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PRODUCTIVE AND PHYSIOLOGICAL RESPONSE OF BROILER CHICKENS EXPOSED TO DIFFERENT COLORED LIGHT-EMITTING DIODE AND REARED UNDER DIFFERENT STOCKING DENSITIES

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ABSTRACT: This study intended to evaluate the effects of different light colors and stocking densities on productive and physiological performance of broiler chickens. A total number of 648 seven-day-old mixed sex broiler chicks (Ross- 308), were randomly distributed and housed into 6 treatments in three replicates for each density 10, 12 and 14 birds/m^2. Treatments were exposed to incandescent light (ICL, 60 Watt) as a control, while the others were distributed according to LED colors into Red light (RL), Blue light (BL), Green light (GL), White light (WL), and Mixed light (ML) produced by a light-emitting diode (LED) with light intensity 5 watt /m^2 at 37.5 lux. Interestingly, results indicate that birds reared under LED-BL and stocked at 10 bird /m^2 exhibited significantly ($p \leq 0.05$) higher productive performance than groups exposed to other light colors and densities. However, the highest livability and European production efficiency factor (EPEF) observed for birds exposed to LED-BL and reared under 10 birds / m^2 compared with other groups. Also, birds exposed to LED-BL and kept under 10 birds / m^2 exhibited less fear and stress response as judged by low corticosterone hormone level and increases of melatonin concentration. In addition, lymphoid organ weights and immunity titer response significantly ($p \leq 0.05$) improved, when bird's exposed to LED-BL and kept under 10 birds/ m^2 compared with other experimental groups. In conclusion, this study revealed that applying LED-BL with 10 birds /m^2 in broiler house is preferable to other colors and densities because it keeps the birds calmer and showed a significant positive effects on productive and physiological performance compared with other light colors and densities.

Key words: Broiler chickens - light color - stocking density.

INTRODUCTION

In recent years, poultry industry has seen an unparalleled growth during last three decades and is now recognized as one of the fastest growing component of agriculture sector (Yadav et al., 2016). Therefore, industrial broiler production requires the control of all environmental conditions because any variation in these conditions can lead to a reduction in yields. However, the poultry industry is currently undergoing a switch from traditional lighting sources like incandescent and fluorescent to light emitting diode (LED) (Archer, 2018). Interestingly, artificial lighting is widely used in broiler production, where light is required for the release of hormones responsible for best growth, and influences animal’s life cycles and controls their behavior to a great extent (Kristensen et al., 2007). Therefore, light is one of the major microclimate exogenous factor for poultry production that influences growth development, physiological functioning, welfare and behavioral processes (Olanrewaju et al., 2016). Moreover, vision is the most important sense for birds, where chickens can see ultraviolet and infrared as well (Rierson, 2011). Furthermore, monochromatic LEDs have small size, adjustable light intensity, specific wavelength, low thermal output and high photoelectric conversion efficiency, these benefits make LEDs very preferable light source in modern poultry management (Yang et al., 2016). However, light color has been considered a powerful management tool that can be used for mitigating several stressors in broilers by modulating many physiological, immunological and behavioral pathways (Xie et al., 2011), among spectra of light, it has been suggested that green and blue lights enhance the immune response better than others. On the other hand, one of the characteristics of large commercial broiler operations is the stocking density of birds per 1 m^2 area and the choice of appropriate genetic material to ensure rapid attainment of required weight gains and the best feed conversion possible (Skomorucha et al., 2004). However, stocking density is a key point in broiler welfare and cost of production (Toghyani et al., 2016). Stocking density is defined as body mass (kg) or number of birds per unit of housing space (m^2). In this connection, Petek et al. (2010) found that at density above 19 birds/m^2 chickens grew more slowly and had a lower FCR than at lower density 15 birds/m^2. Therefore, the objective of this study was to investigate the effects of light colors and stocking densities and their interaction on productive and physiological response of broiler chicken.

MATERIALS AND METHODS

Place and objective study: This study was carried out at the Poultry Experimental Station, Faculty of Agriculture, Al-Azhar University, Naser City, Cairo, Egypt, during the summer season from August to September 2017. The main objective of this study was to examine the effects of light colors and stocking densities and their interaction on productive and physiological response of broiler chickens.

Birds, husbandry and experimental procedure: This study was performed with a total of 648, Ross 308 chicks, which purchased from El-Dakahlia Poultry Company. At 7 days of age all chicks were weighed and randomly allocated to a completely randomized factorial design (6 x 3), with light colors and stocking densities as main effects. Identical care and management were provided to all birds throughout the duration of the study. Birds were housed in 6 separated pens measured 3x4 m^2, which equipped with feeders and drinkers to ensure ad libitum access to feed and water throughout the study.

Each pen contained 108 birds with 3 replicate with 3 stocking densities in each replicate at 10, 12 and 14 birds/m^2, include: incandescent light (ICL, 60 Watt) as a control, while the other light groups were White light (WL), Red light (RL), Blue light (BL), Green light (GL), and Mixed light (ML), produced by a light-emitting diode (LEDs with light intensity 5 watt /m^2 at 37.5 lux at bird head level with a light period of 23:1 h daily. Birds were remained in their allocated light treatments from 7 to 35 days of age. The basal diet (Table1) was formulated according to NRC (1994) to meet all nutrient recommendations published in the Ross-308 rearing guideline (Aviagen, 2007). Pen temperature was maintained at 32± 1°C during the first week and decreased by about 3°C each week until depends on the environmental temperature, while the relative humidity was about 65% as average. The LEDs lamps (Goodi-Tech, Iksan, South Korea) were placed at 2.2 m at head height of the birds using plastic crosses attached to the ceiling and centered in the pens. Light intensity was measured along a horizontal plane at 25 cm above the litter with the photoreceptor sensor of a light meter (digital LUX HI Tester model YF-1065A) pointed toward the light sources. The light bulbs were wiped weekly in order to minimize dust built-up, which would have reduced the intensity and spectra. Newcastle disease vaccine (Pfizer Company, Egypt) was administrated at 7, 14 and 21 days of age via water administration. However, Gumboro vaccine was also administrated in the drinking water at 8 and 18 days of age.

Growth performance: The body weight of birds was recorded individually at start of experiment and at the end of every week. For this purpose, all the birds from each replicate were weighed by using an electrical weighting balance. From the individual weights, the mean weight of all the groups was calculated separately. Birds were offered feed daily ad libitum and feed consumption was calculated at the end of each week. Record of weekly feed consumption and weight gain was used to compute FCR of each experimental group (FCR = feed consumption / weight gain). However, livability was recorded along the experimental period. Also, European production efficiency factor (EPEF) calculated as described by (Marcu et al., 2013).

