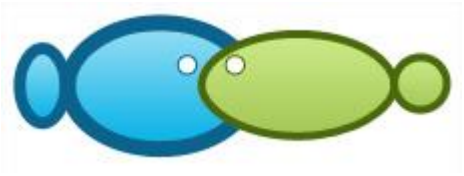

The efficacy of curcumin analog supplementation in improving the liver function of Nile tilapia (*Oreochromis niloticus*)

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Abstract. The current research aimed at determining the benefits of curcumin analog in improving the liver function to support reproduction of nile tilapia (*Oreochromis niloticus*). The experiment is designed by using a complete random design with seven treatments and three repetitions. The parameter observed is the content of Serum Glutamic Pyruvic Transaminase (SGPT), Serum Glutamic Oxaloacetic Transaminase (SGOT), Malondialdehyde (MDA) and Superoxide Dismutase (SOD) and in the liver tissue. The research results showed that the supplementation of curcumin analog in the pellet can improve the liver tissue growth of *O. niloticus*, proven by the decreasing concentration of liver's MDA, SGPT and SGOT in the plasma which in total improves the liver function. Based on the research results, it can be concluded that the supplementation of curcumin analog into the pellet is able to improve the liver function so as to support the reproduction of *O. niloticus*, through the vitellogenin synthesis.
Key Words: pellet, liver tissue growth, SGPT, SGOT, MDA, SOD.

Introduction. Maluku and Papua are two regions in Eastern Indonesia which have a significant production of essential oils, such as the lawang oil. The lawang oil is obtained by distillation from the lawang tree's bark (*Cinnamomum cullilawan*), with a yield of 1.49–3.80% (Ketaren 1985). One of the lawang oil's major components, the safrole (21%) can be used to reactivate dioxolane ring and to convert it to a derivative compound of curcumin analog with anti-cancer properties. The curcumin analog (homolog) compound is predicted to have the same or even better pharmacological nature compared to the parent compound. Some of the conducted researches show that the synthesis of curcumin analog, by the microwave method from the lawang oil, produces good pharmacological characteristics as a precursor of cancer medicines and as a hepatoprotector (Kapelle et al 2015a, 2016, 2019). The curcumin analog compound of lawang oil acts as an anti-tumoral on the T47D breast cancer cell line (Kapelle et al 2015b) and it also shows an effect of hepatoprotection of the mice liver cells, induced by CCl_4 (Kapelle & Manalu 2018).

Curcumin is a polyphenol compound found in turmeric, at a concentration of 3-6%. The turmeric powder consists of 9.61% curcumin and 3.18% essential oil (Nelson et al 2017). Curcumin has phytoestrogen characteristics and hepatoprotection benefits, belonging to the flavonoids group, and it stimulates the liver to synthesize vitellogenin (Ravindran et al 2007; Saraswati et al 2013). Reproduction ability is an important component in the success of fishery cultivation and involves vitellogenin synthesis

activities in the liver cells. Oxidative stress conditions can also cause inflamative reactions and liver tissue damages. The increase of free radicals will activate chemotactic factors which stimulate phagocytic cells, thus increasing the fatty acid radicals. With the help of cyclooxygenase enzymes, the fatty acid radicals will stimulate the excretion of some inflamation mediators such as prostaglandin, thromboxane, leukotriene and hydroperoxide. From the hydroperoxide fatty acids there will be derived the 4-hydroxy-2-alkenals, 2-alkenals and malondialdehyde (Carine et al 2019), which on the long term may cause the MDA concentration increase in the liver.

The Superoxide Dismutase (SOD) enzyme, which detoxifies toxic superox-ide anion radicals, can be used as biomarkers of pollutant induced oxidative stress in aquatic organisms (Borkovi et al 2007). These antioxidants are necessary to maintain the redox status of fish cells. SOD is a group of metalloenzymes that plays a crucial antioxidant role and constitutes the primary defense against the toxic effects of superoxide radicals in aerobic organisms. SOD catalyses the transformation of superoxide radicals to H_2O_2 and O_2 and it is the first enzyme to cope with oxi-radicals (Kappus 1985). SOD antioxidant enzymes are considered the first line of antioxidant defense and serve as sensitive biomarkers of oxidative stress. SOD is considered the first enzyme responsible for scavenging reactive oxygen species (ROS) and protecting cells from damage by free radicals processes (Jiang et al 2009).

