatty acid profile of cobia (*Rachyteron canadum*) fed with curcumin extract

Fatty acid	*Treatment (mL kg^{-1} feed)*			
	A (0)	*B (5)*	*C (10)*	*D (15)*
C14:0 (Myristic)	6.57±0.04^{c}	4.75±0.05^{b}	3.5±0.02^{a}	4.68±0.09^{b}
C15:0 (Pentadecanoic)	2.38±0.06^{b}	1.72±0.06^{a}	2.27±0.04^{b}	2.45±0.08^{b}
C16:0 (Palmitic)	4.77±0.08^{a}	5.14±0.09^{b}	4.97±0.08^{a}	6.09±0.04^{c}
C18:0 (Stearic)	5.75±0.02^{d}	2.71±0.07^{a}	5.52±0.03^{c}	3.11±0.09^{b}
C18:1 n-9 (Oleic/ω9)	1.9±0.03^{a}	3.37±0.02^{b}	3.89±0.08^{b}	5.85±0.01^{c}
C18:2 n-6 (Linoleic/ω6)	2.3±0.07^{a}	4.6±0.09^{b}	4.49±0.07^{b}	5.37±0.02^{c}
C18:3 n-3 (Linolenic/ω3)	2.3±0.09^{a}	2.54±0.05^{b}	3.39±0.03^{c}	4.32±0.01^{d}
C20:0 (Arachidic)	2.7±0.02^{c}	2.3±0.08^{b}	2.02±0.04^{a}	4.05±0.03^{d}
C20:4 n-6 (Arachidonic)	4.19±0.05^{a}	4.07±0.02^{a}	4.15±0.02^{a}	5.13±0.08^{b}
C20:5 n-3 (EPA)	3.08±0.04^{a}	3.83±0.05^{b}	4.07±0.01^{c}	7.95±0.03^{d}
C22:6 n-3 (DHA)	4.23±0.07^{a}	5.23±0.02^{b}	5.68±0.02^{c}	6.87±0.08

Note: different superscripts indicate significant differences ($p<0.05$).

EPA and DHA had the highest concentrations of the essential fatty acids, while palmitic acid had the highest concentration of the non-essential fatty acids in cobia, both in treatment D. EPA had a concentration of 7.95% and palmitic acid a concentration of 6.09%.

Discussion. Growth can be seen from the weight, length, and SGR obtained in this study. The best results were obtained in treatment D, and the lowest in the control. Treatment D had a higher curcumin level than the other treatments. This could have increased fish appetite, TFC, and growth. Curcumin increases feed digestibility (Anggoro et al 2015), and cobia uses feed more efficiently. Curcumin and essential oils found in curcuma can increase appetite in fish (Insana & Farhana 2015). Curcumin and essential oils also function as growth boosters because they stimulate pancreatic juice, releasing amylase, lipase, and protease enzymes. These enzymes can improve the digestion of carbohydrates, fats, and proteins (Halija et al 2019). The high TFC is due to the excellent quality of the feed. The quality of feed can increase feed efficiency, lowering FCR. Good growth is strongly influenced by the amount of feed and the nutritional content provided (Purwati et al 2015). Feeds with appropriate nutritional content can accelerate growth and improve fish survival.

Research on the addition of curcuma to fish feed has been carried out by Prabowo et al (2017), who added curcuma in milkfish diets (12 g kg^{-1} feed), which resulted in a milkfish weight growth of 1.97 g, and by Ardiansyah & Achmad (2020), where the addition of curcuma extract (12 g kg^{-1} of feed) resulted in the growth of tilapia. Prastito et al (2018) obtained a catfish (*Clarias gariepinus*) SGR of 2.46% day^{-1} by adding 6 mL kg^{-1} of curcuma extract to the feed. Likewise, a study by Ivandari et al (2019) found that adding an immunity supplement with the main content of curcuma (15 mL kg^{-1} of feed) resulted in a SGR of *L. calcarifer* of 3.31% day^{-1}. However, research on the use of curcuma in fish feed is still rarely carried out on marine fish, especially cobia. Thus, this study shows that adding curcuma to cobia fish feed can result in better growth.