Blood components: At 35 d of age approximately 4.0 mL of blood was collected from alive 3 females and 3 males after 12 hours of fasting from the jugular vein using 5 ml disposable sterile syringe for each treatment alone. Each blood sample from each individual was divided into-two samples in Eppendorf tubes. One was heparinized using Ethylenediamine-tetraacetic acid (EDTA) as an anticoagulant to study blood hematological parameters including RBCs and WBCs, which done by hemocytometer (Natt and Herrick, 1952). However, heterophil, lymphocyte and heterophil to lymphocyte (H/L) ratio were determined (Gross and Siegel, 1983). Also, packed cell volume (Schalm et al., 1975) and hemoglobin (Young, 2001) were also determined. The other was non-heparinized to determine biochemical parameters including liver enzyme ALT and AST (Retiman and Frankel, 1957) and hormones assays including T3 and T4 (Ellis and Ekins, 1975), corticosterone (De Jong et al., 2001) by using specific kits, which were used for each test. However, melatonin concentration was analyzed with RIA procedure using commercially available melatonin kits (Labor Diagnostika Nord GmbH and Co. KGAm Eichenhain 148531 Nordhorn, Germany) according to the manufacturers' instructions.

Lymphoid organ weights and antibody titer response: At the end of experiment six birds (3 female and 3 male) from each treatment was chosen whose body weights were closest to the mean weight of each pen. Lymphoid organs including spleen, thymus and Bursa of Fabricius were removed and weighed. However, at 35 days of age the antibody titer response was measured against Newcastle disease virus (NDV), blood samples were collected from jugular vein at 35 d of age for Haemagglutination Inhibition test according procedure outlined in OIE (2012). Titer response was expressed as the $\log^2$ of the reciprocal of the highest dilution giving visible Haemagglutination.

Statistical analysis: A 6 x 3 factorial arranged in a randomized complete design was used in this study. The main effects were light colors and stocking densities and the interaction of these 2 factors were performed by using General Linear Models (GLM) procedure of SPSS software program package (SPSS, 2010). All percentages were first transformed to arcsine being analyzed to approximate normal distribution before ANOVA. Differences were considered statistically significant at ($P \leq 0.05$). Data for antibody titers response were normalized using logarithmic transformation prior to analysis. The following model was used for data analysis:

$Y_{ijk} = \mu + \alpha_i + ß_j + (\alpha_i \times ß_j)_{ij} + e_{ijk}$

Where, Y_{ijk} : Observation on the ij individual, μ = overall mean., α_i = effect of colors, $ß_j$ = effect of densities, ($\alpha_i \times ß_j$) = interaction between colors and densities and e_{ijk}= random error.

RESULTS

1-Growth performance:

1-1-Live body weight (LBW) and body weight gain (BWG)

Table 2 shows the mean values of LBW and BWG at different periods of birds exposed to light colors and reared under different stocking densities. Results revealed that, the initial LBW at 7 d of age was similar among the experimental groups reflecting insignificant differences at start of experiment. While, at 21 and 35 days of age the highest ($p \leq 0.05$) LBW observed for birds exposed to LED-BL compared with other light color groups. The same trend was also recorded for BWG, where bird's exposure to LED-BL showed significantly ($p \leq 0.05$) higher values than birds exposed to other light color groups through experiment period. However, the best ($p \leq 0.05$) values for LBW and BWG detected for birds that stocked at 10 birds /m^2 along the experimental period compared with other stocking densities. The interaction effects indicated that the highest values also observed for birds exposed to LED-BL and stocked at 10 bird/m^2 compared with other interaction groups.

1-2- Feed intake (FI) and feed conversion ratio (FCR)

The data of FI and FCR for broiler chickens exposed to light colors and stocked at different densities are presented in Table 3. The analysis of variance indicated that birds that exposed to LED-BL significantly ($p \leq 0.05$) consumed more feed and exhibited better FCR than those recorded for other light color groups. On the other hand, birds stocked under 10 and 12 birds/m^2 significantly ($p \leq 0.05$) consumed more feed than those stocked at 14 birds/m^2. While, FCR recorded ($p \leq 0.05$) better value for birds stocked at 10 birds/m^2 than those stocked at 12 and 14 birds /m^2. However, the interaction effects indicated that birds that exposed to LED-BL and kept under 10 birds /m^2 showed the best values concerning FI and FCR compared with the other interaction groups during different periods of experiment.

1-3-Livability and European production efficiency factor (EPEF)

The effects of light colors and stocking densities on livability and EPEF were presented in Table 4. Data revealed that birds exposed to LED-BL and LED-GL showed significantly ($p \leq 0.05$) higher livability values than those exposed to other light colors groups. However, the highest ($p \leq 0.05$) EPEF also recorded for birds exposed to LED-BL, followed by groups exposed to LED-GL, LED-RL, LED-ML, LED-WL and ICL respectively. Concerning the effect of density, both livability and EPEF showed significantly ($p \leq 0.05$) higher values for birds stocked at 10 birds /m^2, compared with other density group. Regarding the interaction effects data indicated that birds exposed to LED-BL and LED-GL and kept under 10 birds / m^2 exhibited significantly ($p \leq 0.05$) higher livability and EPEF values than other interactions groups.

2-Blood constituents:

2-1-Hematological traits

Results of hematological traits as affected by light colors and densities are given in Table 5. Data revealed that there were insignificant differences observed among light color groups concerning WBCs, lymphocytes, RBCs, Hb and PCV. While, hetrophils percentage and hetrophils: lymphocytes (H/L) ratio showed the converse trend, where birds exposed to different light colors showed the lowest values compared with birds preserved under control group (ICL). The same trend was also observed for the effect of stocking density on former traits, except with, hetrophils percentage and H/L ratio, where birds stocked at 10 and 12 birds/m^2 have the lowest values compared with those kept under 14 birds/m^2. The interaction effects indicated that also insignificant differences observed among the interaction groups for former traits, with exception of, heterophil percentage and H/L ratio where birds exposed to LED-BL and stocked under 10 birds/m^2 recorded the lowest values compared with the other interaction groups.

2-2-Biochemical traits

2-2-1-Liver enzymes

The values of both ALT and AST measured at the end of experiment indicated that birds that exposed to LED-BL recoded significantly ($p \leq 0.05$) low values, followed by those exposed to LED-RL, LED-WL, LED-GL, LED-ML and ICL respectively. However, birds stocked at 10 birds /m^2 exhibited the lowest values of both enzymes compared with other birds that stocked at 12 and 14 birds /m^2. However, the interaction effects indicated that birds that exposed to LED-BL and LED-GL and that stocked at 10 birds/m^2 recorded the lowest values compared with other interaction groups.

