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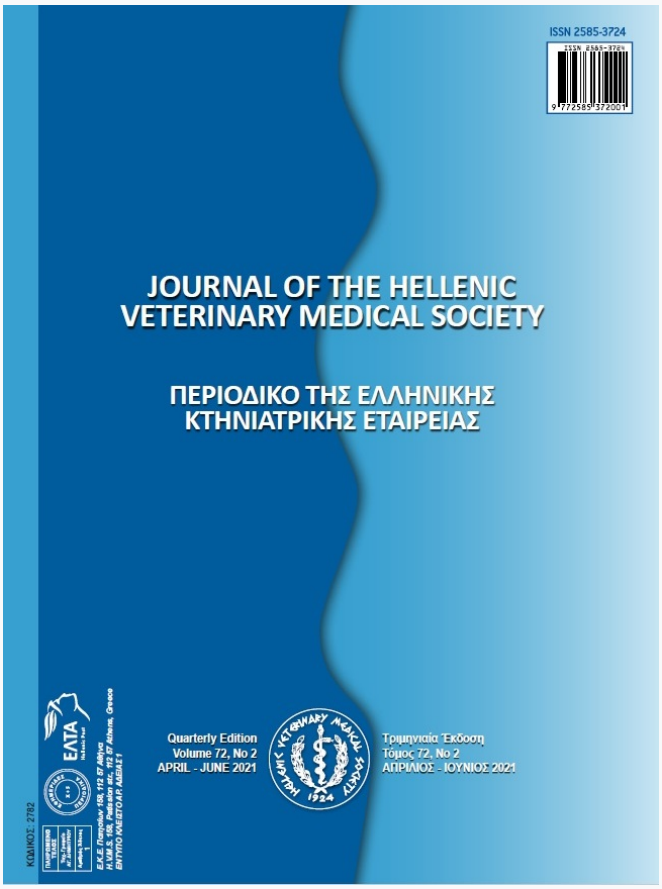

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Research article
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Effect of light colour temperature on expression and serum profile of selected immune markers in layers

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ABSTRACT: This study was carried out to quantify the effects of different temperatures of light colour on expression and serum profile of selected immune markers in Fayoumi layers. A total of 165 Fayoumi healthy pullets, 17 weeks of age were used. At laying, birds were separated in well ventilated environmentally-controlled rooms and allocated into three groups of 55 birds each (5 males and 50 females) for 3 months and these birds represented the base generation (F_0). Fertile eggs were collected and the newly hatched chicks were also divided into three groups from first day of life till 3 months after laying and these represented the first generation (F_1). In the two generations, the first group (control) was exposed to cool white LED light (day light) (6500 kelvin), the second group was exposed to very cool white LED light (sky blue light) (10000 kelvin) and the third group was exposed to warm white LED light (yellow light) (2700 kelvin). Birds of each group of the two generations were evaluated for expression profile of *TLR4 and IL10* genes and serum level of IL10. Results showed that blue light-exposed groups, in the two generations, exhibited a higher up-regulation of *TLR4 and IL10* genes and increased serum level of IL10 compared to groups experienced either white or yellow light colour. Comparison between F_0 and F_1 individuals revealed improved genetic profiles for F_1 birds. The results therefore elucidate the benefits of using blue light in improving the immune status of layers in order to predict the most susceptible risk time for disease incidence and to build up an effective management regimen.

Keywords: Layers; gene expression; immune markers; light; Fayoumi chickens

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INTRODUCTION

Poultry production is an important component of agriculture all over the world. Chickens are considered one of the most popular types of poultry all over the world regardless culture and religion. The reason for popularity could be the high nutritive values poultry products have (Bell et al., 2002; da Silva et al., 2017; Kralik et al., 2018). Fayoumi is one of the native old breeds of chicken in Egypt. It is named for the Faiyum Governorate, southwest of Cairo and west of the Nile (Meyer, 1997; Zhou and Lamont, 2003). They are a lightweight fowl, with roosters weighing in around 2 kilograms (4.4 lb) and hens 1.6 kg (3.5 lb). In roosters, the plumage is silver-white on the head, neck, back and saddle, with the rest in a black and white barring. Hens have heads and necks in the silver-white hue, with the rest barred. Fayoumi has a single comb, red moderately large earlobes and wattles, with a white spot in the earlobes. Fayoumi also has dark horn coloured beaks, and slate blue skin (Zhou and Lamont, 2003).

Artificial light source as an external environment factor is an important aspect affecting growth and immunity in layers. It is well known that lighting factors, such as intensity, exposure time and colour affect physiology and immune competence of chickens (Foss et al., 1972; Rozenboim et al., 1999; Olanrewaju et al., 2006; Xie et al., 2008; Blatchford et al., 2009; James et al., 2018). Light colour is described by chromaticity. Chromaticity is the measure of warmth of the light source (warm light) or coolness (cool light) expressed in degrees Kelvin. The scale ranges from 2000 to 7000K. Chromaticity values of 4000 K and above are considered cool (mostly blue light), while those around 3500 K or 3600 K are called neutral, and those of about 3000 K or below are considered warm (more red light) (Knisley, 1990). Light-emitting diodes (LED) saves energy efficiently and provide sufficient brightness (Hassan et al., 2014). Natural daylight can be also effectively simulated by the application light-emitting diode (LED) than the spectral gaps of other lighting sources (El-Sabrout and Khalil, 2017). Additionally, LEDs are potentially beneficial to the poultry industry due to long life span, moisture resistance, and narrow spectrum (Olanrewaju et al., 2015; Sharideh and Zaghari, 2017). Thus, most of the poultry producers have replaced ICD (inductively coupled discharges) lamps with LEDs. It has been established that the colour of light is a remarkable physical component of light that has a great impact on different productive, reproductive and immune parameters of chickens (Olanrewaju et al., 2015). Moreover, as long as the longer wave lengths are possessed, the higher penetration power of light is attained (Yang et al., 2016).

