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Egg Production, Egg Quality, and Fatty Acid Profile of Indonesian Local Ducks Fed with Turmeric, Curcuma, and Probiotic Supplementation

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ABSTRACT

Indonesian local ducks are commonly raised for egg production purposes. However, the performances of these ducks are still variable and must be improved. This study investigated the effects of turmeric, curcuma, and probiotic supplementations on the egg production and quality of Indonesian local ducks, emphasizing the eggs' fatty acid profile. Two hundred female local ducks aged 16 weeks were randomly allotted to four dietary treatments with five replicates of 10 birds. The ducks were fed a corn and rice bran-based diet containing different supplements, i.e., a diet without supplementation as the control diet, a diet supplemented with turmeric at the level of 4%, a diet supplemented with curcuma at the level of 4%, and a diet supplemented with starbio probiotics at the level of 2%. The measured data were analyzed using analysis of variance using the 13 Systat program and continued with Duncan's Multiple Range Test. Turmeric supplementation increased egg production compared with the control, and the duck fed probiotics consumed more feed than the control. Curcuma supplementation generated the lowest feed consumption, egg production, and physical egg quality than the other treatments (p<0.05). The probiotics supplementation enhanced the blood high-density lipoprotein concentration (p<0.05). Turmeric, curcuma, and probiotics supplementations generate variable responses in egg production and egg quality, including the fatty acid profile in the eggs. Turmeric and probiotics supplementations positively impact egg production, egg quality, or unsaturated fatty acid profile in the egg. However, curcuma supplementation decreased egg production and egg quality of local ducks. Furthermore, the fatty acid profile was not influenced by these supplements. It is concluded that supplementation of turmeric at the level of 4% and probiotics at the level of 2% in the diet can increase egg production and egg quality of local duck.

Keywords: local duck; egg production; egg quality; unsaturated fatty acids

INTRODUCTION

In Indonesia, duck (*Anas plathyrynchos*) farming is commonly intended for egg production. The population of ducks in Indonesia reached about 50.31 million, with total egg production approximately 329.565.69 tons in 2021 (Directorate General of Animal Husbandry and Health, 2021). Many duck breeds in Indonesia have varying performances, both between breeds and within the same breed. The production rate of laying ducks in Indonesia ranges between 60.2% and 72.9%. It is important to note that duck eggs contain higher lipid concentrations than chicken eggs (Ismoyowati & Sumarmono, 2019). Various efforts can be made to increase duck productivity, including selection, improved maintenance management, and the provision of adequate and balanced nutrients. The inclusion of feed supplements, such as turmeric, curcuma, and probiotics, can also increase the production and quality of duck eggs.

Turmeric (*Curcuma domestica* Val.) contains some bioactive components, such as curcumin (7.798%), which has antibacterial effects (Prakasita *et al.*, 2019; Basavaraj *et al.*, 2011) and acts as an antioxidant to restore body tissues by activating the cytochrome enzyme P-450 as the catalysator of the oxidation reaction in releasing free radicals. Inactivated cytochrome P-450 can damage tissue due to the depletion of free radicals (Masubuchi & Horie, 2007). Turmeric contains phytoestrogen that can interact with the endocrine system and affect the hypothalamic–hypophyseal–ovarian axis (Sirotkin *et al.*, 2018). In laying ducks, estrogen has a vital role in follicle development. When many follicles are developed, the yolk components, such as cholesterol, are widely distributed throughout the follicles, eventually decreasing the cholesterol concentrations in the eggs produced (Etches, 1996). Estrogen also stimulates vitellogenin biosynthesis in the liver. As a yolk component, vitellogenin is secreted into the bloodstream and transported into the growing oocytes to be used to synthesize egg yolk (Lu & Zou, 2006).

Curcuma (*Curcuma xanthorrhiza* Roxb.) is a medicinal plant of the rhizome family (Zingiberaceae), a popular ingredient used for seasoning and medicine. Curcuma contains curcuminoid fraction yield at the level of 10.06% from the ethanol extract (Atun *et al.,* 2020), which generates a yellow color in the rhizome and exhibits several properties, such as antibacterial, anticancer, antitumor, and antiinflammation, as well as antioxidant and hypocholesterolemia (Lee *et al.,* 2008).