2-2-2- Hormone assays

Data of hormone assays revealed that bird's that exposed to LED-BL, exhibited the lowest values of T3 and T4 followed by groups exposed to LED-GL, LED-RL, LED-ML, LED-WL and ICL respectively. However, birds that stocked at 10 birds /m^2 recorded significantly ($p \leq 0.05$) lower values of both hormone than birds stocked at 12 and 14 birds /m^2. Concerning the effect of light colors on melatonin and corticosterone concentrations data indicated that the highest level of melatonin and the lowest value of corticosterone concentrations were recorded for birds exposed to LED-BL compared with other light color groups. On the other hand, results indicated that birds that stocked at 10 birds /m^2 recorded the highest values of melatonin and lowest corticosterone concentrations compared with birds stocked at 12 and 14 birds /m^2. However, the data of interaction effects indicated that birds exposed to LED-BL and stocked at 10 birds/ m^2 showed lower values of both T3 and T4 than other interaction groups. Moreover, the values of melatonin concentration indicated that also birds exposed to LED-BL and stocked at 10 birds/ m^2 showed significantly higher ($p \leq 0.05$) values than those recorded for other interaction groups. While, the values of corticosterone level showed the converse trend, where birds exposed to LED-BL and stocked at 10 birds/ m^2 have lower values than those recorded for other interaction groups.

3-Lympohid organ weights and titer response

The influence of light colors and densities on lymphoid organ weights and titer response at the end of experimental period are presented in Table 7. As shown in this Table birds that exposed to LED-BL have higher ($p \leq 0.05$) lymphoid organ weights than birds kept under other color groups. However, birds that stocked at 10 birds/m^2 significantly ($p \leq 0.05$) recorded higher lymphoid organ weights than birds stocked at 12 and 14 birds /m^2. Concerning the effect of colors on immune response data indicated that, when birds exposed to LED-BL showed higher values than birds exposed to other light color groups. Moreover, the highest immunity titer response detected for birds stocked at 10 birds/m^2, followed by those stocked at 12 and 14 birds /m^2 respectively. The same trend was also observed for interaction effects, where bird's exposed to LED-BL and reared under 10 birds /m^2 exhibited the highest lymphoid organ weights and titer response compared with other interaction groups.

DISCUSSION

1-Growth performance

1-1-Live body weight (LBW) and body weight gain (BWG)

It is well known that growth in broiler chickens is affected by light colors and stocking densities. Interestingly, LBW is one of the most important performance parameter, so determination of the effects of light color on LBW is of particular importance that's why many studies have been conducted on this important aspect (Yahav et al., 2000), where broilers are known for their ability to gain extreme amounts of weight in short periods of time (Rierson, 2011). There are conflicting reports on the effects of light color and density on the performance of broiler chickens. However, color is an important aspect that has been considered at one time as a management tool in poultry production (Prayitno et al., 1997). In this study birds which were exposed to LED-BL and conserved under 10 bird/ m^2 had the highest LBW and BWG at the end of experiment. This attributed to birds raised under ICL, LED-WL, LED-RL, LED-GL and LED-ML were more active than birds exposed to LED-BL as judged by greater walking activity which affects behavior of birds, being less active in blue light (Prayitno et al., 1997), therefore more activity resulted in a decrease of performance. In other words birds reared under LED-BL appears to have necessitated greater sleep, where spent relatively more time sitting or dozing. In other explanation, blue light may play a role in alleviating the stress response in broilers (Xie et al., 2008). In this context, Rozenboim et al. (2004) indicated that broiler under blue or green lights become significantly heavier than those reared under red or white lights. This finding is confirmed with Senaratna et al. (2016) indicated that blue or green light is preferable to red or white light for broiler because it keeps the birds calmer and is chosen by the birds themselves. Also, Mohamed et al. (2017) demonstrated that broiler reared under blue and green light had higher body weight and weight gain compared with white light. In addition, Balabel et al. (2017) showed that it is strongly recommended to use an alternative cycling between green and blue light colors in broiler farms to get high growth performance. Obviously, the present study indicated that increased of density resulted in a significant decreases of both LBW and BWG, this could be attributed to increase stress resulted from competition for feed and water (El-Deek and Al-Harthi, 2004). In addition, high stocking density also causes poor air quality due to inadequate air exchange, increased ammonia and reduced access to feed and water, which results in reduced growth rate (Puron et al., 1995). This finding is agreed with Guardia et al. (2011) found that increased stocking density are frequently reported to depress chicken growth performance, but the mechanisms behind this are not fully understood. Similarly, Moreira et al. (2004) showed that broiler at a stocking density of 10 birds/m^2 showed a higher weight gain compared with birds reared at 13 or 16 birds/m^2.

1-2-Feed intake (FI) and feed conversion ratio (FCR)

It's well known that voluntary feed intake is linked to growth rate (Scott, 2005). The results indicate that exposure birds to LED-BL and kept under 10 birds/m^2 are likely to stimulate the appetite and feeding behavior, where the highest FI and best FCR were occurred, proved that broiler raised under LED-BL and kept under 10 birds/m^2 are less active, therefore they used their feed more efficiently than those exposed to other color and density groups. This significant difference ($p \leq 0.05$) may be due to a calming effect of LED-BL and the positive effect of low density on feed intake and feed utilization (Senaratna et al. 2016; Balabel et al., 2017), which finally improves LBW and BWG. This finding are agreed with Karakaya et al. (2009) found that broiler reared under green, blue and green-blue mix light showed significant higher feed consumption as compared to control. Also, Jingsong et al. (2012) indicated that the highest value of FCR was observed for birds exposed to blue light compared with other light. However, Mohamed et al. (2017) demonstrated that broiler reared under blue and green light had higher feed intake and lower feed conversion compared with birds reared under white light. Similarly, Son and Ravindran (2009) reported significantly higher FCR was observed for broiler that were exposed to blue light as compared with birds exposed to white and red light. Regarding with the effect of density the results referred to reduce of FI and worst of FCR under high density of birds, this may be due to increasing competition for feed as a result of increasing stocking density. In other words, high stocking density also causes poor air quality due to inadequate air exchange, increased ammonia and reduced access to feed and water, which results in reduced feed efficiency (Puron et al., 1995). Similarly, Thomas et al. (2004) reported that broiler stocked at 5 birds/m^2 consumed more feed than broiler stocked at 10, 15 or 20 birds/m^2.