Light is also a key microclimatic factor that hits chicken skull at the retinal receptors and travels through neurons to the pineal gland and hypothalamus regulating centers (Egbuniwe and Ayo, 2016). Poultry detect light through the photoreceptors of retina and the extra-retinal photoreceptors in the brain. The brains of birds are equipped with active extra-retinal photoreceptors that receive light energy and transmit it through the skull and tissues. The chicken eye is capable of discriminating light colour due to 7 photoreceptors (1 rod and 6 cones) in the eye (Hartl and Hayer-Hartl, 2002). The chicken retina consists of four types of single cones and a double cone, which are highly responsive to violet, blue, green, and red light (Bowmaker and Knowles, 1977). Photoreceptive pigments located at cones are characterized by a high sensitivity to violet (415 nm), blue (455 nm), green (508 nm), and red (571nm) (Parry et al., 2004). Therefore, light colour has been studied in poultry over the last three decades and its use has increased recently. The use of coloured lighting systems is an option to enhance production of layers in the modern layer industry. Many kinds of lights have been introduced commercially however, light emitting diode (LED) can dramatically save energy and provide adequate illumination (Rozenboim et al., 1998).

Chicken Toll-like receptor (TLR) repertoire consists of ten genes similar to that found in human and is two fewer than mouse (Higgs et al., 2006). The identified TLRs include TLR1 type 1, 2, TLR2 type 1, 2, TLR3, TLR4, TLR5, TLR7, TLR15, and TLR21. Chicken TLRs are present in different organs as thymus, liver, kidney, brain, muscle, spleen, bursa, and testis (Bekeredjian-Ding and Jego, 2009). Toll-like receptors (TLRs) are a family of transmembrane-spanning proteins, which recognize molecules unique to microbes, discriminate self from non-self-antigens, trigger appropriate immune responses, act as sentinels of tissue damage, and mediate inflammatory responses to aseptic tissue injury (Marsh et al., 2009).

Interleukin-10 encodes a 178-aa polypeptide, with a predicted 162-aa mature peptide. It has 45 and 42% aa identity with human and murine IL-10, respectively. The chIL-10 gene structure is similar to (five exons, four introns), but more compact than, that of its mammalian. Chicken IL-10 mRNA expression

was identified mainly in the bursa of Fabricius and cecal tonsils, with low levels of expression also seen in thymus, liver, and lung (Rothwell et al., 2004). IL-10 is one type of the anti-inflammatory cytokines that could control the nature and degree of inflammation responses during infection, and also share an important role in immunity of intestine, and hemostasis (Manzanillo et al., 2015). IL-10 expression is extensively regulated at the post-transcriptional level, which may involve control of mRNA stability via AU-rich elements and by microRNAs such as let-7 or miR-106 (Sharma et al., 2009).

Research has elaborated the effects of light colour temperatures on different parameters of broiler including performance (Hassan et al., 2014; Sultana et al., 2014; Archer, 2016; Shariadeh and Zaghari, 2017; Abdel-Azeem and Borham, 2018), behaviour (Prayitno et al., 1997; Blatchford et al., 2009), welfare (Mohamed et al., 2014), health and productivity (Blatchford et al., 2009; Deep et al., 2010), heat stress (Abdo et al., 2017; Mousa-Balabel et al., 2017), carcass characteristics (Onbaşılar et al., 2007; Olanrewaju et al., 2015), immune parameters (Hassan et al., 2014; Firouzi et al., 2014), blood properties (Firouzi et al., 2014; Seo et al., 2016), and physical traits (Alattar et al., 2019). In layers, research has focused also on many aspects including performance (Kamanli et al., 2015), egg production (Han et al., 2017; EL-Emam et al., 2019), egg quality (Er et al., 2007; Borille et al., 2013; Kamanli et al., 2015; El-Sabrout and Khalil, 2017), behaviour (Mohamed et al., 2010; Sultana et al., 2013; Shi et al., 2019), hatching performance (Yu et al., 2018) and stress response (Liu et al., 2018; Archer, 2019).

Research carried out on the effect of light colour in broiler showed conflicting findings. Blue light colour has been suggested to improve the immune status of birds (Hassan et al., 2014; Mohamed et al., 2014; Seo et al., 2016; Guo et al., 2018; Soliman and Hassan 2019). However, warm light colour has been reported to enhance immunity (Sharideh and Zaghari, 2017). There is a little information regarding the effect of light colour temperature on immune status of layers. Additionally, no previous studies have considered how environmental factors such as the temperature of light colour may affect immunity of layers through successive generations, as well as how these effects can be explored through the approach of gene expression profile of immune markers.

Therefore, the objectives of this study were to evaluate the effect of different light colour temperatures on the immune status of Fayoumi layers by investigating the expression pattern of *TLR4* and *IL10* genes and the serum profile of IL10.

MATERIALS AND METHODS

Experimental birds and design

Base generation (F_0)