The SR of cobia fish during the study did not experience differences, being 100% in all treatments. Environmental factors affect the survival of fish. According to Herawati et al (2018), fish survival is influenced by age and environmental factors. Fish survival is also affected by handling. Curcuma extract could provide a direct immune response to cobia against pathogens. Putri et al (2017) states that curcuma contains anti-bacterial compounds such as flavonoids, saponins, and tannins. Flavonoids function to inactivate bacterial cell membrane proteins, causing the protein structure to be damaged and the bacterial cell wall to be unstable. Saponins function to lyse bacterial cell walls. Meanwhile, tannins damage bacterial cell walls, inactivate enzymes, and destroy genetic material from bacteria. Curcuma contains vitamin C and minerals, which, in addition to playing a role in supporting growth, also act as a booster for the immune system of fish (Ardiansyah & Achmad 2020).

The protein content in treatment D feed was 47.55% and fat content was 14.23%, above the requirements of cobia fish, 45% and 10%, respectively (Setianingsih et al 2019). Protein and fat in feed play an essential role in the structure and function of the fish body for growth, reproduction, and energy (Tocher 2015). Treatment A had the lowest protein and fat content, 42.97% and 12.99%, respectively. Protein in feed must be sufficiently available because a protein deficiency may result in slow growth (Nurhuda et al 2018). If there is an excess of protein, fish cannot catabolize amino acids properly, so feed cannot be appropriately utilized (Monoarfa et al 2020).

Lovell (1988) stated that the lysine requirement at the fry stage is 6.97%. The purpose of lysine in feed is to produce carnitine, which helps growth, guards against ammonia poisoning, and makes the organism more resilient to sudden changes in temperature (Ovie & Eze 2013). According to Kuang et al (2012), quality protein must have a high level of digestibility, and the content of amino acids should be similar to that of the cultivated species. Lysine in feed can increase protein synthesis in the body of cobia, improving growth and survival (Valverde et al 2013). Lysine is also an important part of blood antibodies, which boost the circulatory system and keep cells growing at a normal rate (Baeza-Rojano et al 2013). It can also make other amino acids easier to digest, like the non-essential amino acid tyrosine, which controls how fish eat and how their bodies react to stress (Ovie & Eze 2013). Valverde et al (2013) describe vitamin B1 as an anti-virus that helps calcium absorption, boosts appetite, and produces carnitine, which helps turn fatty acids into energy. It also increases the content of PUFA, because lysine can produce carnitine, which is the key to fatty acid metabolism in fish bodies.

Methionine may act as a chemoattractant for increasing appetite. Methionine had the highest concentration in cobia from treatment D (11.95%). The methionine need of fish is 3.2% (Brown et al 2012). The function of methionine for fish, among others, is to improve the balance and utilization of other amino acids, increase growth, help protein synthesis and physiological functions. Belghit (2014) stated that fish need methionine to make nucleic acids, proteins and cells. In addition, methionine cooperates with vitamin B12 and folic acid in helping the body regulate excessive protein supply in a high-protein diet. Feeds with high methionine content can increase growth and immune responses (Yuan et al 2011; Kuang et al 2012; Boonyoung et al 2013; Ma et al 2013; Rolland et al 2015). Methionine deficiency can cause decreased growth and survival in carp (*Cyprinus carpio*) (Tang et al 2009) and also causes cataracts in *L. calcalifer* (Takagi et al 2011).

Glutamic acid is quantitatively a free amino acid more commonly found in blood plasma and muscles than other free amino acids. Glutamine is a substrate for several amidotransferases involved in synthesizing purines, glucosamine, pyrimidine, and asparagine (Valverde et al 2013). Non-essential amino acids are those that can be synthesized in the body. Glutamine is an energy source and plays a role in the biosynthesis of glucose, amino sugars, and glutathione. Glutamine can improve intestinal structure and function. It is essential in shrimp and fish larvae, considering their digestive tract is not yet developed. With the addition of glutamine, it is hoped to improve the performance of the intestine in digesting feed (Jusadi et al 2015).

Saturated fatty acids can be metabolized and formed into energy for fish growth. This is due to the essential amino acid lysine as a precursor to carnitine, helping metabolize fatty acids (Lu et al 2014; Meyer et al 2014). In saturated fatty acids, the lauric acid will be converted into lauric monoglycerides, anti-viral, anti-bacterial, and anti-protozoal agents.

EPA can affect the growth rate of cobia. Lovel (1988) noted that EPA contributes to the function of cell metabolism. EPA is more active than linoleic and linolenic acids. Cobia's ability to survive in unhospitable environments is strongly influenced by the nutritional quality of the feed consumed, especially essential n-3 HUFA, such as EPA and DHA (Pangkey 2011; Rudtanatip et al 2019). Arachidonic acid (AA) and EPA are substrates needed to form eicosanoids, which play a role in various physiological functions, including ion regulation and egg maturity in female parents (Lovell 1988). AA is a precursor to eicosanoic fatty acids (prostaglandins, thromboxane, and leukotrienes) in fish (Meyer et al 2014) and is one of the main components of phosphatidylinositol. Arachidonic acid (20:4n-6; AA) is also very much needed by larvae.