1-3- Livability and European production efficiency factor (EPEF)

The current results indicated that the highest livability observed for birds exposed to LED-BL and stocked at 10 birds/m^2 compared with other color and density groups. Accordingly, when birds exposed to LED-BL and stocked under 10 birds/m^2 recorded the highest EPEF than other groups. This effect may attributed to LED-BL may play a role in alleviating the stress response in broiler (Xie et al., 2008). However, Lewis and Morris (2000) indicated that blue and green light colors aided in the control of aggressiveness and excessive activity in broilers, therefore mortality rate was low for broilers kept in blue light (Celen and Testik, 1994). Also, high stocking density causes poor air quality due to inadequate air exchange, increased ammonia and reduced access to feed and water, which results in reduced livability (Puron et al., 1995). In this context, Bilgili and Hess (1995) reported that mortality was significantly improved when birds were given more space.

2-Blood components:

2-1-Hematological parameters

Interestingly, blood parameters were affected by different environmental conditions (Onbaşilar et al., 2007), among all the environmental conditions, light color which are becoming well known to affect the physiology of broiler chickens (Seo et al., 2016). Therefore, the importance of hematological and biochemical parameters as diagnostic tools indicators in birds has been documented (Hauptmanova et al., 2006). The results as shown in Table 6 revealed that there is an insignificant effect due to exposed birds to different light colors or densities on all hematological parameters, except with hetrophils percentage or H/L ratio, measured at 35 days of age. Results indicated hetrophil percentage and H/L ratio were significantly ($p \leq 0.05$) decreased for birds exposed to LED-WL, LED-BL, LED-RL, LED-GL and LED-ML compared with birds exposed to ICL and stocked at low density, this attributed to decreased stressful conditions and activity in broiler (Lewis and Morris, 2000). This finding are confirmed by Mumma et al. (2006) reported that H/L ratio increased under the stressful conditions. In our study, the H/L ratio was significantly increased due to the increase of density, this suggested that density seems to be more effective at the onset of physiological stress in broiler. In this context, Thaxton et al. (2006) found a trend for increasing H: L ratio with increasing density in broiler chickens.

2-2-Biochemiacl parameters:

2-2-1-Liver enzymes (ALT and AST).

It is well known that the liver is rich in some enzymes as ALT and AST and its damage often results in releasing these enzymes to the blood, where liver plays an important role in metabolic body processes and its damage often results in releasing these enzymes to the blood (Kaplan et al., 2003). Also, abnormal liver enzyme levels may signal liver damage or alteration in bile flow (Giannini et al., 2005). Clearly, from the present results it's observed that light colors positively affects the liver status, where ALT and AST significantly decreased for birds when exposed to LED-BL and reared under low density, this indicated that light colors and low density had no harmful effect on the liver function. Interestingly, the appearance of normal amounts of certain enzymes of intercellular origin in the blood reflected no damage to an organ or tissue. The decrease value of both ALT and AST for birds exposed to LED-BL and reared under low density may attributed to a calming effect of LED-BL (Senaratna et al. 2016), and thus decreased the movement and they spent more time sitting (Prayitno et al., 1997), which improves the physiological status of liver. This finding are confirmed by Al-Daraji et al. (2008) indicated that GOT related with stress induced increased serum AST activity, where accompanied this case with the drop in the blood's white cells rate stress. In this context, Mohamed et al. (2017) indicate that broiler reared under blue and green light showed lower physiological changes to stress than those reared in white light, this was evident by low levels of GPT and GOT. Also, Abu Tabeekh (2016) showed a significant effect of blue light on serum GOT enzyme level but no significant of GPT. However, result indicated that stocking density significantly ($p \leq 0.05$) affected liver enzymes, where when density increased caused a significant increase of liver enzymes reflected the presence of stress due to high density. Accordingly, activity of liver enzymes was modified in higher density group, which could indicate that increasing density rate could have an adverse effect on health. Therefore, determination of enzymes panel is often reflects the degree of hepatocellular damage and leakage (Jaensch, 2000). Fluctuation of serum concentrations, tissue distribution and the half-life of each individual enzyme are the discrimination factors between these enzymes. This finding are agreed with Alaeldein et al. (2013) indicated that there is an increase in AST level in broiler chickens when stocked at high density (40.0 kg/m^2), which might indicate hepatocellular injures compared with low (28.0 kg/m^2) and medium (37.0 kg/m^2) density.

2-2-2- Hormone assays (T_3, T_4, melatonin and corticosterone concentrations)

Table 6 indicated a significant effects ($p \leq 0.05$) of light color and density on the levels of T_3, T_4, melatonin and corticosterone concentration hormones. Interestingly, thyroid hormones including T3 and T4 are important growth promoters and play a relatively important role in growth inhibition as well as compensatory growth acceleration in broilers (Yahav, 1999). Data revealed that there was a trend toward decreasing both hormones when exposure birds to LED-BL and reared under low density, this may attributed to lower activity. This results obtained by Rozenboim et al. (2004) found the existence of significant differences in the concentration of T4 hormone in the serum of broiler reared in the treatment of switching from blue to green light at 10 day, reaching 7.4 ng / ml compared to those reared under blue, white and green light color. In contrast, Abu Tabeekh (2016) showed that there is no significant effect of stocking density on the concentration of T3 hormone in the blood serum of broiler. Also, Davis et al. (2000) revealed that there is no effect of density on the level of T3 and T4 hormones of Hyline W-36 and DeKalb XL chickens. However, when birds exposed to LED-BL and stocked at 10 birds /m^2 prone to less stress as measured by the plasma corticosterone, where corticosteroid concentrations in blood have been used as a measure of environmental stress in birds (Charmandari et al., 2005). The decrease of corticosterone concentration of birds exposed to LED-BL and reared under low density may attributed to controlling the bird activity and reducing the fearful behavior, being detrimental to the welfare (Senaratna et al., 2016). The results of our findings are in accordance with the study of Senaratna et al. (2016) and Prayitno et al. (1997) they recorded that blue or green light is preferable to red or white light for broiler because it keeps the birds calmer and is chosen by the birds themselves leading to absence of stress. On the other hand, higher corticosterone levels in birds stocked at 12 or 14 birds /m^2 could reflect higher stress conditions. Therefore Onbasilar and Aksoy (2005) reported that increasing cage density, from one to five hens per cage, resulted in a significant increase of the plasma corticosterone. Similar results were obtained by Turkyilmaz et al. (2008) indicated that corticosterone concentration increased from 3.81 to 4.39 ng/ml with increased stocking density of broiler chickens. Regarding with the result of melatonin, this is considered a neuron hormone plays an important role in the health and physiological systems of birds (Pang et al., 1996). Exposure birds to LED-BL and stocked at 10 birds/m^2 are likely induce the secretion of pineal melatonin, which plays an important role in growth performance and the immune functions (Apeldoorn et al., 1999). The finding are disagree with results obtained by Jin et al. (2011) indicated that the concentration of plasma melatonin under green light was the highest, followed by white light, and was the lowest in red light and blue light for broilers.