Some microbial species, including *Bacillus*, *Bifidobacterium*, *Enterococcus*, *Lactobacillus*, *Lactococcus*, *Streptococcus*, and others, have been used as probiotics. *Lactobacillus* and *Bifidobacterium* have been extensively used in humans, while *Bacillus*, *Enterococcus*, and *Saccharomyces* are mostly used in livestock (Mikulski *et al.,* 2012). Probiotics for laying poultry are intended to increase feed efficiency, egg production, egg quality, intestinal microflora modulation, and inhibit the growth of pathogenic bacteria (Zhu *et al.,* 2015).

Adding feed additives to the diets of laying poultry has been shown to improve feed efficiency, animal health, and productivity (Ismoyowati & Sumarmono, 2019). For example, the inclusion of several Phyto biotics improved the performances of growing ducks (Ismoyowati *et al.,* 2015). Herbal additives (phytogenic and medicinal compounds derived from plants) could act as a substitute for the growth-promoting antibiotic (Masoud-Moghaddam *et al.,* 2021). While the addition of probiotics enhances the laying performance of chickens (Zhang *et al.,* 2017), there are limited studies on the supplementations of turmeric, curcuma, and probiotics in the laying ducks, particularly with an emphasis on egg production, egg quality, and the fatty acid profile of the eggs. It is hypothesized that supplementations of turmeric, curcuma, or probiotics in the diet of laying ducks can increase egg production and egg quality. Therefore, this study aimed to investigate the effect of turmeric, curcuma, and probiotics supplementations in the diet of laying ducks on the egg production and egg quality of laying Indonesian local ducks, emphasizing the fatty acid contents of the eggs.

MATERIALS AND METHODS

Ethical Approval

All procedures involving animals were performed by following the Guiding Principles Research Animals and were approved by the Institute of Research and Community Service, Jenderal Soedirman University No. 123/UN23.18/PT.01.05/2020.

Experimental Design and Diet

This experiment used 200 Tegal ducks aged 16 weeks with an average body weight of 1.520±86 g. This type of duck is primarily intended for egg production, with the ability to produce 200 eggs per year. The experimental ducks were allotted to four dietary treatments with five replicates of 10 ducks following a completely randomized design. The four treatments were basal diet without supplementation (control), a basal diet supplemented with 4% turmeric powder (Turmeric), a basal diet supplemented with 4% curcuma powder (Curcuma), and a basal diet supplemented with 2% probiotic (starbio). The herbal additives (turmeric and curcuma) could substitute for the growth-promoting antibiotic, while the addition of probiotics enhanced the laying performances of experimental ducks. The levels of turmeric, curcuma, and probiotic supplementations were based on the most applied levels in the previous studies. The turmeric (*Curcuma domestica* Val.) and curcuma (*Curcuma zanthorrhiza*) powders were made from fresh turmeric and curcuma. They were washed in running water, then thinly sliced (0.5 cm), oven-dried at 55 °C, and ground to powder. The probiotics used in this experiment was Starbio, produced by Lembah Hijau Multifarm Ltd., Solo, Indonesia. Based on information of product specification, Starbio contains various microbes, namely proteolytic (6×10^9 cfu/g Nitrosococcus), lignolytic (6×10^9 cfu/g *Clavaria dendroidea*), non-symbiotic nitrogen fixation (4×10^8 cfu/g *Azotobacter spp*), cellulolytic (8×10^8 cfu/g *Trichoderma polysporeum*), and lipolytic (8×10^8 cfu/g *Spirillum liporerum*). The feed ingredients and nutrient composition of the basal diet are presented in Table 1.

The experimental ducks were kept in litter cages with rice husk as the litter. The cage dimension was 2 m × 2 m × 1 m (length × width × height). During the experiment, the cage temperature was 27-29 ºC, and the relative humidity was 60%-80%. Lighting was provided for 12 hours. The feed and drinking water were offered *ad libitum*. The experimental ducks were allowed to adapt to the cage and experimental diet for one week, and they were then maintained for 12 weeks during the production period.

Performance Measurements

The feed consumption, egg production (as a percentage of hen day production), and egg weights were measured daily. Feed conversion was calculated from the total feed consumed divided by the egg mass (Mousavi *et al.,* 2016). In total, 400 eggs (20 eggs per replicate) were used for the physical egg quality measurement. The physical egg quality, including the yolk and albumen, yolk color score, and eggshell thickness, and the Haugh Unit were measured according to Stadelman & Cotteril (1995). Meanwhile, four eggs from each treatment unit (in total 80 eggs) were used to analyze the fat and fatty acids contents using the Association of Official Agricultural Chemists (AOAC) method (AOAC, 2012a; AOAC, 2012b) and the cholesterol content using the HPLC method. Fatty acid analysis was performed by composited egg fat extraction from each treatment (from 5 replicates to become one sample), homogenized, and then analyzed. Each treatment was analyzed for fatty acids in duplicate.