Malondialdehyde (MDA) is a lipid peroxidation is produced in a direct proportion with the lipid peroxidation. Therefore, it is often used as a speed level indicator of lipid peroxidation process in vivo. MDA (belonging to aldehyde group) results from the peroxidation of double unsaturated fatty acids or Polyunsaturated Fatty Acids (PUFA) of the cell membranes and it is of the markers of the oxidative processes in the body (Carine et al 2019).

Serum Glutamic Pyruvic Transaminase (SGPT) and Serum Glutamic Oxaloacetic Transaminase (SGOT) concentrations are 2 other parameters measured in this research. The two aminotransferase enzymes available in the hepatocytes are sensitive indicators of the hepatocyte damage. SGOT is found in the liver, striated muscles, kidney, brain, pancreas, lungs, leucocytes and erythrocytes (Hastuti & Subandiyo 2020). Meanwhile, SGPT is mainly found in the liver. SGOT is an enzyme found in cytosol and mytocondria, while SGPT is found in cytosol. Normally these two enzymes are also found in small amounts in the serum. Their quantity will increase when the hepatocytes are damaged and the permeability of their membranes increases. According to Qiu et al (2016), the increase of SGPT and SGOT activities in the blood serum is a reflection of the liver damage. The study aimed to evaluate the efficacy of curcumin analog supplementation in improving the liver function to support reproduction of *Oreochromis niloticus*.

Material and Method

Research location and time. The experiment was conducted in April-June 2021 at the Research Institute for Fish Breeding, Sukamandi, Subang, West Java, Indonesia. The *O. niloticus* maintenance was conducted in the Research Institute for Fish Breeding, Sukamandi, Subang, West Java, Indonesia. The analysis of the SGPT, SGOT, MDA and SOD concentrations in the liver was conducted in the Fish Nutrition Laboratory of Fishery and Maritime Science Faculty, Bogor Agricultural University.

Experimental design. This research uses an experimental method. The design used is a complete random design (RAL) with seven treatments and three repetitions. The treatments given are P1 (curcumin analog dosage of 2.4 mg 100 g^{-1} of pellet), P2 (curcumin analog dosage of 4.8 mg 100 g^{-1} of pellet), P3 (turmeric powder dosage of 25 mg 100 g^{-1} of pellet), P4 (turmeric powder dosage of 50 mg 100 g^{-1} of pellet), P5 (commercially pure curcumin dosage of 2.4 mg 100 g^{-1} of pellet), P6 (commercially pure curcumin dosage of 4.8 mg 100 g^{-1} of pellet) and P7 is a control group (curcumin dosage of 0 mg 100 g^{-1} of pellet).

Experimental procedure. Experimental animals used in the research are 105 female *O. niloticus* aged of 6 months, obtained from the Research Institute for Fish Breeding Sukamandi, Subang Municipality, West Java. These red *O. niloticus* specimens have the average total body length of 24.62±1.49 cm with the average body weight of 294.11±51.40 g. The research containers are 21 rectangular outdoor breeding pools with each size of 2x1x1 m^3, and the saturation of 5 fish $pool^{-1}$. The pellet treatment is given for 6 weeks breeding. During this breeding, the *O. niloticus* are given commercial pellets with a protein content of 30% already supplemented with curcumin analog, turmeric powder and commercially pure curcumin according to the treatment dosage. The curcumin analog is obtained from *C. cullilawan* oil through a synthesis process (Kapelle et al 2015a). The turmeric powder is obtained from the Research Institute of Herbal and Aromatic Plants (BALITRO) Cimanggu, Bogor. The pure curcumin used is produced by Xi'an Day Natural Inc. The amount of pellet used is 3% of the body weight, given twice a day, in the morning and in the afternoon. The pellet coating uses CMC (carboxymethyl cellulose) as a binder so that the curcumin analog, turmeric powder and pure curcumin can be bound to the commercial pellet. The amount of added CMC is 3% of the total pellet given.

Sample collection. One *O. niloticus* was randomly taken every two weeks (weeks 2, 4 and 6) from each treatment group. Before carrying out a sample dissection and taking out, the fish was anesthesized by using tricaine methanesulfonate (MS-222) 1 mL L^{-1} air. A blood sample was taken to measure the SGPT and SGOT. The blood quantity was 4 mL of its caudal vena. It was then placed into a reaction tube and stored on ice to be decentrifugated at 3,000 rpm for 20 minutes at 4°C. The analysis on SGPT and SGOT content was carried out with the Reitman and Frankel methods (Bigoniya et al 2009). Then the fish was dissected and its liver organ was taken to analyze the content of MDA and SOD. Such measurement of MDA and SOD content of the liver uses the TBA (tiobarbiturate acid test) method (Capeyron et al 2002). All procedures that involved the experimental fish handling and treatment have been approved by the Animal Ethics Commission, Faculty of Veterinary, Bogor Agricultural University, Number: 004/KEH/SKE/II/2021.