3-Lymphoid organ weights and immune response

It is important to maintain immune function in broilers because poor immune status can decrease disease resistance leading to reduced productivity. It has been well documented that light has effective impact on immune response (Blatchford et al., 2009), but the effect of light color on the immune response is poorly understood. However, lymphoid organs weight are also indicative of the birds' immune status (Pope, 1991). Therefore, there is a close relationship between the environmental factors such as light color and density on lymphoid organs and immune response. In addition, spleen and bursa of Fabricius are used for anatomical and physiological stress indicators for birds (Freire et al., 2003; Puvadolpirod and Thaxton, 2000)), where decreased bursa weight are associated with increased levels of physiological stress. In the present study there is increased in lymphoid organ weights and immune response due to exposure birds to LED-BL and when stocked under low density compared with other groups, indicating strong interaction of light color and stocking density on growth of lymphoid organs and improved immunity against ND disease by increasing Con A-induced peripheral blood T-lymphocyte proliferation. This effect may attributed to blue light would alleviate the negative effects induced by the stress response, subsequently leading to a well-balanced immune response status. Indeed, birds exposed to LED-BL and stocked at 10 birds/m^2 developed more humoral immunity against ND disease virus as compared with the other groups indicating LED-BL color promoted myofibril growth and humoral immune response in the broiler (Sadrzadeh et al., 2011). This finding are agreed with Xie et al. (2008) referred that green and blue light enhance the immune response better than red light. They added that the spleen weight for birds exposed to red light were significantly decreased compared with those of the blue light in older broiler, because the weight of the secondary lymphoid organs decreased

during the stress response. In addition, Mohamed et al. (2017) found that broiler reared under blue and green light had higher liver, spleen relative weight compared with white light. Also, Hassan et al. (2014) indicated that broiler chicks exposed to green and blue colors enhance immunity. However, Zhang et al. (2014) found that green and blue light reportedly enhance broiler immune function. However, Heckert et al. (2002) reported the density treatments 10, 15, and 20 birds/m^2 did not significantly affect the spleen and bursa weights. Similarly, no significant density effects were found on either the absolute bursa weight of birds reared at densities of 8, 19, 29, 40, 45, 51, 61, and 72 birds per 3.3 m^2 (Buijs et al., 2009).

CONCLUSION

Based on the results of the present study it may be inferred that blue color is an alternative to incandescent light bulbs or other light colors and is beneficial for poultry producers, where it improves productive and physiological response of broiler chicken. However, birds reared under low stocking density, 10 birds /m^2, positively affects productive and physiological performance.

Table (1): The ingredients and calculated compositions of experimental diets.

Ingredients	Starter (1-14)	Grower (15-28)	Finisher (29-35)
Ground yellow Corn (8.5%)	55.30	58.01	63.80
Gluten meal (62%)	14.60	12.50	11.60
Soybean meal (44% CP)	25.20	23.0	18.40
Di-calcium	0.78	0.70	0.70
phosphate($CaHPO_4$)	2.10	1.80	1.80
Calcium carbonate ($CaCo_3$)	0.30	0.30	0.30
Sodium chloride (NaCl)	0.81	2.90	2.80
Vegetable oil*	0.30	0.30	0.30
Premix**	0.16	0.19	0.10
DL-Methionine (100%)	0.45	0.30	0.20
L-Lysine (100%)			
Total (Kg)	100	100	100
Calculated diet compositions:			
Crude protein (%).	23.003	21.011	19.018
Metabolizable energy	3022.4	3153.2	3203.1
(Kcal/Kg).	1.0459	0.9093	0.8971
Calcium (%).	0.532	0.5004	0.4822
Available phosphorus (%).	1.422	1.1983	0.9803
L-Lysine (%).	0.6333	0.6233	0.5018
DL-Methionine (%).	1.0597	1.0169	0.8656
Methionine + Cystine (%).			

* Vegetable oil*: soybean oil and sun flower oil

**The Premix (Vit. &Min) was added at a rate of 3 kg per ton of diet and supplied the following (as mg or I.U. per kg of diet): Vit. A 12000 I.U., Vit. D3 2000 I.U., Vit. E 40 mg, Vit. K3 4 mg, Vit. B1 3 mg, Vit. B2 6 mg, Vit. B6 4 mg, Vit. B12 0.03 mg, Niacin 30 mg, Biotin 0.08 mg, Pantothenic acid 12 mg, Folic acid 1.5 mg, Choline chloride 700 mg, Mn 80 mg, Cu 10 mg, Se 0.2 mg, I 40 mg, Fe 40 mg, Zn 70 mg and Co 0.25mg.

- Diet formulated according NRC (1994).

Table (2) : The effects of light colors and stocking densities on live body weight and body weight gain of broiler chickens at different periods of experiment (Means ±SE).

