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Impact of curcumin supplementation in monochromatic light on lipid serum profile of sexually mature female Magelang ducks

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ABSTRAK

Produksi lipid dan lipoprotein mengalami peningkatan yang bervariasi pada unggas betina yang sedang memproduksi telur. Penelitian ini dirancang untuk mempelajari pengaruh suplementasi kurkumin dengan cahaya monokromatik pada profil lipid serum itik magelang. Penelitian ini menggunakan seratus sembilan puluh dua ekor itik magelang betina dengan rancangan acak lengkap pola faktorial 4×4, terdiri atas 3 ulangan dan setiap ulangan menggunakan 4 ekor itik magelang betina. Faktor pertama adalah dosis kurkumin yang terdiri atas 4 level, yaitu 0, 9, 18, dan 36 mg/ekor/hari. Faktor kedua adalah warna cahaya monokromatik yang terdiri atas 4 level, yaitu putih, merah, hijau, dan biru. Analisis data menggunakan ANOVA dua arah (dosis kurkumin×warna cahaya). Hasil penelitian menunjukkan bahwa konsentrasi trigliserida, kolesterol, *very low density lipoprotein* (VLDL), dan *low density lipoprotein* (LDL) dalam serum lebih rendah dengan konsentrasi *high density lipoprotein* (HDL) yang lebih tinggi pada itik yang disuplementasi kurkumin 36 mg/ekor/hari pada berbagai warna cahaya dibanding itik kontrol tanpa suplementasi kurkumin. Kombinasi dosis kurkumin 18 atau 36 mg/ekor/hari dengan penambahan cahaya monokromatik merah, hijau, atau biru berpotensi memodulasi metabolisme lipid yang ditunjukkan dengan peningkatan konsentrasi HDL dan penurunan konsentrasi trigliserida, kolesterol, VLDL, serta LDL serum pada itik magelang betina dewasa kelamin.

Kata kunci: cahaya monokromatik, kurkumin, itik magelang, lipoprotein

ABSTRACT

An experiment was conducted to study the effect of curcumin supplementation in expose monochromatic light on serum lipid concentrations of sexually mature female magelang duck. One hundred and ninety two female magelang ducks were assigned into a completely randomized design with a 4×4 factorial arrangement and each experimental unit was repeated 3 times, each with 4 female magelang ducks. The first factor was dose of curcumin supplementation consisted of 4 levels i.e., 0, 9, 18, and 36 mg/duck/day. The second factor was the color of monochromatic light consisted of 4 levels i.e., white, red, green, and blue colors. The data were analyzed by two-way ANOVA. The result showed that serum concentrations of triglyceride, cholesterol, very low density lipoprotein (VLDL), and low density lipoprotein (LDL) were lower ($P<0.05$) while high density lipoprotein (HDL) were higher ($P<0.05$) in experimental ducks supplemented with a curcumin dose of 36 mg/duck/day in variety of monochromatic light colors compared to control experimental ducks without curcumin supplementation. The curcumin doses of 18 or 36 mg/duck/day within red, green, or blue light had the potential to modulate lipid metabolism, as indicated by the increased serum concentration of HDL and the decreased serum concentrations of triglyceride, cholesterol, VLDL, and LDL of the experimental female magelang ducks.

Keywords: monochromatic light, curcumin, lipoprotein, magelang duck

INTRODUCTION

Egg yolk is the main source of energy, protein, minerals, and lipid for growth and development of embryos of birds as well as for human consumption. Biosynthesis of egg yolk takes place in the liver and is stimulated by estrogen. Estrogen plays an important role in the production of yolk precursor namely vitellogenin (VTG) and very low density lipoprotein (VLDLy) (Walzem, 1996; Salvante *et al*., 2007). As a result of estrogen stimulation during sexual maturity of female birds, total lipid production in the liver is increased. The plasma lipid concentration increased from 3 mg ml^{-1} in un-laying turkeys to 21 mg ml^{-1} during laying period (Bacon *et al*., 1974). Our previous study also found the increased serum vitellogenin (Kasiyati *et al*., 2016a) and fat droplet in hepatocytes vacuoles of magelang ducks supplemented with curcumin in exposed to white, red, green, or blue light (Kasiyati *et al*., 2016b).