Blood Lipid Profile Analyses

Blood samples for lipid profile analyses were collected from two ducks per replicate (in total 40 ducks) after

Table 1. Feed ingredients and nutrient compositions of experimental diet without supplementation (control), supplemented with turmeric powder, curcuma powder, and probiotics

Feed ingredients (%)	Treatments			
	Control	Turmeric	Curcuma	Probiotics
Corn meal	40	38	38	39
Rice bran	32	30	30	31
Soybean waste	15	15	15	15
Fishmeal	10	10	10	10
Turmeric	0	4	0	0
Curcuma	0	0	4	0
Probiotic	0	0	0	2
Palm oil	1	1	1	1
Premix vitamin and mineral	1	1	1	1
Lysine	0.5	0.5	0.5	0.5
Methionine	0.5	0.5	0.5	0.5
Nutrient content				
Crude protein (%)	17.62	17.45	17.83	17.92
Metabolizable energy (kcal/kg)	2870	2833	2894	2870
Crude fiber (%)	6.09	6.31	6.11	6.09
Crude fat (%)	4.81	5.11	5.08	4.81
Calcium (%)	2.85	2.83	2.81	2.85
Phosphorus (%)	1.52	1.52	1.52	1.52
Lysine (%)	1.02	1.02	1.02	1.02
Methionine (%)	0.69	0.70	0.71	0.71
Methionine + Cystine (%)	0.90	0.92	0.93	0.93

eight weeks of treatment. The blood sample (3 mL) was collected from the vena axillaries and stored in a sterile mini-tube containing an anticoagulant. Whole blood was centrifuged, and plasma was placed in a minitube and analyzed for lipid profile. The blood lipid profile consisted of triglycerides, total cholesterol, and high-density lipoprotein (HDL) concentrations, were determined by the spectrophotometric method. The contents of low-density lipoprotein (LDL) in the plasma were calculated based on the Friedewald equation (Friedewald *et al*., 1972).

Statistical Analysis

The collected experimental data were subjected to an analysis of variance in a completely randomized design using the Systat 13 program (Systat Software, Inc., San Jose, CA). The Duncan test was employed to measure the difference between treatments at α = 0.05 (Steel *et al.*, 1996). The data concerning the fatty acid profile in the egg were presented descriptively since the chemical analysis was performed in a composite manner.

RESULTS

Productive Performance and Physical Egg Quality

Turmeric powder supplementation increased egg production without affecting the egg weight, feed consumption, and feed conversion compared with the control (p<0.01; Table 2). The experimental ducks fed ration supplemented with probiotics consumed more feed than the control (129.17 g vs. 128.15 g; p<0.01). However, this increased feed consumption did not significantly affect the productive performance of the experimental ducks. On the contrary, supplementation of 4% curcuma powder in the basal diet reduced feed consumption and egg production compared with the other treatments. Consequently, the feed conversion for the experimental ducks fed basal ration supplemented with curcuma powder (Curcuma group) was higher than that of the other treatments (p<0.01).

Supplementation of the basal diet with turmeric powder, curcuma powder, and probiotics did not change the yolk weight and yolk-color score. However, all dietary supplementations generated a lower albumen weight than non-supplemented diet (p<0.01; Table 3). Furthermore, turmeric powder and probiotics supplementations produced a similar Haugh Unit, higher than that in experimental ducks supplemented with curcuma powder (p<0.01). In addition, feeding experimental ducks with basal diets supplemented with turmeric powder and probiotics produced a thicker eggshell, but experimental ducks fed the basal diet supplemented with curcuma powder produced a thinner eggshell than the control (p<0.01).

Blood Lipid Profile and Yolk Fatty Acids Contents

Turmeric powder supplementation in the basal diet decreased blood HDL concentration, while probiotic supplementation increased the blood HDL concentrations compared with the experimental control ducks without supplementation (p<0.01; Table 4). However, total blood cholesterol tended to decrease following turmeric powder, curcuma powder, and probiotic supplementations (p=0.098). In addition, these supplements did not influence the other blood-lipid parameters, such as LDL, triglycerides, yolk fat, and yolk cholesterol.