A total of 165 Fayoumi healthy pullets (17 weeks) with a similar body weight (900 ± 30 gram) were used in this experiment. Pullets were purchased from a governmental farm for poultry breeding in Fayoum Governorate, Egypt. All birds were housed in the same room till the time of laying at a density of 8 birds/m^2. The photoperiod was 12L: 12D, the relative humidity ranged from 67 to 77 % (Cao et al., 2008), and the house average temperature was 28 °C. Ventilation and temperature were checked daily and kept adjusted throughout the experiment (Rosa et al., 2019). From the 19th week the lighting schedule was gradually increased half an hour every week till it reached 16L: 8D lighting schedule at laying time (Han et al., 2017). As soon as laying started, at 24 weeks, the birds were allocated into three groups in three separate, well-ventilated, environmentally-controlled rooms according to the light colour temperature. Each room had a floor area of 9 m^2 (3m width x 3m depth) and was used for housing of 55 birds (5 males and 50 females). The first group (control) was exposed to cool LED white light (day light) (6500 kelvin). The second group (sky blue light) was exposed to very cool LED white light (10000 kelvin) and the third group (yellow light) was exposed to warm LED white light (2700 kelvin) till the end of the experiment. Light intensity was 25 lx (1.4-ft candle) during the light phase and 0 lx during the dark phase of the photoperiod (Mohammed et al., 2010). The intensity of light was recorded near the floor, nearly at the level of bird height. Artificial light systems were placed 10 cm above the birds using plastic crosses attached to the ceilings of the rooms. Feed intake was calculated daily according to standard farm husbandry practices to meet the nutrient recommendations for poultry of National Research Council (NRC, 1994) and drinking water were allowed ad-libitum throughout the experimental period.

First generation (F_1)

Eggs were collected daily, and egg number and egg weight were recorded daily for each group. All eggs

for incubation were sorted in order to remove cracks, morphological deformities and dirt. At 28 weeks of age, fertile eggs were collected for 5 days from each group. They were incubated in a humidified egg incubator at 37 °C and 70% RH. The newly hatched chicks (F_1) were wing banded, weighed at hatch and then every two weeks, and were inoculated based on the program of vaccination of the Local Veterinary Organization. Chicks were divided into three groups from first day of life as the base generation control cool white, sky blue light and yellow light but were subjected to a continuous artificial lighting during the first 8 weeks of age. This artificial light was decreased to 12 hours light and 12 dark at 17th week of age, then was gradually increased by one hour/month till reached 16 hours light at the 21st week of age (Han et al., 2017). Chicks were offered a ration for starters (19 % CP and 2800 Kcal/Kg) from the time of hatch to the age of 8 weeks, a ration for growers (15 % CP and 2700 Kcal/kg) from the age of 9 to 20 weeks, and then were fed a balanced ration for layers covering their nutritional requirements (16 % CP and 2700 Kcal/kg) till the end of the experiment (Baghban-Kanani et al., 2020). Table 1 shows the ingredients and chemical composition of the diet.

Sample collection

In both base and first generations, tissue and blood samples were taken in each group from 50 females and 5 males. Tissue samples were taken from spleen for RNA extraction. The samples were put in Eppendorf containing RNA later (Qiagen, Germany), to minimize the action of endogenous RNase. The blood samples were collected without anticoagulant from wing veins into clean and dry centrifuge tubes, were allowed to clot at room temperature, and were then centrifuged at 3000 rpm for 5 min. Serum was stored at -20 °C until biochemical analysis. Research Ethics Committee, Faculty of Veterinary Medicine, Mansoura University approved the protocol of the study.

Table 1. Ingredients and chemical composition of the diet used in the experiment.

Ingredient	Starter (0-8 wk.)	Growing (9-20 wk.)	Laying (21wk.-till end of experiment)
Yellow corn (kg)	63	63	65
Soybean meal (44% cp) (kg)	30	16.50	23.3
Wheat bran (kg)	3	16.70	1.90
Di- calcium phosphate (kg)	1.80	1.30	1.50
Limestone (kg)	1.50	1.80	7.6
Nacl (kg)	0.30	0.30	0.30
Premix (vitamins minerals mixture) (kg)	0.30	0.30	0.30
Methionine (kg)	0.10	0.10	0.10
Total (kg)	100	100	100
Calculated analysis:			
Metabolizable energy k Cal /kg	2800	2700	2700
Crude protein %	19	15	17
C/P ratio	147	193	168
Calcium %	1	.90	3.30
Available phosphate %	0.45	0.40	0.40
Lysine %	0.95	0.70	0.73
Methionine %	0.38	0.30	0.32
Methionine and cystine %	0.70	0.54	0.62

Table 2. Oligonucleotide primers sequence, accession number, annealing temperature and PCR product size of *TLR4, IL10 and β-Actin* genes.

Gene	Primer (forward)	Product length (bp)	Accession number	Reference
TLR4	F:5-GAGAACCTCAATGCGATGC-3 R:5-ATAGGAACCTCTGACAACG-3	272	NM_001030693	(Lu et al., 2013)
IL10	GGAGCTGAGGGTGAAGTTTG-3 -5: F TAGAAGCGCAGCATCTCTGA-3 -5: R	416	AJ621254	(Lu et al., 2013)
β-Actin	F:5-GAGAAATTGTGCGTGACATCA-3 R:5-CCTGAACCTCTCATTGCCA-3	152	NM_205518.1	(Yuan et al., 2007)

Table 3. Reverse transcription and real time PCR program for *TLR4, IL10 and β-Actin* genes.

Gene	Reverse transcription	Primary denaturation	Amplification (40 cycles)			Dissociation curve (1 cycle)		
			Secondary denaturation	Annealing	Extension	Secondary denaturation	Annealing	**Final extension**
TLR4	50˚C 30 min	94˚C 15 min.	94˚C 15 sec	56˚C 30 sec.	72˚C 30 sec	94˚C 1 min.	56˚C 1 min.	72˚C 1 min.
IL10	50˚C 30 min.	94˚C 15 min.	94˚C 15 secs	59˚C 30 sec.	72˚C 30 sec.	94˚C 1 min.	59˚C 1 min.	72˚C 1 min.
β. actin	50˚C 30 min.	94˚C 15 min.	94˚C 15 sec.	51˚C 30 sec.	72˚C 30 sec.	94˚C 1 min.	51˚C 1 min.	72˚C 1 min.