Curcumin also improves liver function (hepatoprotective) and acts as hipolipidemia, especially lowering serum triglyceride concentration, LDL cholesterol, and blood glucose concentrations (Gandhi *et al*., 2011). Curcumin supplementation can stimulate the secretion of bile acids and activity of lipase, amylase, and protease, which are responsible for metabolism of nutrients and increase the digestibility (Rajput *et al*., 2013). Various studies have suggested curcumin supplementation to improve feed digestibility and animal productivity, and improve the health status of both animals and humans (Gandhi *et al*., 2011; Isroli *et al*., 2017). Most researchers have focused the role of curcumin on laying hens and broilers, whereas little is known about the role of curcumin of the duck. Therefore, this presents study used of curcumin combined with monochromatic light to support duck egg production.

Various techniques have been studied to increase egg production of poultry; one is the use of artificial light. Information of light is received by the hypothalamus through the penetration of retinohypothalamus or directly on the cranial bone and brain tissue and will control the secretion and release of *gonadotropin releasing hormone* (GnRH) (Lewis and Morris, 2000). GnRH is responsible for the secretion of sex steroid hormones and stimulation of gonadal development of male and female animals. Sex steroids (androgens and estrogens) has vital role as lipolysis agents in animals and humans (Chen *et al*., 2005). Overall, light with a low intensity affects the secretion of GnRH that eventually decreases concentration of sex steroids (Deep *et al*., 2010). Moreover, the results of our previous experiment showed the decreased serum concentrations of triglyceride and cholesterol, as well as the low weight of abdominal fat of quail raised with the use of green or blue light (Kasiyati *et al*., 2010). Furthermore, the curcumin function as hepatoprotector combined with the use of monochromatic light can stimulate secretion of reproductive hormone, in turn, interaction of both curcumin and monochromatic light will support lipid synthesis of sexually mature female magelang ducks. The present experiment was designed to study the use of curcumin supplementation within artificial monochromatic light on serum lipid profile of sexually mature magelang ducks to support egg production.

MATERIALS AND METHODS

Local Ducks, Breeding Management, and Research Design

One hundred and ninety two female magelang ducks with 16 weeks of ages and body weight of 1500 ± 0.69 g were used in the experiment. The experimental ducks were obtained from Breeding Center for Non-Ruminant Livestock Farming, Banyubiru, Ambarawa, Central Java, Indonesia. The experimental ducks were randomly selected and placed into 48 cage plots and acclimatized for a week before treatment. Each cage plot contained four ducks. Each duck was marked at the ankles using colored cable ties (white, red, black, and blue). The research cages were in the form of litter system with a base made of rice husk mixed with calcite. Each cage plot had a size of 100×170×75 cm^3, equipped with feeding container and two nipple drinkers, and cages were partitioned by wooden slats coated with calcirata (GRC board).

The monochromatic light source was light emitting diode (LED) with the color of white (control), red, green, and blue with G45 type Koss and voltage of 220V. The lamps were arranged in series, hung on the top center of each cage plot. The light source was 70 cm away from the cage floor in order to obtain an intensity of 10 lux for each cage. The light intensity was measured using luxmeter/lightmeter (Lutron Taiwan, LX-100) every single week in five points for each cage plot. The lamp circuit was equipped with an adapter for managing voltage, stabilizer to stabilize the input and output electrical current, as well as timer to maintain the duration of the lighting period.

The experimental ducks were raised at ambient temperature of 28-32°C. The feed and water were provided *ad libitum*. The feed used during the experiment was in the form of wet mash formulated with curcumin, adapted to the nutritional needs of laying ducks development in the period of 16-20 weeks old (grower) and a production period of 21-25 weeks old (breeder) with different protein and metabolized energy contents. The composition of the materials and nutrient content of the feed was the result of the calculation using Excel program (Table 1). The formula for feed requirements at each stage of laying duck was prepared referring to previous study (Kasiyati *et al*., 2016b). The curcumin extract (78.94%) in the form of flour was obtained from Plamed Green Science Ltd, China. The curcumin doses used in this research were 0, 9, 18, and 36 mg/duck/day. Curcumin was added and mixed previously with the micronutrients. After mixed homogenously, the mixture was then added to the feed materials with larger composition. The feed supplemented with curcumin was given twice daily in the morning at 07.00 am and in the afternoon at 03.00 pm. The duck handling during the experiment used the protocols approved by the Animal Ethics Committee, Faculty of Veterinary Medicine, Bogor Agricultural University.