Table 2. Productive performance of ducks fed basal diet without supplementation (control), supplemented with turmeric powder, curcuma powder, and probiotics

Variables	Treatments					
	Control	Turmeric	Curcuma	Probiotics	SEM	p Value
Feed consumption (g)	128.50^{b}	128.88^{ab}	127.48^{c}	129.17^{a}	0.175	<0.001
Egg production (%)	70.71^{b}	79.01^{a}	49.43^{c}	73.86^{b}	4.028	0.002
Egg weight (g)	62.06	63.00	61.49	62.29	0.246	0.182
Feed conversion	2.99^{b}	2.65^{b}	4.28^{a}	2.87^{b}	0.177	<0.001

Note: ^{a,b,c} Means in the same row with different superscripts differ significantly (p<0.01).

Table 3. Physical quality of eggs ducks fed basal diet without supplementation (control), supplemented with turmeric powder, curcuma powder, and probiotics

Variables	Treatments					
	Control	Turmeric	Curcuma	Probiotics	SEM	p Value
Albumen weight (g)	34.40^{a}	32.83^{b}	31.44^{c}	33.08^{b}	0.257	<0.001
Yolk weight (g)	18.41	18.35	18.00	18.39	0.153	0.787
Yolk color	7.86	7.63	7.71	7.40	0.073	0.139
Haugh unit	88.66^{a}	86.52^{a}	81.62^{b}	88.45^{a}	0.860	0.003
Eggshell thickness (mm)	0.43^{b}	0.51^{a}	0.32^{c}	0.54^{a}	0.199	<0.001

Note: ^{a,b,c} Means in the same row with different superscripts differ significantly (p<0.01).

Table 4. Profiles of blood and yolk lipid content of ducks fed basal diet without supplementation (control), supplemented with turmeric powder, curcuma powder, and probiotics

Variables	Treatments					
	Control	Turmeric	Curcuma	Probiotics	SEM	p Value
Total blood cholesterol (mg/dl)	253.70	203.70	209.26	229.63	7.960	0.098
Blood HDL (mg/dl)	65.27^{b}	53.17^{b}	64.53^{b}	91.67^{a}	3.944	<0.001
Blood LDL (mg/dl)	188.44	150.54	144.73	137.96	8.095	0.111
Blood triglyceride (mg/dl)	235.71	226.19	238.09	245.24	15.285	0.981
Yolk fat (%)	33.88	35.21	34.88	35.47	0.374	0.485
Yolk cholesterol (%)	13.66	13.48	12.91	13.99	0.334	0.743

Note: ^{a,b,c} Means in the same row with different superscripts differ significantly (p<0.01).

Furthermore, the fatty acid profiles of the yolk were changed by these supplements (Table 5). It seemed that curcuma powder supplementation generated the lowest. In contrast, probiotic supplementation generated the highest saturated fatty acid (SFA), mono-unsaturated fatty acid (MUFA), and poly-unsaturated fatty acid (PUFA) concentrations, as well as the highest ratios of MUFA/SFA, PUFA/SFA, and (MUFA+PUFA)/SFA. SFA consists of fatty acids that do not contain double bonds, including myristic, pentadecanoic, palmitic, heptadecanoic, stearic, arachidic, behenic, and lignoceric acids. MUFA consists of fatty acids that contain one double bond, including myristoleic, palmitoleic, elaidic, oleic, and eicosenoic acids. PUFA consists of fatty acids that have two or more double bonds, including linoleic, linolenic, g-linolenic, arachidonic, eicosadienoic, eicosatrienoic, eicosapentaenoic, and docosahexaenoic acids.