RNA extraction and real time PCR

The RNA extraction was done using RNeasy Mini Kit (Qiagen, Germany), according to the protocol of the manufacturer. To remove any contaminating genomic DNA, RNA was treated with RNAse free-DNAse I (Qiagen, Germany). The expression profile of *TLR4* and *IL10* genes was carried out in spleen. The relative expression was quantified using SYBR Green PCR Master Mix (2x SensiFast™ SYBR, Bioline). Primer sequences and annealing temperatures are shown in Table 2. The housekeeping β-actin gene was used as an internal control. The reverse transcription of the extracted mRNA and the real time PCR program schedule for each gene is illustrated in Table 3. The real time PCR procedures for selected immune genes were carried out according to procedures described by Ateya et al., (2019). Stratagene MX3005P software was used to determine CT values. In order to detect variation of gene expression on the RNA of different samples, CT of each sample was compared with that of the control group according to "ΔΔCt" method stated by Yuan et al., (2006).

Biochemical analysis

IL-10 was determined using ready-made interleukin-10 (IL-10) ELISA Kits provided by Quantikine Company according to the method described by Zdanov et al. (1996).

Data analysis

Results were expressed as means ± standard error of the mean. Analysis was done using one-way analysis of variance (ANOVA) to test all groups' unpaired values. Duncan Multiple Range Test was used to separate the means among the treatment groups. Differences were considered to be significant at the level of ($P \leq 0.05$).

RESULTS

The impact of light colour temperature on the pattern of expression of immunity genes (*TLR4 and IL10*) was explored in males and females of F_0 and F_1 generations (Figure 1). Blue colour light-exposed groups exhibited a significant up-regulation of the *TLR4 and IL10* in both males and females compared to both white (control) and yellow colour light-exposed groups. Comparison of F_0 and F_1 generations revealed that F_1 generation had a higher up-regulation of *TLR4 and IL10* genes than F_0 in both males and females.

The impact of light colour temperature on the serum profile of IL10 was explored in both males and

females of F_0 and F_1 generations (Figure 2). There was a significant effect to the light colour temperature on serum levels of IL10. Blue colour light-exposed groups exhibited a significant increase in serum IL10 values in both males and females compared to both white (control) and yellow colour light-exposed groups. Comparison of F_0 and F_1 generations elucidated that F_1 generation had higher values of IL10 than F_0 in both males and females.

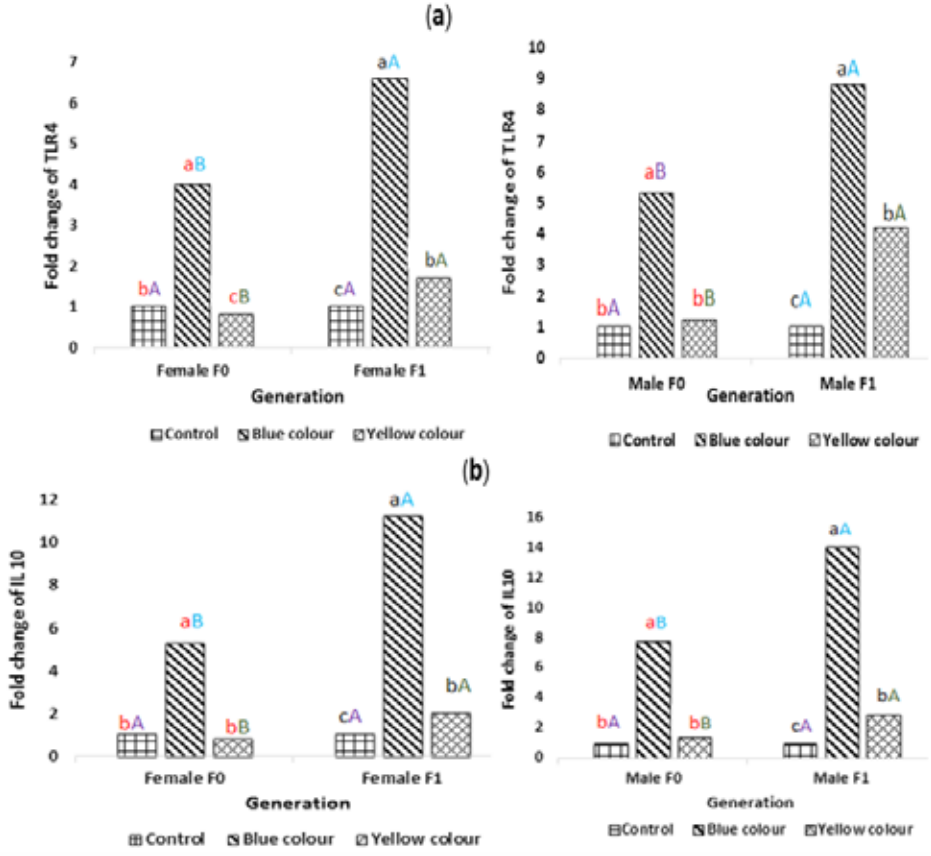

Figure 1. Relative expression of *TLR4* (a) and *IL10* (b) in males and females of base (F_0) and first (F_1) generation. Small letter indicates a significant difference between groups at the same generation. Capital letter indicates a significant difference between the two generations.