The experimental ducks were assigned into a completely randomized design (CRD) with a 4×4 factorial arrangement with 3 replications and each replication used 4 ducks. The first factor was the dose of curcumin supplementation consisted of 4 levels i.e., 0, 9, 18, and 36 mg/duck/day. The second factor was light color consisted of 4 colors i.e., white, red, green, and blue. The curcumin supplementation and the use of monochromatic light in the experimental ducks were conducted for eight weeks, starting from age of 17 to 25 weeks.

The Sample Collection and Parameters Measurement

The collections of blood serum were conducted at the end of treatment, when the ducks reached 25 weeks of age or undergone sexual maturity. Each treatment was represented by three ducks to take blood through the brachial wing vein using a 3 mL syringe (BD syringe). Blood sample was collected in a test tube for each individual. The test tubes containing blood samples were allowed to stand for 24 hours at a temperature of 4°C, and were later centrifuged at 3000 rpm for 10 minutes. The individual serum formed was transferred into a micro-tube (eppendorf tubes), stored at -20°C for analysis of triglyceride by the GPO-PAP method (Bekal *et al*., 2011); cholesterol by the CHOD-PAP method (Elwakkad *et al*., 2012); HDL, LDL, and VLDL by PEG method (CHOD-PAP), and readings were taken with a UV-Vis spectrophotometer (Nauck *et al*., 1998). Glucose concentration was measured by GOD-PAP method and protein concentration was measured by Biuret method (Abudabos *et al.*, 2013).

Statistical Analysis

The data obtained were analyzed by using two-way ANOVA (curcumin doses×light colors). The whole data analysis was done by general linear model procedure on SAS v9.0 program (SAS Institute, 2002). If the interaction effect was significant, it would be continued with interaction test using Least Significantly Different (LSD). And if there was a significant effect of main factors, the analysis would be continued with Duncan's multiple range tests. The relationship of each parameter can be seen from the magnitude of the correlation coefficient (r).

RESULTS AND DISCUSSION

Serum Triglyceride and Cholesterol at Sexual Maturity of Magelang Ducks

The present study showed that the interactions between doses of curcumin and light

Table 1. Feed Composition and Nutrient Content from Calculated Value for Each Phase of Local Duck Breeding

Feed Composition (%)	Grower Feed (16-20 weeks)	Production Feed (21-25 weeks)
Yellow corn	57	58
Rice barn	15	11.05
Corn gluten meal	6	3.5
Soybean meal	11	13
Fishmeal	5.15	3.5
Palm oil	4	2.7
Dicalcium phosphate	0.1	0.1
CaCO3	1.25	7.5
Salt	0.2	0.1
Premix*	0.3	0.3
L-lysine	0	0.1
DL-methionine	0	0.15
Total	100	100
Nutrient content from calculation result		
ME (kcal/kg)	3133.13	2898.95
Protein (%)	18.01	16.02
Fat (%)	7.22	5.08
Crude fibers (%)	3.76	3.29
Lysine (%)	0.87	0.91
Methionine (%)	0.43	0.51
Methionine+Cysteine (%)	0.70	0.76
Linoleic acid (%)	2.02	1.72
Ca (%)	0.88	3.14
P (%)	0.47	0.38
Na (%)	0.16	0.11
Cl (%)	0.21	0.14

*Each kg of premix produced by PT Mensana Aneka Satwa contains: Vitamin A, 1.200.000 IU; Vitamin D3, 200.000 IU; Vitamin E, 800 mg; Vitamin K, 200 mg; Vitamin B1, 200 mg; Vitamin B2, 500 mg; Vitamin B6, 50 mg; Vitamin C, 2500 mg; DL-methionine, 8000 mg; L-lysine, 3000 mg; Ca, 280.000 mg; P, 150.000 mg; Mn, 12.000 mg; Fe, 2000 mg; I, 20 mg; Co, 20 mg; Zn, 10.000 mg; and Cu, 400 mg