Parameter measurement

Malondialdehyde (MDA) assay. As much as 1 g of *O. niloticus* liver stored frozen was finely chopped under cold conditions and dissolved in 2 mL of phosphate buffer saline (PBS) KCl at a pH=7.4. The mixture formed was centrifuged at 10,000 rpm for 20 minutes and then the supernatant was taken for further MDA assay. The MDA concentrations of the liver, determined by the peroxidation activity of the liver cell membranes, were measured by using the TBA method (Singh et al 2002). TEP (1.1.3.3-Tetraethoxy-propane ≥96%) MW 220.31 (ALDRICH, USA) was used as a standard for MDA.

Superoxide dismutase (SOD) assay. The SOD sample activity was analysed according to Misra & Fridovich (1972). The principle of this method is based on the ability of SOD to inhibit epinephrine autoxidation to adrenochrome. As much as 1 g of fresh liver was put in a tube and added with 2 mL PBS, homogenized and then centrifuged at 10,000 rpm for 20 minutes. The obtained supernatant was transferred into a new tube as a sample for further analysis. Epinephrine 0.003 M solution was prepared by dissolving 5,496 mg of epinephrine with 10 mL HCL 0.01N. Measurements by spectrophotometer were carried out. 2,800 µL of 0.05M sodium carbonate buffer, 100 µL of the sample and 100 µL of epinephrine solution were added into the cuvette and the absorption was measured with a wavelength of 480 nm.

SGPT and SGOT assays. A kinetic method was used to determine SGPT and SGOT activities according to the recommendations of the Expert Panel of the International

Federation of Clinical Chemistry. The concentrations of SGPT and SGOT were measured by using the kit of GPT (ALAT) and kit of GOT (ASAT) (Human, Germany).

Statistical analysis. The data obtained were processed by using the analysis of variance (ANOVA). The differences between the means of the treatment were tested by using the Tukey simultaneous test. The significance level was $p<0.05$.

Results

Concentrations of MDA in the liver tissues. The MDA concentration of fish liver after curcumin supplementation for 6 weeks was presented in Table 1 shows significant differences ($p<0.05$) among the treatments. Group P1 showed the lowest MDA level (1.15±0.13 μg g^{-1} sample), followed by groups P2 (1.52±0.20 μg g^{-1} sample), P3 (1.81±0.38 μg g^{-1} sample), P4 (1.68±0.45 μg g^{-1} sample), P5 (1.88±0.42 μg g^{-1} sample), P6 (1.85±0.64 μg g^{-1} sample), P7 (2.12±0.51 μg g^{-1} sample). In the second week, MDA concentration after supplementation of inter-group curcumin analog did not show a significant difference, but in the fourth and sixth week after curcumin analog supplementation, the MDA concentration showed significant differences among the group treatments. The curcumin analog supplementation in the pellet caused a decrease of the MDA concentration in the liver, compared to the control treatment.

Table 1

MDA (μg g^{-1} sample) concentrations of *Oreochromis niloticus* supplemented by curcumin analog for 6 weeks

Sampling	*Treatment groups*						
	P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*
Week 2	$1.73±0.06^{a}$	$1.87±0.22^{a}$	$1.81±0.38^{a}$	$1.84±0.14^{a}$	$1.88±0.42^{a}$	$1.98±0.52^{a}$	$2.17±1.55^{a}$
Week 4	$1.15±0.13^{b}$	$1.52±0.20^{b}$	$1.87±0.24^{a}$	$1.68±0.45^{ab}$	$2.31±0.82^{a}$	$1.85±0.64^{ab}$	$2.12±0.51^{ab}$
Week 6	$1.75±0.20^{b}$	$1.80±0.11^{b}$	$3.29±0.17^{a}$	$2.47±0.44^{ab}$	$2.97±0.56^{a}$	$2.76±0.67^{ab}$	$2.26±0.40^{ab}$

Data presented is average value ± standard deviation. The numbers followed by different letters on the same line show real differences ($P<0.05$).