DISCUSSION

Productive Performance and Physical Egg Quality

Probiotics supplementation resulted in the highest feed consumption, whereas curcuma powder supplementation generated the lowest feed consumption, although of small magnitudes. Turmeric powder supplementation positively affected duck performance, as indicated by the higher egg production than the other treatments. On the contrary, feeding with curcuma powder supplementation adversely affected the productive performance, as indicated by the lower feed consumption and egg production and the higher feed conversion ratio. Based on the results, turmeric powder supplementation showed the best response on egg production and eggshell thickness of the experimental ducks. A previous study showed that turmeric powder supplementation did not negatively affect the physiological condition and growth of experimental ducks (Zhang *et al.,* 2017; Ismoyowati *et al.,* 2019). In laying quails, turmeric supplementation improved egg production and quality (Putri *et al.,* 2020). Turmeric rhizome contains 2.5%–6.0% essential oil composed of turmerone, alpha and beta turmerone, alpha atlanton, beta caryophyllene, linalool, 1.8 cineol, zingiberene, dd-phellandrene, d-sabinene, and bomeol. It also contains 3%–5% curcuminoid and its derivatives, namely, desmethoxycurcumin and bisdemethoxycurcumin (Hayakawa *et al.,* 2011). Turmeric powder exhibits a beneficial effect on the digestive system by improving mucin secretion, and it acts as a gastro-protectant (Malekizadeh *et al.,*

Table 5. The profiles of egg yolk fatty acids of ducks fed basal diet without supplementation (control), supplemented with turmeric powder, curcuma powder, and probiotics

Fatty acids (%)	Treatments			
	Control	Turmeric	Curcuma	Probiotics
Myristic acid (C14:0)	0.31	0.27	0.29	0.33
Myristoleic acid (C14:1)	0.03	0.02	0.03	0.04
Pentadecanoic acid (C15:0)	0.05	0.04	0.06	0.05
Palmitic acid (C16:0)	21.56	19.91	20.97	23.46
Palmitoleic acid (C16:1)	1.54	1.49	1.42	1.79
Heptadecanoic acid (C17:0)	0.18	0.12	0.18	0.16
Stearic acid (C18:0)	4.90	3.79	4.28	4.81
Elaidic acid (C18:1n9t)	0.18	0.14	0.16	0.18
Oleic acid (C18:1n9c)	41.87	38.97	36.73	43.57
Linoleic acid (C18:2n6c)	7.85	7.88	5.54	10.08
Linolenic acid (C18:3n3)	0.15	0.19	0.08	0.23
g-Linolenic acid (C18:3n6)	0.12	0.14	0.05	0.19
Arachidic acid (C20:0)	0.03	0.02	0.03	0.04
Arachidonic acid (C20:4n6)	2.40	2.95	0.45	3.58
Eicosenoic acid (C20:1)	0.25	0.21	0.17	0.22
Eicosadienoic acid (C20:2)	0.26	0.22	0.22	0.24
Eicosatrienoic acid (C20:3n6)	0.21	0.27	0.07	0.27
Eicosapentaenoic acid (C20:5n3)	0.05	0.03	0.05	0.03
Behenic acid (C22:0)	0.05	0.06	0.04	0.07
Docosahexaenoic acid (C22:6n3)	0.18	0.27	0.05	0.31
Lignoceric acid (C24:0)	0.09	0.04	0.13	0.08
Nervonic acid (C24:1)	0.02	0.02	0.02	0.03
Total fatty acids identified	82.29	77.04	71.00	89.74
SFA	27.17	24.25	25.98	29.00
MUFA	43.86	40.83	38.5	45.79
PUFA	11.22	11.95	6.51	14.93
PUFA n-3	0.38	0.49	0.18	0.57
PUFA n-6	10.58	11.24	6.11	14.12
PUFA/SFA	0.41	0.49	0.25	0.51
MUFA/SFA	1.61	1.68	1.48	1.58
(MUFA+PUFA)/SFA	2.03	2.18	1.73	2.09
PUFA n-6/n-3	27.84	22.94	33.94	24.77

Note: SFA= saturated fatty acids; MUFA= monounsaturated fatty acids; PUFA= polyunsaturated.

2012). Supplementation of turmeric powder in the basal diet of experimental ducks may improve the concentration of vitellogenin in the serum as a precursor of egg yolk formation, leading to an increase in the number of developing egg follicles (Saraswati *et al.*, 2013).

Moreover, a decrease in egg production following 4% curcuma powder supplementation observed in this study was in contrast with the previous results reported in laying hens (Frita *et al.*, 2017). This decrease can be attributed to the excessive alkaloid content in curcuma powder. Curcuma powder contains an alkaloid, which may disrupt the function of intestinal villi during nutrient absorption, resulting in lower egg productions in the experimental ducks fed a diet supplemented with curcuma powder (Siahaan *et al.*, 2013). The other possible explanation for the decrease in egg production in experimental ducks supplemented with curcuma powder is that the active compounds of alkaloids in the curcuma powder inhibit the rate of vitellogenesis in the liver cells (Van den Berge *et al.*, 2012). The liver functions as a vitellogenesis organ to produce vitellogenin containing fatty acids, which are secreted into the blood vessel and distributed and deposited into the ovarium as the precursor of yolk follicle formation. Any disorder in the liver function could decrease vitellogenin synthesis and deposition in the ovary, decreasing follicle recruitment, growth, and development and eventually decreasing egg production.