color decreased ($P<0.05$) serum triglyceride concentrations. The experimental ducks supplemented with curcumin at a dose of 36 mg/duck/day in white, red, green, and blue lights had lower ($P<0.05$) serum triglyceride concentrations by 17.93, 19.15, 17.86, and 16.59% compared to experimental ducks without curcumin supplementation but using the same monochromatic light (Table 2). Conversely, serum triglyseride concentrations in the experimental ducks exposed the red, green, or blue lights in curcumin at doses of 9, 18, or 36 mg/duck/day were not significantly different, compared to the white light in the same doses of curcumin. Similar to the decreased serum triglyceride concentrations, the experimental ducks supplemented with curcumin at a dose of 36 mg/duck/day using the white, red, green, or blue lights had lower ($P<0.05$) serum cholesterol concentrations by 20.63, 24.76, 31.94, or 34.52%, respectively, compared to control experimental ducks without curcumin supplementation but using the same color of monochromatic light (Table 2). The experimental ducks exposed the red, green, or blue light in curcumin at a dose of 18 mg/duck/day also had lower ($P<0.05$) serum cholesterol concentrations by 3.20, 6.46, or 10.73%, respectively, compared to white light in the same a dose of curcumin. A greater decrease ($P<0.05$) in serum cholesterol concentrations by 12.74 and 18.24%, respectively, were present in the experimental ducks exposed the green and blue light in curcumin at a dose of 36 mg/duck/day, compared to white light in the same a dose of curcumin.

Based on the result in the present study, it is clear that decreased of triyglyseride and cholesterol concentrations was associated with synergism of curcumin and light colors in improving digestibility, uptake, and metabolism both of triglyseride and cholesterol. The interaction between curcumin at a dose of 36 mg/duck/day in green or blue light expected increased triglyseride and cholesterol catabolism in liver cells without followed by decreased uptake of triglyseride and cholesterol from intestinal. Optimized lipids catabolism increase substrate supply for the biosynthesis of yolk egg precursors. Curcumin supplementation of sexually mature female magelang ducks was closely related with the role of curcumin as hepatoprotector (Kasiyati *et al*., 2016b), supported by the use of monochromatic light can stimulate secretion of lipolytic hormones so the lipids were

Table 2. Serum Triglyceride and Cholesterol Concentrations at Sexual Maturity of Magelang Ducks Supplemented with Curcumin in Exposed the Monochromatic Light#)

Light Colors	Curcumin Doses (mg/duck/day)			
	0	9	18	36
Triglyceride (mg dL^{-1})				
White	112.50±0.18[a]	104.80±0.24[bcd]	96.40±0.25[fgh]	92.33±0.30[hi]
Red	111.57±0.24[a]	102.32±0.16[cde]	94.87±0.18[fghi]	90.20±0.06[i]
Green	109.77±0.34[ab]	99.85±0.47[def]	94.61±0.33[fghi]	90.16±0.27[i]
Blue	106.97±0.26[abc]	98.72±0.34[efg]	93.14±0.10[ghi]	89.22±0.17[i]
Cholesterol (mg dL^{-1})				
White	273.73±0.47[a]	267.94±0.71[bc]	253.50±0.64[e]	217.26±1.40[i]
Red	273.62±0.40[a]	269.67±0.45[ab]	245.38±1.41[f]	205.88±1.06[j]
Green	273.58±0.64[a]	262.97±0.13[cd]	237.12±0.28[g]	189.59±1.21[k]
Blue	271.29±0.06[ab]	258.98±0.54[d]	226.29±1.12[h]	177.64±0.85[l]

#)There was an interaction (P<0.05) between curcumin dose and light color.
a-iMeans of triglyceride values followed by different letters are significantly different (P<0.05).
a-lMeans of cholesterol values followed by different letters are significantly different (P<0.05).
The results are presented as mean ± SD.

easily converted into the egg yolk component. Furthermore, the use of green or blue light could be decreasing oxidative stress in birds (Ke *et al*., 2011), so that biosynthesis of the egg yolk component in the liver cells more optimal.

The liver of laying birds during sexual maturity have a great capability in converting lipids into the egg yolk component and directly taken by the plasma to be deposited into the growing ovarian follicle oocytes. The hypolipidemic effect of between curcumin supplementation and the use of monochromatic light color in experimental ducks may be due to the increased rate of these lipids depositions into the developing oocytes in the ovarian follicle. Meanwhile, reports on previous studies showed that some mechanisms of curcumin in lowering lipid biosynthesis, were curcumin increasing lipase activities. Lipase plays an important role in the breakdown of lipids in the alimentary tract (Chattopadhyay *et al*., 2004; Akram *et al*., 2010) and curcumin inhibiting the activity of a liver enzyme responsible for cholesterol synthesis, which is the 3-hydroxyl-methylglutaryl CoA-reductase (HMG-CoA reductase), so as the production of cholesterol can significantly decrease (Crowell, 1999; Galib *et al.,* 2011).