Concentrations of superoxide dismutase (SOD) in the liver tissues. The SOD concentrations in the fish liver after 6 weeks of curcumin supplementation are presented in Table 2. The highest value was found in group P1 (12.16±0.45 μg g^{-1} sample), followed by groups P2 (8.12±0.59 μg g^{-1} sample), P3 (7.42±0.34 μg g^{-1} sample), P4 (6.36±1.93 μg g^{-1} sample), P5 (8.89±0.88 μg g^{-1} sample), P6 (7.17±0.68 μg g^{-1} sample) and P7 (6.18±0.34 μg g^{-1} sample). SOD concentrations in the second week did not show significant differences among the treatment groups. However, in the fourth and sixth week after curcumin analog supplementation, the SOD concentrations show significant differences among the treatment groups.

Table 2

SOD (μg g^{-1} sample) concentrations of *Oreochromis niloticus* supplemented by curcumin analog for 6 weeks

Sampling	*Treatment group*						
	P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*
Week 2	$6.91±0.34^{a}$	$6.41±0.28^{a}$	$6.84±0.15^{a}$	$6.36±1.93^{a}$	$6.30±0.42^{a}$	$6.15±0.61^{a}$	$6.18±0.34^{a}$
Week 4	$7.15±0.68^{a}$	$6.89±0.20^{b}$	$6.43±0.06^{bc}$	$6.33±0.16^{cd}$	$5.20±0.42^{b}$	$6.83±0.50^{bc}$	$5.98±0.25^{d}$
Week 6	$12.16±0.45^{a}$	$8.12±0.59^{b}$	$7.42±0.34^{bc}$	$6.00±0.91^{cd}$	$8.89±0.88^{b}$	$7.17±0.68^{bc}$	$5.27±0.31^{d}$

Data presented is average value ± standard deviation. The numbers followed by different letters on the same line show real differences ($P<0.05$).

Concentrations of glutamic pyruvic transaminase (SGPT) in the serum of O. niloticus. The research result shows that SGPT concentrations in nile tilapia serum are around 14.17-45.69 U L^{-1} presented in Table 3. The lowest value was found in group P1

(14.17±0.62 U L^{-1}), followed by groups P2 (18.78±0.51 U L^{-1}), P3 (28.26±3.75 U L^{-1}), P4 (31.00±3.36 U L^{-1}), P5 (37.70±0.62 U L^{-1}), P6 (40.55±0.46 U L^{-1}) and the highest value was in group P7 (45.69±0.93 U L^{-1}). SGPT concentrations after the supplementation of curcumin analog for six weeks showed significant differences among the treatment groups.

Table 3

SGPT (U L^{-1}) content of *Oreochromis niloticus* being supplemented by curcumin analog for 6 weeks

Sampling	*Treatment group*						
	P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*
Week 2	15.21±0.85^{d}	19.83±0.44^{d}	28.26±3.75^{c}	38.14±3.78^{b}	38.70±0.74^{b}	40.55±0.46^{ab}	45.69±0.93^{a}
Week 4	15.45±0.46^{f}	19.05±0.60^{e}	29.21±0.37^{d}	31.00±0.36^{c}	37.70±0.62^{d}	41.83±0.15^{b}	44.44±1.23^{a}
Week 6	14.17±0.62^{f}	18.78±0.51^{e}	37.47±0.51^{d}	39.95±0.21^{c}	37.85±0.60^{d}	42.04±0.70^{b}	45.00±0.55^{a}

Data presented is average value ± standard deviation. The numbers followed by different letters on the same line show real differences (P<0.05).

Concentrations of glutamic oxaloacetic transaminase (SGOT) in the serum of O. niloticus. SGOT concentrations in *O. niloticus* serum were around 37.40-46.30 U L^{-1} (Table 4). The lowest value was found in group P1 (14.17±0.62 U L^{-1}), followed by groups P2 (41.64±1.22 U L^{-1}), P3 (42.29±0.33 U L^{-1}), P4 (44.43±0.23 U L^{-1}), P5 (42.06±1.77 U L^{-1}), P6 (43.96±0.80 U L^{-1}) and the highest value was in group P7 (46.30±0.65 U L^{-1}). SGOT concentrations after supplementation of curcumin analog for six weeks showed significant differences among treatment groups.