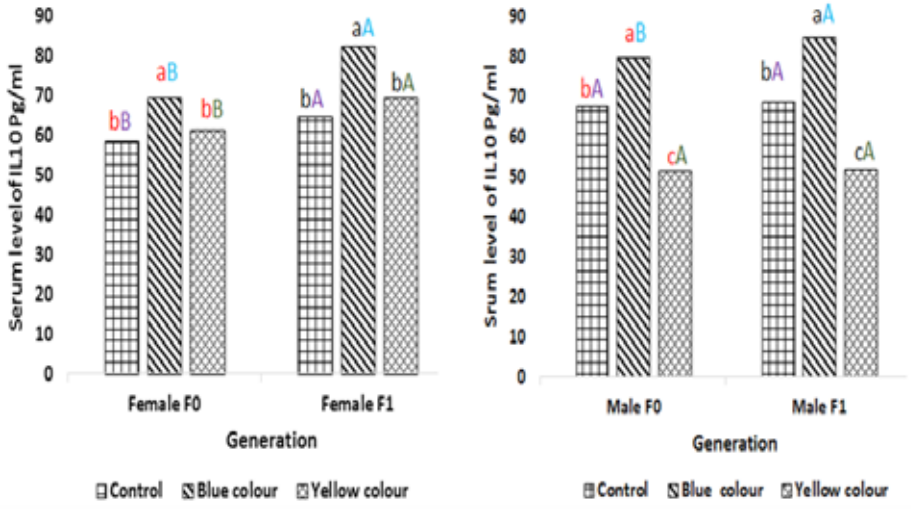

Figure 2. Serum level of IL10 in males and females of base (F_0) and first (F_1) generation. Small letter indicates a significant difference between groups at the same generation. Capital letter indicates a significant difference between the two generations.

DISCUSSION

Light is as an important management tool to manipulate layer immunity. Light colour in particular is considered an important aspect of light that has been considered at one time as a management tool in poultry production (Prayitno et al., 1997). Photoperiod, wavelength, light intensity and more importantly light colour are characteristics that have to be taken into consideration in the selection of artificial light sources and the design of lighting programs for chickens (Thiele, 2010).

Maintenance of layers immune function has therefore become a necessity to avoid reduction in disease resistance and productivity. It has been shown that chicken serum composition could be modulated by lighting program (Onbaşılar et al., 2007). Toll-like receptors (TLRs) are highly conserved proteins secreted from macrophage and dendritic cells, participate in pathogen detection, enhance the production of inflammatory cytokines and up-regulate co-stimulatory molecules (Krishnan et al., 2007; Underhill and Ozinsky. 2002). In avian species, ten TLRs have been identified. Chicken *TLR4* is expressed in different locations including blood and spleen (Kogut et al., 2005). IL-10 is known as the anti-inflammatory cytokine secreted by macrophages, monocytes, and B cells (Eskdale et al., 1997). It also possesses pleiotropic effects in inflammation and immunoregulation (Pestka et al., 2004; Saraiva and O'Garra, 2010). Moreover, gene expression regulation can be exerted at a posttranscriptional level (Said et al., 2010; Haritova and Stanilova, 2012).

Findings of the current study revealed that blue colour light-exposed group had the highest up-regulation of *IL-10 and TLR4* gene expression in both males and females of F_0 and F_1 generations. As far as we are concerned there is a lack of studies exploring the effect of light colour temperature on immune status in layers particularly those considered gene expression of immune markers. Light has been shown to have a remarkable effect on immune response (Moore and Siopes, 2000; Onbaşılar et al., 2007; Blatchford et al., 2009) however, this effect may be poorly understood (Xie et al., 2008). The improved immune profile of the birds experienced blue colour light in the current study could be attributed to specific action of the colour blue of light on immune system of birds. Blue light colour has been shown to have a remarkable positive effect on splenocyte and mononuclear cells proliferations and to increase levels of nitric oxide that activates macrophage for phagocytosis and production of antimicrobial compounds (Seo et al., 2016). The improved immune profile emerged by blue light colour could also be due to a higher peripheral blood T-lymphocyte proliferation (Xie et al., 2008; Zhang et al., 2014; Chen et al., 2016; Guo et al., 2018), a higher H/L ratio (Mohamed et al., 2014; Mousa-Balabel et al., 2017) and its role in modifying heat shock biomarker activities toward enhancing immunity levels and reducing negative impacts of heat stress (Abdo et al., 2017). Other causes for the beneficial effect of blue light colour could be the ability of blue light to improve blood antioxidant (total antioxidant capacity, superoxide dismutase, and glutathione peroxidase), and increase B-lymphocyte proliferation in broilers (Li et al., 2015). Nevertheless, improved immune profile in Japanese quail exposed to warm white colour has been also reported (Moore and Siopes, 2003), and was referred to the release of melatonin that stimulates cellular and humoral immune response. Warm light colour was also reported to increase number of WBC (Abu Tabeekh, 2016).

In the current study we found that blue colour light-exposed group showed the highest level of IL-10 in both males and females of F_0 and F_1 generations. The results of serum profile also coincided with those of the gene expression pattern. There is also little information on serum profile of immune markers in layers exposed to different light colour temperatures. There is also controversy between the results reported in the current experiment and those of previous work. The reason for such controversy could be differences in the light source, light colour temperatures, light intensity and species/strain of the bird. It could also be that previous experiments were conducted on only one generation of birds. For instance, Abu Tabeekh, (2016) investigated how light colour affected some blood parameters of layers and reported that birds experienced warm light colour exhibited higher white blood cell counts than those received red light (RL), blue light (BL), green light (GL), and blue-green mix light (BGL).

The effect of light colour temperature was previously investigated in broiler chickens, and there were also controversies between the results. An enhanced IgG and IgA was reported in broiler receiving mixed green-blue light compared to those receiving either monochromatic green or blue light (Hassan et al., 2014). A significant enhanced proliferation of splenocyte and blood mononuclear cells was observed in chickens reared in blue compared to those reared in

green light-emitting diode (LED) (Seo et al., 2016). Similarly, blue light-exposed Cobb broiler chicks showed a significant increase in interlukien-1β (IL-1β) compared to those exposed to warm light (Mohamed et al., 2014). In the same respect, Guo et al., (2018) found an improved a-Naphthyl-acetate esterase and increased antibody production in broilers exposed to intermediate or low-intensity blue lights. Soliman and Hassan, (2019) reported also that blue light colour-exposed broiler chickens showed a significant increase in anti-Newcastle antibody titer as well as a highly remarkable decline in total bacterial count (TBC), and total Enterobacteriaceae count compared to red and white-exposed groups. On contrary, Sharideh and Zaghari, (2017) traced the effect of light emitting diodes with different colour temperatures on immune responses of male broiler and reported that warm-white light was the most suitable to provide the optimum level of immunity.