Serum VLDL, LDL, and HDL at Sexual Maturity of Magelang Ducks

The lipoprotein profile as lipid carriers was significantly affected by doses of curcumin in light colors (curcumin doses×light colors interaction). Serum VLDL concentrations in the experimental ducks supplemented with curcumin doses of 18 or 36 mg/duck/day in the white, red, green, and blue light had lower (P<0.05), compared to control experimental ducks without curcumin supplementation in the same color of monochromatic light (Table 3). In contrast, serum VLDL concentrations in experimental ducks exposed to red, green, or blue lights at doses of curcumin 9, 18, or 36 mg/duck/day were not significantly different, compared to white light in the same doses of curcumin.

Similar to the profiles of serum VLDL concentrations, the experimental ducks supplemented with curcumin at dose of 36 mg/duck/day and exposed white, red, green, and blue lights had lower (P<0.05) serum LDL concentrations by 11.16, 13.16, 13.17, and 13.29%, respectively, compared to control

Table 3. Lipid Carrying Lipoprotein in the Form of VLDL, LDL, and HDL at Sexual Maturity of Magelang Ducks Supplemented with Curcumin in Exposed the Monochromatic Light#)

Light Colors	Curcumin Doses (mg/duck/day)			
	0	9	18	36
VLDL (mg dL^{-1})				
White	22.50±0.04^{a}	20.96±0.05^{ab}	19.28±0.05^{b}	18.47±0.06^{b}
Red	22.31±0.05^{a}	20.46±0.03^{ab}	18.97±0.04^{b}	18.05±0.02^{b}
Green	21.95±0.07^{a}	19.97±0.09^{ab}	18.92±0.07^{b}	18.03±0.05^{b}
Blue	21.39±0.05^{ab}	19.74±0.07^{ab}	18.63±0.02^{b}	17.84±0.04^{b}
LDL (mg dL^{-1})				
White	222.23±0.30^{a}	215.97±0.37^{bc}	205.13±0.29^{de}	197.44±0.30^{fgh}
Red	223.26±0.13^{a}	211.90±0.14^{cd}	201.82±0.64^{ef}	193.89±0.44^{gh}
Green	219.97±0.27^{ab}	211.01±0.20^{cd}	200.74±0.36^{ef}	190.99±0.49^{h}
Blue	218.74±0.29^{abc}	208.29±0.16^{de}	199.58±0.45^{efg}	189.68±0.55^{h}
HDL (mg dL^{-1})				
White	40.99±0.68^{d}	43.06±0.08^{cd}	45.75±0.04^{bcd}	48.26±0.15^{ab}
Red	41.48±0.08^{d}	43.81±0.11^{cd}	45.60±0.70^{bcd}	49.30±0.13^{ab}
Green	41.30±0.40^{d}	44.27±0.14^{bcd}	46.87±0.08^{abc}	50.75±0.12^{a}
Blue	42.52±0.18^{cd}	44.93±0.13^{bcd}	47.42±0.29^{abc}	51.67±0.29^{a}

#)There was an interaction (P<0.05) between curcumin dose and light color.
a,bMeans of VLDL values followed by different letters are significantly different (P<0.05).
a-hMeans of LDL values followed by different letters are significantly different (P<0.05).
a-dMeans of HDL values followed by different letters are significantly different (P<0.05).
VLDL: very low density lipoprotein; LDL: low density lipoprotein; HDL: high density lipoprotein.
The results are presented as mean ± SD.

experimental ducks in the same color of monochromatic light. On the other hand, serum LDL concentrations in experimental ducks exposed to red, green, or blue lights at doses of curcumin 18 or 36 mg/duck/day were not significantly different, compared to white light in the same doses of curcumin (Table 3).

In contrast to the VLDL and LDL, interaction between doses of curcumin and the color of monochromatic light increased (P<0.05) serum HDL concentrations. The experimental ducks supplemented with curcumin at a dose of 36 mg/duck/day in the white, red, green, or blue light had higher (P<0.05) serum HDL concentrations by 15.06, 15.86, 18.62, and 17.71%, respectively, compared to control experimental ducks without curcumin supplementation in the same color of monochromatic light (Table 3).