Items / Treatments	Live Body weight(g)			Body weight gain(g)		
	7days	21days	35days	7-21 days	22-35 days	7-35 days
Effect of light colors (LC):						
ICL(1)	181.96	738.95^{d}	1653.10^{e}	556.99^{d}	914.15^{d}	1471.14^{e}
LED-WL(2)	182.85	756.94^{d}	1700.72^{d}	574.09^{d}	943.78^{cd}	1517.87^{d}
LED-BL(3)	182.45	832.04^{a}	1930.04^{a}	649.59^{a}	1098.00^{a}	1747.59^{a}
LED-RL(4)	184.21	798.30^{bc}	1843.00^{b}	614.09^{bc}	1044.70^{b}	1658.79^{b}
LED-GL(5)	184.47	814.84^{ab}	1880.54^{b}	630.37^{ab}	1065.70^{ab}	1696.07^{b}
LED-ML(6)	183.62	783.96^{c}	1767.26^{c}	600.34^{c}	983.30^{c}	1583.64^{c}
SEM	1.47	8.29	13.72	8.26	15.45	12.55
Sig.	NS	*	*	*	*	*
Effect of density (D):						
10/m^2	182.95	808.84^{a}	1851.88^{a}	625.89^{a}	1043.04^{a}	1668.93^{a}
12/m^2	183.35	789.01^{b}	1791.37^{b}	605.66^{b}	1002.36^{b}	1608.02^{b}
14/m^2	183.49	764.67^{c}	1744.08^{c}	581.18^{c}	979.41^{b}	1560.59^{c}
SEM	1.04	5.86	9.70	5.84	10.92	8.87
Sig.	NS	*	*	*	*	*
Interaction (LC*D):						
ICL*10	177.87	750.94^{ghi}	1690.91^{ghi}	573.07^{fghi}	939.97^{efg}	1513.04^{hi}
ICL*12	184.13	739.90^{hi}	1649.29^{hi}	555.77^{ghi}	909.40^{fg}	1465.16^{ij}
ICL*14	183.90	726.04^{i}	1619.13^{i}	542.14^{i}	893.09^{g}	1435.23^{j}
LED-WL*10	183.13	774.69^{defgh}	1752.13^{efg}	591.56^{defghi}	977.44^{defg}	1569.00^{fgh}
LED-WL*12	181.84	758.42^{fghi}	1704.40^{gh}	576.58^{efghi}	945.98^{efg}	1522.56^{hi}
LED-WL*14	183.59	737.71^{hi}	1645.67^{hi}	554.13^{hi}	907.96^{fg}	1462.08^{ij}
LED-BL*10	182.59	878.66^{a}	2031.06^{a}	696.07^{a}	1152.40^{a}	1848.47^{a}
LED-BL*12	182.45	832.82^{bc}	1906.58^{bc}	650.37^{ab}	1073.76^{abc}	1724.13^{bc}
LED-BL*14	182.29	784.65^{cdefgh}	1852.50^{cd}	602.36^{cdefgh}	1067.85^{abc}	1670.21^{cde}
LED-RL*10	182.60	810.10^{bcde}	1862.82^{cd}	627.50^{bcdef}	1052.72^{bcd}	1680.22^{cde}
LED-RL*12	185.03	801.03^{bcdef}	1837.35^{cd}	616.00^{cde}	1036.32^{bcd}	1652.32^{cde}
LED-RL*14	185.03	783.79^{defgh}	1828.86^{cde}	598.76^{defgh}	1045.07^{bcd}	1643.83^{def}
LED-GL*10	187.28	838.91^{ab}	1962.35^{ab}	651.63^{b}	1123.44^{ab}	1775.07^{b}
LED-GL*12	183.82	815.32^{bcd}	1891.29^{bc}	631.50^{bcd}	1075.97^{abc}	1707.47^{bcd}
LED-GL*14	182.34	790.32^{cdefg}	1788.00^{def}	607.98^{cdefg}	997.68^{cdef}	1605.66^{efg}
LED-ML*10	184.22	799.75^{bcdefg}	1812.06^{de}	615.53^{bcdef}	1012.31^{cde}	1627.84^{ef}
LED-ML*12	182.85	786.60^{cdefgh}	1759.37^{efg}	603.75^{cdefgh}	972.77^{defg}	1576.52^{fgh}
LED-ML*14	183.81	765.55^{efghi}	1730.38^{fg}	581.74^{defghi}	964.83^{defg}	1546.57^{gh}
SEM	2.55	14.36	23.77	14.31	26.76	21.74
Sig.	NS	*	*	*	*	*

$^{a, b, c \ldots}$ Means having different superscripts within columns in the same effect are significantly different (P≤ 0.05).

1-ICL= Incandescent light, 2- WL= White light, 3- BL= Blue light, 4- RL= Red light, 5-GL=Green light, 6- ML =Mix light

Table (3): The effects of light colors and stocking densities on feed intake and feed conversion ratio of broiler chickens at different periods of experiment (Means ±SE).

Items / Treatments	Feed intake(g)			Feed conversion ratio		
	7-21days	22-35days	7-35days	7-21 days	22-35 days	7-35 days
Effect of light colors (LC):						
ICL(1)	871.33^{d}	1780.00^{d}	2651.33^{d}	1.56^{a}	1.95^{a}	1.80^{a}
LED-WL(2)	879.33^{cd}	1801.00^{d}	2680.33^{d}	1.53^{ab}	1.91^{ab}	1.76^{ab}
LED-BL(3)	906.83^{a}	1978.33^{a}	2885.16^{a}	1.40^{d}	1.80^{d}	1.65^{d}
LED-RL(4)	888.66^{bc}	1913.33^{b}	2801.99^{b}	1.44^{c}	1.83^{c}	1.69^{c}
LED-GL(5)	898.83^{ab}	1936.66^{b}	2835.49^{b}	1.42^{cd}	1.81^{c}	1.67^{c}
LED-ML(6)	884.17^{c}	1864.16^{c}	2748.33^{c}	1.47^{bc}	1.90^{bc}	1.73^{b}
SEM	4.14	9.28	11.79	0.02	0.03	0.01
Sig.	*	*	*	*	*	*
Effect of density (D):						
10/m^{2}	892.41^{a}	1900.58^{a}	2792.99^{a}	1.43^{b}	1.83^{b}	1.67^{b}
12/m^{2}	891.75^{a}	1872.91^{b}	2764.66^{b}	1.47^{ab}	1.87^{ab}	1.72^{ab}
14/m^{2}	880.41^{b}	1863.25^{b}	2743.66^{b}	1.51^{a}	1.91^{a}	1.76^{a}
SEM	2.92	6.56	8.33	0.01	0.02	0.01
Sig.	*	*	*	*	*	*
Interactions (LC*D):						
ICL*10	870.50^{def}	1709.50^{i}	2580.00^{h}	1.52^{abc}	1.82^{d}	1.71^{bc}
ICL*12	882.50^{bcdef}	1817.50^{fg}	2700.00^{efg}	1.59^{a}	2.00^{abc}	1.84^{ab}
ICL*14	861.00^{f}	1813.00^{g}	2674.00^{fg}	1.59^{a}	2.03^{ab}	1.87^{a}
LED-WL*10	888.50^{abcde}	1866.50^{ef}	2755.00^{cde}	1.50^{abc}	1.91^{abcd}	1.76^{bc}
LED-WL*12	882.50^{bcdef}	1837.50^{fg}	2720.00^{ef}	1.53^{abc}	1.94^{abcd}	1.79^{bc}
LED-WL*14	867.00^{ef}	1699.00^{i}	2566.00^{h}	1.56^{ab}	1.87^{bcd}	1.76^{bc}
LED-BL*10	908.50^{a}	2035.00^{a}	2943.50^{a}	1.30^{d}	1.77^{d}	1.59^{d}
LED-BL*12	907.00^{ab}	1955.00^{cd}	2862.00^{b}	1.40^{cd}	1.82^{d}	1.66^{bcd}
LED-BL*14	905.00^{ab}	1945.00^{cd}	2850.00^{b}	1.51^{abc}	1.83^{cd}	1.71^{bc}
LED-RL*10	896.00^{abc}	1915.00^{de}	2811.00^{bc}	1.43^{bcd}	1.82^{d}	1.68^{bcd}
LED-RL*12	885.00^{abcdef}	1915.00^{de}	2800.00^{bcd}	1.44^{bc}	1.85^{cd}	1.70^{bc}
LED-RL*14	885.00^{abcdef}	1910.00^{de}	2795.00^{bcd}	1.48^{abc}	1.83^{cd}	1.70^{bc}
LED-GL*10	908.00^{a}	2025.00^{ab}	2933.00^{a}	1.40^{cd}	1.80^{d}	1.65^{cd}
LED-GL*12	901.00^{abc}	1955.00^{cd}	2856.00^{b}	1.43^{bcd}	1.82^{d}	1.67^{bcd}
LED-GL*14	887.50^{abcde}	1830.00^{fg}	2717.50^{ef}	1.46^{abc}	1.83^{cd}	1.70^{bc}
LED-ML*10	883.00^{bcdef}	1852.50^{fg}	2735.50^{def}	1.43^{bcd}	1.83^{cd}	1.69^{bcd}
LED-ML*12	892.50^{abcd}	1757.50^{g}	2650.00^{h}	1.48^{abc}	1.81^{d}	1.68^{bcd}
LED-ML*14	877.00^{cdef}	1982.50^{bc}	2859.50^{b}	1.51^{abc}	2.05^{a}	1.85^{a}
SEM	7.17	16.07	20.42	0.03	0.05	0.02
Sig.	*	*	*	*	*	*