In conclusion light colour temperature has a pronounced effect on immune status of layers particularly Egyptian Fayoumi chickens. These findings recommend using blue light for better immune status in poultry farms to predict the most susceptible risk time for disease incidence and to build up an efficient management protocol. More studies are needed to investigate the effect of light colour temperature on other chicken breeds. Expression profile of other immune genes is also needed to understand their regulation mechanisms.

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CONFLICT OF INTEREST

None of the authors have any conflict of interest to declare.

AUTHOR CONTRIBUTIONS

A. Ateya conceived, designed the experiment, performed the gene expression and wrote the manuscript; H. EL-Emam collected samples, contributed to doing the gene expression and writing of the manuscript. U. Abou-Ismail, I. El-Araby, and M. Fouda analyzed data and contributed to writing of the manuscript.

REFERENCES

Abdel-Azeem AF, Borham BE (2018) Productive and physiological response of broiler chickens exposed to different colored light-emitting diode and reared under different stocking densities. Egypt Poult Sci J 38(4): 1243-1264.

Abdo SE, El-Kassas S, El-Nahas AF, Mahmoud S (2017) Modulatory effect of monochromatic blue light on heat stress response in commercial broilers. Oxid Med Cell Longev 2017: 1-13.

Abu Tabeekh MAS (2016) An investigation on the effect of light color and stocking density on some blood parameters of broilers and layers. Donn J Agric Res 3(2): 8-12.

Alattar E, Elwasife K, Radwan E (2019) The Effect of Light-Emitting Diode Light on the Physical Traits of Chicks. Open J Anim Sci 9(4): 481-491.

Archer GS (2018) Effect of type of Light Source and Location of Light Source on Layer Production, Stress and Fear During the Start of Lay. Int J Poult Sci 17(2): 92-99.

Archer GS (2019) How Does Red Light Affect Layer Production, Fear, and Stress? Poult Sci 98(1): 3-8.

Archer GS (2016) Comparison of raising broiler chickens under light emitting diode or incandescent light at differing intensities on growth, stress and fear. Int J Poult Sci 15(11): 425-431.

Ateya AI, Arafat N, Saleh RM, Ghanem HM, Naguib D, Radwan HA, Elseady YY (2019) Intestinal gene expressions in broiler chickens infected with Escherichia coli and dietary supplemented with probiotic, acidifier and synbiotic. Vet Res Commun 43 (2):131-142.

Baghban-Kanani P, Hosseintabar-Ghasemabad B, Azimi-Youvalari S, Seidavi AR, Laudadio V, Mazzei D, Tufarelli V (2020) Effect of dietary sesame (Sesame indicum L) seed meal level supplemented with lysine and phytase on performance traits and antioxidant status of late-phase laying hens. Asian Autral J Anim 33(2): 277-285.

Bekeredjian Ding I, Jego G (2009) Toll-like receptors-sentries in the B-cell response. Immunology 128(3): 311-323.

Bell DD, Weaver WD, North MO (2002) The World's Commercial Chicken Meat and Egg Industries. In Commercial Chicken Meat and Egg production. Ed Kluwer Academic Publishers, The Netherlands, pp. 3-17.

Blatchford R, Klasing K, Shivaprasad H, Wakenell P, Archer G, Mench J (2009) The effect of light intensity on the behavior, eye and leg health, and immune function of broiler chickens. Poult Sci 88(1): 20-28.

Borille R, Garcia, RG, Royer, AFB, Santana MR, Colet S, Naas IA, Caldara FR, Almeida ICL, Rosa ES, Castilho VAR (2013) The use of light-emitting diodes (LED) in commercial layer production. Braz J Poult Sci 15(2): 135-140.

Bowmaker J, Knowles A (1977) The visual pigments and oil droplets of the chicken retina. Vision Res 17(7): 755-764.

Cao J, Liu W, Wang Z, Xie D, Jia L, Chen Y (2008) Green and blue mono-

chromatic lights promote growth and development of broilers via stimulating testosterone secretion and myofiber growth. J Appl Poult Res 17(2):211-218.

Chen F, Reheman A, Cao J, Wang Z, Dong Y, Zhang Y, Chen Y (2016) Effect of melatonin on monochromatic light-induced T-lymphocyte proliferation in the thymus of chickens. J Photochem Photobiol B 161(8): 9-16.

da Silva DCF, dE Arruda AMV, Gonçalvis AA (2017) Quality characteristics of broiler chicken meat from free-range and industrial poultry system for the consumers. J Food Sci Technol 54(5): 1818-1826.

Deep A, Schwean-Lardner K, Crowe T, Fancher B, Classen H (2010) Effect of light intensity on broiler production, processing characteristics, and welfare. Poult Sci 89(11): 2326-2333.

Egbuniwe IC, Ayo JO (2016) Physiological roles of avian eyes in light perception and their responses to photoperiodicity. Worlds Poult Sci J 72(3): 605-614.

EL-Emam HA, Ateya AI, EL- Araby IE, Abou-Ismail UA, Fouda MM (2019) The Effect of colour temperature of light on egg production parameters and gene expression pattern of Heat Shock Protein 27 in layers. Mans Vet Med J 20(4): 9-14.

El-Sabrout K, Khalil MH (2017) Effect of LED lighting on hatchability and chick performance of chicken eggs. Pak J Zool 49(6): 2323-2325.

Er D, Wang Z, Cao J, Chen Y (2007) Effect of monochromatic light on the egg quality of laying hens. J Appl Poult Res 16(4): 605-612.

Eskdale J, Kube D, Tesch H, Gallagher G (1997) Mapping of the human IL10 gene and further characterization of the 5' flanking sequence. Immunogenetics 46(2): 120-8.