As soon as synthesized in the liver, egg yolk lipids in the form of VLDL (triglyceride-rich) will be secreted from the liver into the bloodstream to be transported and deposited in the growing oocytes in the ovarian follicles. There are some indications that oocytes maximally uptake the circulating VLDL in the blood, supported by the negative correlation between VLDL with F1 follicle diameter (r = -0.57). This result showed that the decreased in the concentration of VLDL in the experimental ducks supplemented with curcumin and exposed monochromatic light were in line with the increased rate of deposition precursors of yolk in the developing follicle. The finding of present study in VLDL concentrations of female magelang ducks was in agreement with the report of Hermier (1997) that the concentration of VLDL in the plasma reflects the rate of the triglyceride use for the synthesis and secretion of lipoproteins and its deposition in the fat depot, or as a component of egg yolk precursor. Walzem (1996) and Cherian (2015) also reported the VLDL deposited in the egg yolk in the developing oocytes in the ovary is estimated to have a smaller diameter than half of the normal VLDL circulating in the body. VLDL is undergoing a form of specialization, specifically in egg-laying birds, referred to as VLDL yolk (VLDLy). Significantly, there is no exogenous lipid transported directly from the liver into the yolk, only triglyceride synthesized *de novo* packaged into VLDL to be transported and deposited into the developing oocytes in the ovarian follicles.

The results in this current study demonstrated that the decreased serum concentrations of LDL in the experimental ducks due to the interaction among curcumin doses and light color. It was also associated with the increased rate of LDL deposition into the developing oocyte in the ovary. Similar to the results of previous studies, the increased transport of lipoproteins into ovarian oocytes will significantly reduce the proportion of VLDL, LDL, and HDL in the blood plasma (Gornall and Kuksis, 1973). Additionally, the highest of serum HDL in the experimental duck supplemented with curcumin at dose of 36 mg/duck/day in the green or blue light indicated that curcumin in monochromatic light involed in the HDL cholesterol metabolism. Moreover, the increase in bioavailability of curcumin can effectively increase the concentration of HDL (Daneshyar *et al*., 2011; Chandrakala and Tekulapally, 2014; Mirzabeigi *et al*., 2015).

Serum Glucose at Sexual Maturity of Magelang Ducks

Results of the experiment showed that serum glucose concentrations significantly affected by light colors in doses of curcumin (P<0.05). The serum glucose concentrations in the experimental ducks exposed blue light and supplemented with curcumin at a dose of 36 mg/duck/day was higher (P<0.05) by 7.7%, compared to controlled experimental ducks in the same light without curcumin supplementation (Table 4). Conversely, serum glucose concentrations in the experimental ducks supplemented with curcumin at doses of 9, 18, or 36 mg/duck/day in red, green, or blue lights were not significantly different, compared to the same doses of curcumin in the white light. It is assumed that the interaction between the blue light and curcumin supplementation stimulates glucose uptake from the intestine and increase glucose uptake by the liver cells. Glucose is then converted into fatty acids as component for the biosynthesis of precursors of egg yolk or stored in the liver as glycogen.

High concentration of glucose in the serum of experimental ducks supplemented with curcumin at doses of 36 mg/duck/day in the white, red, or blue light were also supported by the negative correlation between glucose and triglyceride (r = -0.84) or glucose and cholesterol serum (r = -94). This fact represents the reduction in triglyceride and cholesterol uptake by the intestinal cells stimulates an increase in glucose absorption when the eggs biosynthesis occurred in sexually mature experimental ducks supplemented with curcumin and exposed monochromatic light. Additionally, curcumin supplementation in the white, red, or blue light may be increased glucose metabolism, primarily to support daily activity and ensuring sustainability in the eggs biosynthesis. Glucose can be converted into essential nutrients and main source of energy in the form of ready to use and easily mobilized. Ghorbani *et al*., (2014) reported that curcumin was also involved in glucose homeostasis through various means, such as stimulation of the absorption of glucose by increasing gene expression of glucose transporter 4 (GLUT4), GLUT3, and GLUT2, and stimulates the secretion of insulin by the pancreas. Meanwhile, the use of monochromatic light in laying fowls can prevent hypoglycemic through gluconeogenesis (Hassan *et al.*, 2013; Pan *et al.*, 2014; Tabeekh, 2016)