The microbes contained in the probiotics grow in the digestive system and form a bacterial ecosystem that exhibits a positive effect, such as improving the immune system. Probiotics also stimulate physical changes in the intestinal structure, particularly the villus development or the ratio of villus height to crypt depth in the ileum due to the increase in nutrient digestion, leading to the improved availability of protein and fat for egg formation (Peralta-Sánchez *et al.*, 2019). However, the probiotics dosage applied in this study did not positively affect egg production.

Supplementation of the basal diet with curcuma powder reduced the albumen weight because the alkaloid in the curcuma powder reduces the absorption of amino acid from the diet, leading to lower availabilities of amino acids for albumen synthesis (Dei Cas &

Ghidoni, 2019). The egg weight is affected by the weight of the albumen and egg yolk, which is mainly composed of protein (Ratriyanto *et al.,* 2018). The depletion of protein and amino acid in feed during the growth phase could inhibit sex maturity and decrease egg size (Siahaan *et al.,* 2013).

The yolk weight in this study was not affected by the treatments. Similarly, a previous study reported that supplementation of amino acids in feed did not significantly affect the yolk weight of chicken eggs. Apparently, the genetic factor has a more significant effect on yolk weight (Mori *et al.,* 2020). In addition, the contributing factors that affect egg yolk weight are nutrient content, including dietary supplementation and lipoprotein, including phosvitin and lipovitellin (Ezzat *et al.,* 2011; Hafeez *et al.,* 2016). Again, as was mentioned previously, the main organ producing precursors of vitellogenin is liver. The hepatoprotector effects of turmeric powder will improve liver function to produce vitellogenin as a precursor of egg yolk synthesis in the growing follicles, as was observed in the experimental ducks supplemented with turmeric powder.

Furthermore, turmeric powder, curcuma powder, and probiotics supplementations in feed did not change the score of yolk color (Table 3). This finding suggests that supplementations of experimental ducks with turmeric powder, curcuma powder, and probiotics did not contribute to the pigment, such as carotenoid, which can change the yolk color (Simanjuntak *et al.,* 2013). The yolk's carotenoid is the hydroxy component called xanthophyll, lutein, and zeaxanthin (Jacob & Miles, 2011; Rodriguez-Sanchez *et al.,* 2019). The finding of this study indicated that the feed used in this study contained few coloring substances.

The increased eggshell thickness following turmeric powder and probiotic supplementations was in line with the previous study. The probiotics supplementation containing Bacillus subtilis in laying chickens produced 7.5%–8.4% thicker eggshells than the non-supplemented group (Abdelqader *et al.,* 2013). This improvement may be attributed to the increase in the health status of ducks, which is linear to the improved condition in the intestines. The positive impact of probiotics supplementation on eggshell quality is associated with the enhanced availability and digestibility of calcium, as observed by a previous study (Mikulski *et al.,* 2012). Turmeric powder also improves the oviductal environment, particularly the isthmus and uterus, where calcification occurs, leading to improvements in eggshell thickness.

Blood and Yolk Lipid Profile

The tendency to decrease blood cholesterol concentration in this study might be associated with the presence of curcumin in turmeric powder and curcuma powder and the beneficial bacteria in probiotics. Furthermore, probiotics showed the best response in enhancing the HDL level in the blood, which is needed to absorb cholesterol, carry it back to the liver, and flush it from the body. Probiotics supplementation can maintain the balanced composition of microorganisms in the digestive system, improving nutrient digestibility and maintaining animal health. Curcumin can regulate lipid metabolism in poultry. Furthermore, a study in broilers showed that curcumin alters the lipid profile and decreases the gene expression levels of fatty acid synthase and acetyl CoA carboxylase related to lipogenesis and lipolysis because these genes might be directly responsible for the effect of curcumin on the fatty acid synthesis and lipogenesis (Xie *et al.,* 2019).