Firouzi S, Nazarpak HH, Habibi H, Jalali SS, Nabizadeh Y, Rezaee F, Ardali R, Marzban M (2014) Effects of Color Lights on Performance, Immune Response and Hematological Indices of Broilers. J World Poult Res 4(2): 52-55

Guo YL, Ma SM, Du JJ, Chen JL (2018) Effects of light intensity on growth, anti-stress ability and immune function in yellow feathered broilers. Rev Bras Cienc Avic., 20(1): 79-84.

Foss D, Carew JL, Arnold E (1972) Physiological development of cockerels as influenced by selected wavelengths of environmental light. Poult Sci 51(6): 1922-1927.

Han S, Wang Y, Liu L, Li D, Liu Z, Shen X, Xu H, Zhao X, Zhu Q, Yin H (2017) Influence of three lighting regimes during ten weeks growth phase on laying performance, plasma levels-and tissue specific gene expression-of reproductive hormones in Pengxian yellow pullets. PloS One 12(5):1-11.

Haritova AM, Stanilova SA (2012) Enhanced expression of IL-10 in contrast to IL-12B mRNA in poultry with experimental coccidiosis. Exp Parasitol 132(3): 378-82.

Hartl FU, Hayer-Hartl M (2002) Molecular chaperones in the cytosol: from nascent chain to folded protein. Science 295(5561): 1852-1858.

Hassan MR, Sultana S, Choe HS, Ryu KS (2014) A comparison of monochromatic and mixed LED light color on performance, bone mineral density, meat and blood properties, and immunity of broiler chicks. J Poult Sci 51(2): 195-202.

Higgs R, Cormican P, Cahalane S, Allan B, Lloyd AT, Meade K, James T, Lynn DJ, Babiuk LA, O'Farrelly C (2006) Induction of a novel chicken Toll-like receptor following Salmonella enterica serovar Typhimurium infection. Infect Immun 74(3): 1692-1698.

James C, Asher L, Herborn K, Wiseman J (2018) The effect of supplementary ultraviolet wavelengths on broiler chicken welfare indicators. Appl Anim Behav Sci 209(1): 55-64.

Kamanli S, Durmus I, Demir S, Tarim B (2015) Effect of different light sources on performance and egg quality traits in laying hens. Eur Poult Sci 79: 1-7.

Knisley JR (1990) Updating light sources for new and existing facilities. Electrical Construction and Maintenance 89: 49-60.

Kogut MH, Iqbal M, He H, Philbin V, Kaiser P, Smith A (2005) Expression and function of Toll-like receptors in chicken heterophils. Dev Comp Immunol 29(9): 791-807.

Kralik G, Kralik Z, Grčević M, Hanžek D (2018) Quality of Chicekn Meat. In: Animal Husbandry and Nutrition. InTech. https://doi.org/10.5772/intechopen. 72865. BoD - Books on Demand, Germany.

Krishnan J, Selvarajoo K, Tsuchiya M, Lee G, Choi S (2007) Tolllike receptor signal transduction. Exp Mol Med 39(4): 421-438.

Li J, Cao J, Wang Z, Dong Y, Chen Y (2015) Melatonin plays a critical role in inducing B lymphocyte proliferation of the bursa of Fabricius in broilers via monochromatic lights. J Photochem Photobiol B 142(1): 29-34.

Liu K, Xin H, Settar P (2018) Effects of light-emitting diode light v. fluorescent light on growing performance, activity levels and well-being of non-beak-trimmed W-36 pullets. Animal 12(1): 106-115.

Lu H, Adedokun SA, Adeola L, Ajuwon KM (2013) Anti-inflammatory effects of non-antibiotic alternatives in coccidia challenged broiler chickens. J Poult Sci 51(1): 14-21.

Manzanillo P, Eidenschenk C, Ouyang W (2015) Deciphering the crosstalk among IL-1 and IL-10 family cytokines in intestinal immunity. Trends Immunol 36(8): 471-478.

Marsh BJ, Williams-Karnesky RL, Stenzel-Poore MP (2009) Toll-like receptor signaling in endogenous neuroprotection and stroke. Neuroscience 158(3): 1007-1020.

Meyer B (1997) Egyptian chicken plan hatches... 50 years later. Iowa Stater, May 1997 (available at www.iastate.edu/IaStater/1997/may/chicken.html).

Mohammed H, Grashorn M, Bessei W (2010) The effects of lighting conditions on the behaviour of laying hens. Arch Geflugelkd 74(3): 197-202.

Mohamed RA, Eltholth MM, El-Saidy NR (2014) Rearing broiler chickens under monochromatic blue light improve performance and reduce fear and stress during pre-slaughter handling and transportation. Biotech Anim Husb 30(3): 457-471.

Moore CB, Siopes TD (2000) Effects of lighting conditions and melatonin supplementation on the cellular and humoral immune responses in Japanese quail Coturnix coturnix japonica. Gen Comp Endocrinol 119(1): 95-104.

Moore CB, Siopes TD (2003) Melatonin Enhances Cellular and Humoral Immune Responses in the Japanese Quail (Coturnix Coturnix Japonica) via an Opiatergic Mechanism. Gen Comp Endocrinol 131(3): 258-263.

National Research Council, NRC (1994) Nutrient requirements of poultry: 1994. National Academies Press.

Olanrewaju H, Purswell J, Maslin W, Collier S, Branton S (2015) Effects of color temperatures (kelvin) of LED bulbs on growth performance, carcass characteristics, and ocular development indices of broilers grown to heavy weights. Poult Sci 94(3): 338-344.

Olanrewaju H, Thaxton J, Dozier W, Purswell J, Roush W, Branton, S (2006) A review of lighting programs for broiler production. Int J Poult Sci 5(4): 301-308.