Table 4

SGOT (U L^{-1}) content of *Oreochromis niloticus* supplemented by curcumin analog for 6 weeks

Sampling	*Treatment group*						
	P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*
Week 2	41.57±0.75^{d}	42.77±0.31^{cd}	43.03±0.65^{bcd}	44.43±0.23^{abc}	42.06±1.77^{d}	45.32±0.42^{ab}	46.30±0.65^{a}
Week 4	39.29±0.50^{d}	41.79±1.25^{cd}	42.29±0.33^{bc}	44.66±0.88^{ab}	42.93±1.55^{abc}	43.96±0.80^{abc}	45.20±1.03^{a}
Week 6	37.40±0.50^{c}	41.64±1.22^{b}	42.82±0.59^{b}	45.12±0.47^{a}	42.95±0.07^{b}	45.52±0.57^{a}	45.30±0.77^{a}

The data presented is average value ± standard deviation. The numbers followed by different letters on the same line show real differences (P<0.05).

Discussion. In fish, the metabolism during the reproduction period influences the liver cell activities and the vitelogenin synthesis. Continuous activities make the liver cells exposed to oxidant compound (Kasiyati et al 2016a). Imbalance between oxidant compounds and antioxidants will cause opportunities for damage to cells. This can also trigger free radicals increase in the body. Reactive oxygen species (ROS) can cause lipid peroxidation in the cell membranes, indicated by the increasing value of MDA in the liver. MDA is the end result of lipid peroxidation and is due to damages in the cell membrane (Sun et al 2012). The damage in cell membrane occur in presence of the oxidant compounds which may come from outside or inside the cell. The oxidant compounds coming from inside the cell, are by-products of the metabolism processes. Such metabolism process also creates free radicals in the body (Valko 2007).

The research results showed that in *O. niloticus* which was given pellet with curcumin analog supplementation, the MDA concentration in the liver decreased, compared to the control (Table 1). It is predicted that the low MDA concentration indicates an inhibition of the free radical production by curcumin, by increasing the antioxidant concentrations in the *O. niloticus* liver. It means that the curcumin can protect the liver from any damage caused by oxidant substances. The changes in the liver cells are caused by the antioxidant activity of the curcumin analog. The subsequent mechanism is the donation of hydrogen atoms to the superoxide anions. Such reaction creates a new compound which is more stable, a preventing the creation of

Polyunsaturated Fatty Acid (PUFA) in the cell membranes and decreasing the MDA liver concentration (Carine et al 2019).

The research conducted by Kapelle & Manalu (2018) showed that the lawang oil curcumin analog has hepatoprotecting effects on the mice liver cells, against the stress induced by the CCl_4. This curcumin activity supports the liver function, by protecting it against any damage, as an exogenous antioxidant, and by influencing endogenous glutathione peroxidase (GTH) antioxidant production (Manju 2012). The research conducted by Rawung et al (2021) also showed that the highest MDA concentration is found in the catfish group which is not given any treatment of curcumin and the lowest MDA concentration is found in the group under curcumin treatment. The concentration of gold fish MDA liver after being supplemented by a curcumin dosage of 5 g kg^{-1} pellet also showed the lowest MDA value of 26.32 µg g^{-1} sample (Rawung & Saruan 2020). The turmeric powder supplementation can also be used in the oviparous animals and fish to increase the liver functions and the capacity to synthesize vitelogenin (stored in the follicles which are developing during reproduction). The supplementation of turmeric powder can hinder damage of liver cells in Siam catfish fish, which is shown by a decrease of the MDA concentration in their liver (Dewi et al 2018). The catfish given additional turmeric in their pellet are able to decrease the MDA levels due to the antioxidant compound contained in the turmeric (Tung et al 2019).

The antiinflamatory and hepatoprotective characteristics of the curcumin analog and of the curcumin are due to the inhibitory action of the flavonoids on the lypooxygenase and cyclooxygenase enzymes, causing a decrease in the lipid peroxydation, MDA concentrations and inflammatory reactions which can hinder and damage the liver tissues. Flavonoids are scavengers of free radicals by donating hydrogen atoms to superoxide anions, which creates a more stable compound (Dixa & Vimal 2004).