Ester cholesterol from feed undergoes hydrolysis, is converted to cholesterol, and is absorbed by the intestines with the non-esterified cholesterol and other lipids (Levy *et al.,* 2015). The blood cholesterol tended to decrease because it is used to synthesize other steroid compounds, such as bile acid or hormones (Gunadi *et al.,* 2021). For instance, dietary supplementation of turmeric powder (Sirotkin *et al.,* 2018), curcuma powder (Liu *et al.,* 2020), or probiotics (Zhang *et al.,* 2019) have also been shown to increase the synthesis of progesterone, luteinizing hormone, estradiol, and follicle-stimulating hormone. The lower cholesterol concentration was due partly to bile salt deconjugation by bacteria, which produces hydrolase enzyme. Probiotics can increase bile acid excretion through feces, leading to a reduced cholesterol concentration in the serum, as cholesterol is a precursor of bile acid (Huang *et al.,* 2013; Rukayadi & Hwang, 2013). Previous studies reported that supplementation of turmeric powder at the level of 3% lowered total blood cholesterol concentrations of experimental ducks (Ismoyowati *et al.,* 2019). Turmeric powder plays a role in decreasing cholesterol levels by improving bile acid production (Xie *et al.,* 2019). The curcumin increases one of the enzymes in the liver, namely, cholesterol-7-alphahydroxylase, which converts cholesterol to bile acid and eventually reduces cholesterol (He *et al.,* 2018).

The tendency to decrease cholesterol concentration may be correlated with the depleting thymoquinone and MUFA in cholesterol synthesis due to hepatocyte or fractional reabsorption in the small intestine (Khalaji *et al.,* 2011). Acetyl CoA is less available in poultry receiving feed with curcumin supplementation, which may decrease the triacylglycerol concentration in the liver. Curcumin directly stimulates beta-oxidation in the hepatocyte, increases the absorption of non-esterified fatty acid, and catalyzes triacylglycerol into fatty acid and glycerol (Xie *et al.,* 2019). However, the present study showed that turmeric powder, curcuma powder, and probiotics supplementations did not affect the fat and cholesterol content in the yolk of duck eggs, indicating that these supplements did not interfere with the fat deposition during yolk formation. The cholesterol level in the blood is less correlated with the level in the egg since it is also a precursor of other substances, such as bile acid or hormones (Liu *et al.,* 2020; Gunadi *et al.,* 2021). Furthermore, curcumin in sufficient quantities can interfere with the reabsorption of cholesterol in the intestinal tract, thereby reducing cholesterol reabsorption. Niemann-Pick protein C1-Like 1 (NPC1L1) is a specific transporter for cholesterol absorption on the surface of the plasma membrane (Feng *et al.,* 2010).

The highest percentage of fatty acid in the ducks' egg yolk is MUFA, followed by SFA, and PUFA. SFA consisted of eight fatty acids. Palmitic acid (C16: 0) showed a relatively higher concentration than the other SFAs. Probiotics play a role in changing lipid metabolism. The study was in accordance with Milkulski *et al*. (2012), who reported the effect of probiotics on fatty acid composition in chicken egg yolks. Supplementation of 8.0×10^8 cfu/kg *Pediococcus acidilactici* to the diet increased the proportion of PUFAs, including linoleic and linolenic acids. However, changes in the fatty acid profile did not change the ratio of PUFA n-6/PUFA n-3. Lipoprotein metabolism in laying hens may differ, but the information is still limited. The concentration of MUFA was relatively low, except oleic acid (C18:1n9c), which showed a higher concentration than the other fatty acids. The PUFA identified in this study consisted of three n-3 and four n-6 fatty acids. The PUFA ratio of n-6 to n-3 (between 22.94 and 33.94, Table 5) obtained in this study is higher than that observed in a previous study, 7.39 (Sinanoglou *et al.*, 2011).

CONCLUSION

Turmeric powder, curcuma powder, and probiotics supplementations generate variable responses in egg production and egg quality, as well as the fatty acid profile in eggs. Turmeric supplementation increased egg production and eggshell thickness, while probiotics supplementation increased feed consumption, eggshells thickness, and the concentration of MUFA and PUFA. Curcuma powder supplementation decreased egg production and the egg quality of local duck. Finally, supplementation of the basal diet with turmeric powder at the level of 4% or probiotics at the level of 2% can increase egg production and quality of local ducks.

CONFLICT OF INTEREST

We certify no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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