Onbaşılar EE, Erol H, Cantekin Z, Kaya U (2007) Influence of intermittent lighting on broiler performance, incidence of tibia dyschondroplasia, tonic immobility, some blood parameters and antibody production. Asian Austral J Anim 20(4): 550-555.

Parry JW, Poopalasundaram S, Bowmaker JK, Hunt DM (2004) A novel amino acid substitution is responsible for spectral tuning in a rodent violet-sensitive visual pigment. Biochemistry 43(25): 8014-8020.

Pestka S, Krause CD, Sarkar D, Walter MR, Shi Y, Fisher PB (2004) Interleukin-10 and related cytokines and receptors. Annu Rev Immunol 22(1): 929-79.

Prayitno D, Phillips C, Omed H (1997) The effects of color of lighting on the behavior and production of meat chickens. Poult Sci 76(3): 452-457.

Rothwell L, Young JR, Zoorob R, Whittaker CA, Hesketh P, Archer A, Smith AL, Kaiser P, (2004) Cloning and characterization of chicken IL-10 and its role in the immune response to Eimeria maxima. Immunol 173(4): 2675-2682.

Mousa-Balabel TM, Mohamed RA, Saleh MM (2017) Using different light colors as a stress factor on broiler performance in Egypt. Aust J Basic Appl Sci 11(9): 165-170.

Rosa E, Arriaga H, Calvet S, Merino P (2019) Assessing ventilation rate measurements in a mechanically ventilated laying hen facility. Poult Sci 98(3): 1211-1221.

Rozenboim I, Biran I, Uni Z, Robinzon B, Halevy O (1999) The effect of monochromatic light on broiler growth and development. Poult Sci 78(1): 135-138.

Rozenboim I, Zilberman E, Gvaryahu G (1998) New monochromatic light source for laying hens. Poult Sci 77: 1695-1698.

Said EA, Dupuy FP, Trautmann L, Zhang Y, Shi Y, El-Far M, Hill BJ, Noto A, Ancuta P, Peretz Y, Fonseca SG, Van GJ, Boulassel MR, Bruneau J, Shoukry NH, Routy JP, Douek DC, Haddad EK, Sekaly RP (2010) Programmed death-1-induced interleukin-10 production by monocytes impairs CD4+ T cell activation during HIV infection. Nat Med 16(4): 452-459.

Saraiva M, O'Garra A (2010) The regulation of IL-10 production by immune cells. Nat Rev Immunol 10(3): 170-181.

Seo HS, Yoon MKR, Roh JH, Wei B, Ryu KS, Cha SY, Jang HK (2016) Effects of various LED light colors on growth and immune response in broilers. J Poult Sci 53(1):76-81.

Sharideh H, Zaghari M (2017) Effect of light emitting diodes with different color temperatures on immune responses and growth performance of male broiler. Ann Anim Sci 17(2): 545-553.

Sharma A, Kumar M, Aich J, Hariharan M, Brahmachari SK, Agrawal A, Ghosh B (2009) Posttranscriptional regulation of interleukin-10 expression by hsa-miR-106a. Proc Natl Acad Sci USA 106(14):5761-5766.

Shi H, Li B, Tong Q, Zheng W, Zeng, D, Feng G (2019) Effects of LED Light Color and Intensity on Feather Pecking and Fear Responses of Layer Breeders in Natural Mating Colony Cages. Animals 9(10): 814.

Soliman ES, Hassan RA (2019) Impact of lighting color and duration on productive performance and Newcastle disease vaccination efficiency in broiler chickens. Vet World 12(7): 1052-1059.

Sowunmi A, Gbotosho GO Happi CT Folarin OA, Balogun ST (1999) SPSS for Windows release 10.01 (standard version) SPSS for Windows release 10.01 (standard version).

Sultana S, Hassan MR, Choe HS, Kang MI, Kim BS, Ryu KS (2013) Effect of various LED light color on the behavior and stress response of laying hens. Indian J Anim Sci 83(8): 829-833.

Thiele H-H (2010) Light stimulation of commercial layers. World Poult 26: 18-21.

Underhill DM, Ozinsky A (2002) Toll-like receptors: key mediators of microbe detection. Curr Opin Immunol 14(1): 103-110.

Xie D, Wang Z, Dong Y, Cao J, Wang J, Chen J, Chen Y (2008) Effects of monochromatic light on immune response of broilers. Poult Sci 87(8):1535-1539.

Yang Y, Yu Y, Pan J, Ying Y, Zhou H (2016) A new method to manipulate broiler chicken growth and metabolism: Response to mixed LED light system. Sci Rep 6(1): 25972.

Yu Y, Li Z, Zhong Z, Jin S, Pan J, Rao X, Yu Y (2018) Effect of monochromatic green LED light stimuli during incubation on embryo growth, hatching performance, and hormone levels. Am Soc Agric Biol Eng 61(2): 661-669.

Yuan J, Guo Y, Yang Y, Wang Z (2007) Characterization of fatty acid digestion of Beijing fatty and arbor acres chickens. Asian Austral J Anim 20(8):1222-1228.

Yuan JS, Reed A, Chen F, Stewart CN (2006) Statistical analysis of real-time PCR data. BMC Bioinformatics 7: 85.

Zdanov A, Schalk-Hihi C, Wlodawer A (1996) Crystal structure of human interleukin-10 at 1.6 A resolution and a model of a complex with its soluble receptor. Protein Sci 5(10): 1955-1962.

Zhang Z, Cao J, Wang Z, Dong Y, Chen Y (2014) Effect of a combination of green and blue monochromatic light on broiler immune response. J Photochem Photobiol B 138(9): 118-123.

Zhou H, Lamont SJ (2003) Chicken MHC class I and II gene effects on antibody response kinetics in adult chickens. Immunogenetics 55(3): 133-140.