The decreasing value of MDA is influenced by the production of SOD antioxidant enzyme, which prevents the ROS. SOD is an endogen antioxidant produced by the liver to neutralize the oxidant compounds existing in the cells. The research results showed that curcumin analog supplementation in the pellet is able to increase the SOD enzymes in the liver (Table 2). This is in line with the research done by Rawung & Saruan (2020), which found that a curcumin supplementation in the pellet with the dosage of 2.5 g kg^{-1} increased the SOD concentration by 10.44 unit mg^{-1} (Rawung & Saruan 2020). Supplementation of turmeric powder into the pellet is also able to increase the SOD concentration of Siam catfish (Dewi et al 2018). Curcumin (in turmeric) has a compound which can give signals to the Nrf2 genes (Alrawaiq & Abdullah 2014). This Nrf2 has the ability to induce the production of SOD enzymes into the liver cells.

Low MDA concentration and high SOD concentration after a supplementation treatment with curcumin analog show that curcumin is able to improve the damage caused by ROS, due because to its role as an antioxidant. When curcumin inhibits the ROS formation, it prevents the specific signals of ROS formation by giving an oxygen atomto stabilize the reaction. Then, through NRf-1 path, the curcumin orders the brain to produce SOD, which scavenge the ROS (Kocaadam & Sanlier 2015).

A curcumin analog dosage of 2.4 mg 100 g^{-1} of pellet is able to improve SOD activities, which are higher compared to the dosage of 4.8 mg 100 g^{-1} of pellet. This is explained by the curcumin flavonoid autooxidation into free radicals (due to its instability at physiological pH). The autooxidation mechanism is caused by the mitochondrial succinoxydase enzymes inhibition and it produces peroxyde hydrogen, superoxide and hydroxyl radicals. Flavonoids (e.g. curcumin, naringin, apigenin) also have phenolic B ringswhich are prone to experience pro-oxidation (Skibola et al 2000). The increase of free radicals reduces the SOD liver concentration. Supplementation of curcumin analog with different dosages into the pellet also causes a decrease of the SGPT and SGOT concentrations in the Nile Tilapia's plasma. The statistical analysis result shows that supplementation of curcumin analog really influences the content of SGPT and SGOT plasma ($P<0.05$), compared to the control treatment. The dosage of curcumin analog supplementation of 2.4 mg 100 g^{-1} of pellet shows optimal results in improving the physiological condition of *O. niloticus*, which is shown by the liver function improvement.

The best hepatoprotective effect of the curcumin analog is shown by the decrease of the SGPT (14.27 U L^{-1}) content in P1 treatment (2.4 mg curcumin analog 100 g^{-1} of pellet) and of the SGOT (28.50 U L^{-1}) in P2 treatment (4.8 mg curcumin analog 100 g^{-1} of pellet), compared to the control, with the content of SGPT (69.02 U L^{-1}) and SGOT (67.69 U L^{-1}) (Table 3). The research result of Rawung et al (2021) shows a decrease in the content of SGPT and SGOT in the blood of a catfish group given a curcumin treatment. The curcumin analog is hepatoprotective in a white mice group given a CCL_4 treatment, which is shown by the low content of SGPT and SGOT (Kapelle & Manalu 2018; Kapelle et al 2019).

A research on the benefits of curcumin as hepatoprotector showed a positive influence of curcumin in the liver, which is indicated by the decrease of the SGPT and SGOT serum content (Gandhi et al 2011). Saraswaty et al (2013) reported that the dosage increase of turmeric powder up to 54 mg $fish^{-1}$ day^{-1} shows an optimal result in improving the physiological condition of Japanese quails, shown by their liver function improvement. The hepatoprotective effect of the turmeric powder is related to the decrease of the contents of SGPT and SGOT by 15.63 and 9.65%, respectively, compared to the control. A supplementation of turmeric powder into the pellet has the function of inducing a hepatoprotective effect and to decrease the concentration of SGPT and SGOT of Siam catfish (Dewi et al 2018). According to Kasiyati et al (2016), the bioactive components of curcumin protect the hepatocytes from the damage caused by free radicals, which is indicated by the SGPT and SGOT contents decrease in the curcumin-supplemented ducks. The serum analysis has been used to determine the organ disfunctions, especially in the liver. According to Kesbiç (2019) and Sanchez et al (2019), the improvement of SGPT and SGOT content in the serum is an indicator of liver disfunctions.

Conclusions. The study showed that a curcumin analog supplementation can hinder the oxidative damage in the *O. niloticus* hepatocytes by reducing the concentrations of MDA in the liver and of SGPT and SGOT in the serum, and thus by protecting and improving the liver functions, which support the reproduction of *O. niloticus*, through the vitellogenin synthesis.

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Conflict of interest. The authors declare no conflict of interest.

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