Serum Protein at Sexual Maturity of Magelang Ducks

The interaction between the dose of curcumin supplementation and the use of monochromatic light did not affect serum protein concentration of sexually mature female magelang ducks. However, serum protein concentration significantly affected by curcumin supplementation or using monochromatic light. Experimental ducks supplemented with curcumin at doses of 9, 18, and 36 mg/duck/day increased (P<0.05) serum protein concentration by 10.70, 21.70, and 35.78%, respectively, compared to control experimental ducks without curcumin supplementation. Regardless of curcumin supplementation, experimental ducks in the blue light had higher (P<0.05) serum protein concentrations by 5.87, 5.02, and 4.75%, compared to those using white, red, and green lights, respectively (Table 5).

The research clearly showed that curcumin supplementation increased total protein concentration in the experimental ducks. This fact indicated that curcumin supplementation increased the rate of protein synthesis in the liver in experimental ducks. Liver cells of experimental ducks have a huge capacity to synthesize proteins during sexual maturity. Protein synthesized in the liver is a major component precursor in the biosynthesis of vitellogenin. The alternative assumption is that curcumin supplementation increases protein uptake by the hepatocyte due to the increased need of substrate and precursor by the liver to biosynthesize vitellogenin. Furthermore, the increased protein concentration in the serum of experimental ducks supplemented

Table 4. Serum Glucose Concentrations (mg dL^{-1}) at Sexual Maturity of Magelang Ducks Supplemented with Curcumin in Exposed the Monochromatic Light[#)]

Light Colors	Curcumin Doses (mg/duck/day)			
	0	9	18	36
White	113.45±1.38^{cd}	111.19±0.33^{d}	114.93±0.09^{bcd}	116.71±0.13^{abc}
Red	111.46±0.89^{d}	113.11±0.16^{cd}	114.95±0.08^{bcd}	117.27±0.08^{abc}
Green	114.16±0.69^{bcd}	114.17±0.72^{bcd}	115.78±0.11^{abcd}	118.32±0.08^{ab}
Blue	111.44±1.13^{d}	113.82±0.13^{cd}	116.09±0.13^{abc}	120.10±0.18^{a}

[#)]There was an interaction (P<0.05) between curcumin dose and light color.
$^{a\text{-}d}$Means followed by different letters are significantly different (P<0.05).
The results are presented as mean ± SD.

Table 5. Serum Protein Concentrations (g dL^{-1}) at Sexual Maturity of Magelang Ducks Supplemented with Curcumin in Exposed the Monochromatic Light[*)]

Light Colors	Curcumin Doses (mg/duck/day)				Mean
	0	9	18	36	
White	3.22±0.06	3.45±0.05	3.88±0.05	4.45±0.15	3.75^{b}
Red	3.18±0.06	3.66±0.29	3.96±0.02	4.35±0.05	3.78^{b}
Green	3.35±0.11	3.59±0.07	3.83±0.40	4.37±0.09	3.79^{b}
Blue	3.34±0.05	3.78±0.04	4.18±0.06	4.58±0.09	3.97^{a}
Mean	3.27^{d}	3.62^{c}	3.96^{b}	4.44^{a}	

[*)]No interaction (P>0.05) among the main effect (curcumin doses×light colors).
$^{a\text{-}d}$Means followed by different letters in the same row are significantly different (P<0.05).
$^{a\text{-}b}$Means followed by different letters in the same column are significantly different (P<0.05).
The result are presented as mean ± SD.

with curcumin is related to the increased serum glucose concentrations that is supported by the positive correlation between glucose concentration and protein concentration (r = 0.90). The highest concentration of protein also found in the experimental ducks used blue light. The experimental ducks in the blue light showed behavior that was calmer and quieter and was not aggressive that was assumed to facilitate the optimum protein synthesis in the liver. Other studies have reported that blue light increased the total protein of laying hens and stimulated androgen synthesis in broiler. Androgen plays an important role in increasing protein synthesis (Tabeekh, 2016).

CONCLUSION

The dose of curcumin of 18 or 36 mg/duck/day within the red, green, or blue light has the potential to modulate lipid metabolism, as indicated by elevated HDL and decreased triglyceride, cholesterol, VLDL, and LDL serum concentrations in sexually mature female magelang ducks.

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