Conclusions. The addition of 15 mL of curcuma extract per kg of feed (2.33 mg curcumin) resulted in the highest of TFC, biomass, absolute length, SGR, PER, FUE, and FCR of cobia, with sequential values of 823.33 g, 36.38 g, 9.98 cm, 2.46% ind day^{-1}, 1.84%, 88.46%, 1.13, while the SR value of each treatment was 100%. Treatment D (15 mL curcuma extract kg^{-1} feed) had the highest protein and fat content, with 62.15% and 8.04%, respectively. The essential amino acid with the highest concentration was methionine (11.95%), and the most elevated essential fatty acid was EPA (7.95%).

Acknowledgements. This research was funded by the Research Grants Faculty of Fisheries and Marine Sciences (Funds Other Than State Budget Diponegoro University 2023) Number 05/UN7.F10/PP/III/2023.

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

References

Amelinda E., Widarta I. W. R., Darmayanti L. P. T., 2018 [Effect of maceration time on antioxidant activity of curcuma rhizome extract (*Curcuma xanthorrhiza*)]. Journal of Food Science and Technology 7(4):165-174. [In Indonesian].

Anggoro D., Rezki R. Z., Siswarni M. Z., 2015 [Multi-stage extraction of curcumin from curcuma (*Curcuma xanthorrhiza* Roxb.) using ethanol solvent]. Journal of Chemical Engineering 4(2):40-49. [In Indonesian].
Ardiansyah, Achmad R., 2020 [Effect of addition of curcuma extract (*Curcumas xantrorrhiza*) on commercial feed on growth and survival of tilapia seeds (*Orechromis niloticus*)]. Jurnal Agrisains 21(3):103-110. [In Indonesian].
Baeza-Rojano E., Domingues P., Guerra-García J. M., Capella S., Noreña-Barroso E., Caamal-Monsreal C., Rosas C., 2013 Marine gammarids (Crustacea: Amphipoda): a new live prey to culture *Octopus maya* hatchlings. Aquaculture Research 44(10):1602-1612.
Belghit I., Skiba-Cassy S., Guerden I., Dias K., Surget A., Kaushik S., Panserat S., Seiliez I., 2014 Dietary methionine availability affects the main factors involved in muscle protein turnover in rainbow trout (*Oncorhynchus mykiss*). British Journal of Nutrition 112(2):493-503.
Benetti D. D., Sardenberg B., Welch A., Hoenig R., Orhun M. R., Zink I., 2008 Intensive larval husbandry and fingerling production of cobia *Rachycentron canadum*. Aquaculture 281(1-4):22-27.
Boonyoung S., Haga Y., Satoh S., 2013 Preliminary study on effects of methionine hydroxy analog and taurine supplementation in a soy protein concentrate-based diet on the biological performance and amino acid composition of rainbow trout [*Oncorhynchus mykiss* (Walbaum)]. Aquaculture Research 44(9):1339-1347.
Brown N., Eddy S., Plaud S., 2012 Utilization of waste from a marine recirculating fish culture system as a feed source for the polychaete worm, *Nereis virens*. Aquaculture 322-323:177-183.
Cendrianti F., Muslichah S., Ulfa E. U., 2014 [Antihyperuricemic activity test of extracts of n-hexane, ethyl acetate, and 70% ethanol from tempuyung leaves (*Sonchus arvensis* L.) in hyperuricemic male mice]. E-Jurnal Pustaka Kesehatan 2(2):207-217. [In Indonesian].
Gopakumar G., Nazar A. K. A., Tamilmani G., Sakhthivel M., Kalidas C., Romamorth N., Palanichamy S., Maharshi V. A., Srinivasa K., Sydarao G., 2012 First experience in the larva culture of cobia, *Rachycentron canadum* (Linnaeus, 1752) in India. Indian Journal Fisheries 59(1):59-63.
Halija, Zainuddin H., Budi S., 2019 Analysis of growth performance and survival of tilapia (*Oreochromis niloticus*) supplemented with temulawak (*Curcuma xanthorriza*) in feed]. Journal of Aquaculture Environment 1(2):8-11. [In Indonesian].
Herawati V E., Hutabarat J., Pinandoyo, Rismaningsih N., Karnaradjasa O., 2019 Mass culture of *Daphnia magna* Straus, 1820 in fermented medium as feed to enhance nutrient quality and growth performance of Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) larvae. Asian Fisheries Science 32:182-189.
Herawati V. E., Nugroho R. A., Pinandoyo, Hutabarat J., Prayitno B., Karnaradjasa O., 2018 The growth performance and nutrient quality of Asian swamp eel *Monopterus albus* in Central Java Indonesia in a freshwater aquaculture system with different feeds. Journal of Aquatic Food Product Technology 27(6):658-666.
Insana N., Farhana W., 2015 [Substitution of curcuma flour (*Curcuma xanthorrhiza*) in feed with different doses on growth and survival of tilapia seeds (*Oreochromis niloticus*)]. Octopus 4(2):382-395. [In Indonesian].
Ivandari R. I., Linayati, Mardiana T. Y., 2019 [The effect of giving immunostimulants with different doses on the growth of white snapper (*Lates calcarifer*)]. Jurnal LITBANG Kota Pekalongan 16:19-31. [In Indonesian].
Jusadi D., Aprilia T., Suprayudi M. A., Yaniharto D., 2015 Free amino acid enriched rotifer for larval grouper *Cromileptes altivelis*. Indonesian Journal of Marine Sciences 20(4):207-214.
Kuang S. Y., Xiao W. W., Feng L., Liu Y., Jiang J., Jiang W. D., Hu K., Li S. H., Tang L., Zhou X. Q., 2012 Effects of graded levels of dietary methionine hydroxy analogue on immune response and antioxidant status of immune organs in juvenile Jian carp (*Cyprinus carpio* var. Jian). Fish & Shellfish Immunology 32(5):629-636.
Lovell T., 1988 Nutrition and feeding of fish. 2nd Edition. Kluwer Academic, 265 p.