$^{a, b, c \dots}$ Means having different superscripts within columns in the same effect are significantly different (P≤ 0.05).

1-ICL= Incandescent light, 2- WL= White light, 3- BL= Blue light, 4- RL= Red light, 5- GL=Green light, 6- ML =Mix light

Table (4): The effects of light colors and stocking densities on feed intake and feed conversion ratio of broiler chickens at different period of experiment (Means ±SE).

Items / Treatments	Traits	
	Livability (%)	**EPEF[7]**
Effect of light colors (LC):		
ICL[(1)]	86.59[c]	240.89[e]
LED-WL[(2)]	88.50[c]	257.63[d]
LED-BL[(3)]	95.12[a]	333.04[a]
LED-RL[(4)]	92.51[ab]	303.19[b]
LED-GL[(5)]	94.43[a]	318.86[ab]
LED-ML[(6)]	89.20[bc]	274.48[c]
SEM	1.24	5.62
Sig.	*	*
Effect of density (D):		
$10/m^2$	92.71[a]	308.80[a]
$12/m^2$	91.23[ab]	287.04[b]
$14/m^2$	89.24[b]	268.20[c]
SEM	0.87	3.97
Sig.	*	*
Interactions (LC*D):		
ICL*10	87.50[bcd]	261.16[ghij]
ICL*12	86.84[cd]	235.86[jk]
ICL*14	85.42[d]	225.66[k]
LED-WL*10	90.63[abcd]	272.63[fghi]
LED-WL*12	89.47[abcd]	257.87[hij]
LED-WL*14	85.42[d]	242.37[ijk]
LED-BL*10	96.88[a]	367.55[a]
LED-BL*12	94.74[ab]	325.58[bc]
LED-BL*14	93.75[abc]	305.98[cde]
LED-RL*10	93.75[abc]	312.86[cde]
LED-RL*12	92.11[abcd]	300.24[cdef]
LED-RL*14	91.67[abcd]	296.47[cdef]
LED-GL*10	96.88[a]	344.74 [ab]
LED-GL*12	94.74[ab]	321.03[bcd]
LED-GL*14	91.67[abcd]	290.80[defg]
LED-ML*10	90.63[abcd]	293.88[cdef]
LED-ML*12	89.47[abcd]	281.65[efgh]
LED-ML*14	87.50[bcd]	247.91[ijk]
SEM	2.12	9.73
Sig.	*	*

[a, b, c …] Means having different superscripts within columns in the same effect are significantly different ($P \leq 0.05$).

1-ICL= Incandescent light, 2- WL= White light, 3- BL= Blue light, 4- RL= Red light, 5- GL=Green light, 6- ML =Mix light

7-EPEF= European production efficiency factor

Table (5): The effects of light colors and stocking densities on hematological traits of broiler chickens at different periods of experiment (Means ±SE).

Items / Treatments	Hematological traits						
	WBCS (k/µ L)[7]	**L %[8]**	**H %[9]**	**H/L ratio[10]**	**RBCS (M/µ L)[11]**	**Hb (g/dL)[12]**	**PCV%[13]**
Effect of light colors (LC):							
ICL[(1)]	12900	70.66	27.22[a]	0.38[a]	4550000	12.22	36.44
LED-WL[(2)]	13900	71.22	22.55[b]	0.32[b]	4460000	12.61	37.55
LED-BL[(3)]	11490	73.66	20.22[b]	0.27[b]	4193000	11.73	35.18
LED-RL[(4)]	11900	73.55	22.11[b]	0.30[b]	4389000	11.66	35.00
LED-GL[(5)]	11290	73.11	21.66[b]	0.29[b]	4232000	11.81	35.44
LED-ML[(6)]	12820	72.55	22.445[b]	0.31[b]	4424000	12.46	7.38
SEM	1038.05	1.14	1.50	0.02	145300	0.38	1.07
Sig.	NS	NS	*	*	NS	NS	NS
Effect of density (D):							
10/m²	12580	72.16	19.72[b]	0.27[b]	4306000	12.14	36.33
12/m²	12310	72.72	22.33[b]	0.30[b]	4399000	11.93	35.62
14/m²	12260	73.00	25.05[a]	0.35[a]	4420000	12.17	36.52
SEM	734	0.81	1.06	0.01	102800	0.34	0.75
Interactions (LC*D):							
ICL*10	14570	67.33	31.66[a]	0.45[a]	4677000	11.89	35.00
ICL*12	12000	71.66	24.33[abcd]	0.34[abc]	4230000	11.33	34.00
ICL*14	12130	73.00	25.66[abcd]	0.35[abc]	4743000	13.44	40.33
LED-WL*10	13900	69.00	18.00[cde]	0.26[bcd]	4527000	12.89	38.66
LED-WL*12	16170	71.66	23.00[abcde]	0.32[bcd]	4567000	12.88	37.66
LED-WL*14	11630	73.00	26.66[abc]	0.36[ab]	4287000	12.05	36.16
LED-BL*10	12170	73.00	14.66[e]	0.20[d]	4127000	11.89	35.66
LED-BL*12	10070	75.00	21.00[bcde]	0.28[bcd]	4367000	11.74	35.23
LED-BL*14	12230	73.00	25.00[abcd]	0.34[abc]	4087000	11.55	34.66
LED-RL*10	10030	73.00	18.33[bcde]	0.25[bcd]	3890000	11.78	35.33
LED-RL*12	12670	74.66	21.00[bcde]	0.28[bcd]	4580000	11.78	35.33
LED-RL*14	13000	73.00	27.00[ab]	0.37[ab]	4580000	11.44	34.33
LED-GL*10	10870	74.66	17.66[de]	0.24[cd]	4697000	12.16	36.50
LED-GL*12	11530	71.66	21.66[bcde]	0.30[bcd]	4250000	11.50	34.50
LED-GL*14	11470	73.00	25.66[abcd]	0.35[abc]	4163000	11.78	35.33
LED-ML*10	13970	73.00	18.00[cde]	0.25[bcd]	4363000	12.28	36.83
LED-ML*12	11400	71.66	23.00[abcde]	0.32[bcd]	4367000	12.33	37.00
LED-ML*14	13100	73.00	26.33[abcd]	0.36[abc]	4543000	12.77	38.33
SEM	1797.95	1.98	2.60	0.03	251700	0.66	1.85

[a, b, c …] Means having different superscripts within columns in the same effect are significantly different ($P \leq 0.05$).