Lu N., Shu G., Xie Q. P., Zhu X. T., Gao P., Zhou G. X., Wang S., Wang L. N., Xi Q. Y., Zhang Y. L., Jiang Q. Y., 2014 Myristic acid (MA) promotes adipogenic gene expression and the differentiation of porcine intramuscular adipocyte precursor cells. Journal of Integrative Agriculture 13(11):2488-2499.
Ma R., Hou H., Mai K., Bharadwaj A. S., Cao H., Ji F., Zhang W., 2013 Comparative study on the effects of L-methionine or 2-hydroxy-4-(methylthio) butanoic acid as dietary methionine source on growth performance and anti-oxidative responses of turbot (*Psetta maxima*). Aquaculture 412-413:136-143.
Meyer A., Kirsch H., Domergue F., Abbadi A., Sperling P., Bauer J., Cirpus P., Zank T. K., Moreau H., Roscoe T. J., Zahringer U., Heinz E., 2004 Novel fatty acid elongases and their use for the reconstitution of docosahexaenoic acid biosynthesis. Journal of Lipid Research 45(10):1899-1909.
Monoarfa V. D., Mansyur K., Tis'in M., Ndobe S., 2020 [Addition of temulawak tube (*Curcuma xanthorhiza* roxb) to food on the growth of koi fish (*Cyprinus carpio*)]. Journal of Fisheries Marine and Aquatic Science 2(1):96-105. [In Indonesian].
Nguyen M. V., Espe M., Conceicao L. E. C., Le H. M., Yufera M., Engrola S. A. D., Jordal A. E. O., Ronnestad I., 2019 The role dietary methionine concentrations on growth, metabolism, and N-retention in cobia (*Rachycentron canadum*) at elevated temperatures. Aquaculture Nutrition 25(2):495-507.
Nurhuda A. M., Samsudari S., Zubaidah A., 2018 Effect of differences in fasting time interval on growth and protein efficiency ratio of gouramy (*Osphronemus gouramy*). Aquatic Sciences Journal 5(2):59-63. [In Indonesia].
Ovie S. O., Eze S. S., 2013 Lysine requirement and its effect on the body composition of *Oreochromis niloticus* fingerlings. 25th Annual Conference of the Fisheries Society of Nigeria, pp. 573-579.
Pangkey H., 2011 [Requirements of essential fatty acids in marine fish]. Journal of Fisheries and Tropical Marine 7(2):93-102. [In Indonesian].
Pinandoyo, Herawati V. E., Nugroho R. A., 2019 [The effect of different addition of curcuma's extract (*Curcuma's xanthorrhiza* Roxb) in artificial feed on growth and immunity of juvenile tiger shrimp (*Penaeus monodon*)]. Ecology, Environment and Conservation 25(2):488-496. [In Indonesian].
Prabowo A. S., Madusari B. D., Mardiana T. Y., 2017 [Effect of temulawak (*Curcuma xanthorriza*) addition in artificial feed on the growth of milkfish (*Chanos chanos*)]. Pena Akuatika 15(1):41-50. [In Indonesian].
Prastito, Pinandoyo, Nugroho R. A., Herawati V. E., 2018 The effect of curcuma (*Curcuma's xanthorrhiza* Roxb) extract addition to the increase of feed consumption, efficiency and the growth of catfish (*Pangasius*)]. Jurnal Ilmu Perikanan dan Sumberdaya Perairan 7(1):638-645. [In Indonesian].
Purwati D., Herliwati, Fitriliyani I., 2015 [Effect of addition of vitamin c and curcuma extract to commercial feed on papuyu fish post larva growth (*Anabas testudineus*, Bloch)]. Fish Scientiae 5(10):60-72.
Putri R., Mursiti S., Sumarni W., 2017 [Antibacterial activity of the combination of temu putih and temulawak against *Streptococcus mutans*]. MIPA Journal 40(1):43-47. [In Indonesian].
Rolland M., Dalsgaard J., Holm J., Gómez-Requeni P., Skov P. V., 2015 Dietary methionine level affects growth performance and hepatic gene expression of GH–IGF system and protein turnover regulators in rainbow trout (*Oncorhynchus mykiss*) fed plant protein-based diets. Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology 181:33-41.
Rudtanatip T., Boonsri B., Praiboon J., Wongprasert K., 2019 [Bioencapsulation efficacy of sulfated galactans in adult *Artemia salina* for enhancing immunity in shrimp *Litopenaeus vannamei*. Fish & Shellfish Immunology 94:90-98.
Setianingsih L., Santoso L., Saputra S., 2019 [Effect of diets with different protein level for cobia (*Rachycentron canadum*) growth in controlled tank]. Journal of Aquaculture Engineering and Technology 7(2):846-855. [In Indonesian].
Sukaryo, 2016 [Isolation of curcumin from curcuma by extraction process using 96% alcohol solvent]. Journal of Neo Teknika 2(1):12-16. [In Indonesian].

Susilowati T., Kawijil, Ariviani S., 2014 [Antioxidant capacity and curcuminoid content of curcuma's (*Curcuma xanthorrhiza*) rhizome extract using water solvent with variation of solvent proportion and heating method]. Biofarmation 12(2):83-89. [In Indonesian].
Takagi S., Shimeno S., Hosokawa H., Ukawa M., 2011 Effect of lysine and methionine supplementation to a soy protein concentrate diet for red sea bream *Pagrus major*. Fisheries Science 67(6):1088-1096.
Tang L., Wang G. X., Jiang J., Feng L., Yang L., Li S. H., Kuang S. Y., Zhou X. Q., 2009 Effect of methionine on intestinal enzymes activities, microflora and humoral immune of juvenile Jian carp (*Cyprinus carpio* var. Jian). Aquaculture Nutrition 15(5):477-483.
Tocher D. R., 2015 Omega-3 long-chain polyunsaturated fatty acids and aquaculture in perspective. Aquaculture 449:94-107.
Valverde J. C., Martínez-Llorens S., Vidal A. T., Jover M., Rodríguez C., Estefanell J., Gairín J. I., Domingues P. M., Rodríguez C. J., García B. G., 2013 Amino acids composition and protein quality evaluation of marine species and meals for feed formulations in cephalopods. Aquaculture International 21(2):413-433.
Yuan Y. C., Gong S. Y., Yang H. J., Lin Y. C., Yu D. H., Luo Z., 2011 Effects of supplementation of crystalline or coated lysine and/or methionine on growth performance and feed utilization of the Chinese sucker, *Myxocyprinus asiaticus*. Aquaculture 316(1-4):31-36.
Zonneveld N., Huisman E. A., Boon J. H., 1991 Principles of fish culture. PT Gramedia Pustaka Utama, Jakarta, p. 318.
*** AOAC, 2005 Official methods of analysis. 18th Edition. Association of Official Analytical Chemists, pp. 806-842.

Received: 05 May 2023. Accepted: 10 June 2023. Published online: 29 July 2023.
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How to cite this article:
Herawati V. E., Elfitasari T., Windarto S., 2023 Effect of *Curcuma xanthorrhiza* extract added in feed on the growth and body composition of cobia (*Rachycentron canadum*). AACL Bioflux 16(4):2025-2038.