1-ICL= Incandescent light, 2- WL= White light, 3- BL= Blue light, 4- RL= Red light, 5- GL=Green light, 6- ML =Mix light, 7- WBCs=white blood cells, 8-L=Lymphocyte, 9- H=Hetrophil, 10-H/L= Hetrophil/ Lymphocyte, 11-RBCs=Red blood cells, 12- Hb=Hemoglobin, 13-PCV=Packed cell volume

Table (6): The effects of light colors and stocking densities on blood biochemical traits of broiler chickens at different periods of experiment (Means ±SE).

Items / Treatments	Liver enzymes		Hormone assays			
	ALT (U/L)	**AST (U/L)**	**Free T3 (ng/100 mL)**	**Free T4 (ng/100mL)**	**Melatonin (µg/100mL)**	**Corticosterone (µg/100 mL)**
Effect of light colors (LC):						
ICL(1)	60.00^{a}	99.66^{a}	1.60^{a}	1.25^{a}	22.10^{f}	519.83^{a}
LED-WL(2)	52.44^{b}	84.66^{b}	1.43^{b}	1.01^{b}	22.48^{e}	502.33^{b}
LED-BL(3)	36.00^{d}	48.66^{d}	0.80^{e}	0.50^{e}	44.36^{a}	315.73^{f}
LED-RL(4)	43.33^{c}	62.66^{c}	1.01^{d}	0.70^{d}	31.22^{c}	463.37^{d}
LED-GL(5)	39.11^{cd}	56.00^{cd}	0.90^{de}	0.60^{de}	33.11^{b}	453.40^{e}
LED-ML(6)	49.33^{b}	75.33^{b}	1.21^{c}	0.80^{c}	30.23^{d}	492.70^{c}
SEM	2.00	4.03	0.05	0.04	0.03	0.12
Sig.	*	*	*	*	*	*
Effect of density (D):						
10/m^2	40.55^{c}	59.16^{c}	1.04^{c}	0.64^{c}	32.51^{a}	445.76^{c}
12/m^2	47.44^{b}	68.33^{b}	1.15^{b}	0.75^{b}	30.32^{b}	455.73^{b}
14/m^2	52.11^{a}	86.00^{a}	1.28^{a}	1.05^{a}	28.92^{c}	472.18^{a}
SEM	1.41	2.85	0.03	0.03	0.02	0.08
Sig.	*	*	*	*	*	*
Interaction (LC*D):						
ICL*10	56.00^{abc}	95.00^{ab}	1.40^{bcd}	1.04^{cd}	25.90^{k}	512.10^{c}
ICL*12	58.66^{ab}	94.00^{ab}	1.59^{ab}	1.12^{bc}	20.31^{n}	522.30^{b}
ICL*14	65.33^{a}	110.00^{a}	1.81^{a}	1.60^{a}	20.90^{o}	525.10^{a}
LED-WL*10	49.33^{bcd}	78.00^{bc}	1.37^{bcd}	0.88^{d}	24.23^{L}	498.30^{g}
LED-WL*12	54.66^{abcd}	76.00^{bc}	1.46^{bc}	0.85^{de}	22.90^{m}	502.20^{f}
LED-WL*14	53.33^{bcd}	100.00^{a}	1.46^{bc}	1.31^{b}	20.31^{n}	506.50^{e}
LED-BL*10	26.66^{g}	40.00^{f}	0.70^{i}	0.38^{f}	45.56^{a}	301.10^{r}
LED-BL*12	37.33^{efg}	50.00^{def}	0.76^{hi}	0.49^{f}	44.40^{b}	312.30^{p}
LED-BL*14	44.00^{def}	56.00^{cdef}	0.94^{fghi}	0.62^{ef}	43.13^{c}	333.80^{q}
LED-RL*10	36.00^{fg}	44.00^{ef}	0.88^{ghi}	0.56^{f}	33.04^{e}	459.10^{m}
LED-RL*12	47.33^{bcdef}	68.00^{cd}	1.02^{fgh}	0.62^{ef}	31.00^{g}	463.13^{L}
LED-RL*14	46.66^{cdef}	76.00^{bc}	1.13^{defg}	0.94^{cd}	29.63^{i}	467.90^{k}
LED-GL*10	31.00^{g}	42.00^{f}	0.75^{hi}	0.37^{f}	35.11^{d}	422.90^{o}
LED-GL*12	37.33^{efg}	56.00^{cdef}	0.90^{fghi}	0.57^{f}	33.00^{e}	448.50^{n}
LED-GL*14	48.66^{bcde}	70.00^{cd}	1.04^{efgh}	0.86^{d}	31.22^{f}	448.80^{h}
LED-ML*10	44.00^{def}	56.00^{cdef}	1.13^{defg}	0.61^{ef}	31.21^{f}	481.10^{j}
LED-ML*12	49.33^{bcd}	66.00^{cde}	1.18^{cdef}	0.84^{de}	30.33^{h}	486.00^{i}
LED-ML*14	54.66^{abcd}	104.00^{a}	1.33^{bcde}	0.96^{cd}	29.14^{j}	511.00^{d}
SEM	3.47	1.14	0.09	0.07	0.06	0.21
Sig.	*	*	*	*	*	*

$^{a, b, c \ldots}$ Means having different superscripts within columns in the same effect are significantly different (P≤ 0.05). 1-ICL= Incandescent light, 2- WL= White light, 3- BL= Blue light, 4- RL= Red light, 5-GL=Green light, 6- ML =Mix light

Table (7): The effects of light colors and stocking densities on lymphoid organs and antibody titer response of broiler chickens at different periods of experiment (Means ±SE).

Items / Treatments	Lymphoid organ weights (g)			Titer response against NDV (log^2)
	Spleen	Bursa of Fabricius	Thymus	
Effect of light colors (LC):				
ICL(1)	1.46^{c}	1.41^{d}	6.96^{d}	2.50^{d}
LED-WL(2)	1.78^{b}	1.45^{d}	7.02^{d}	2.66^{d}
LED-BL(3)	2.40^{a}	2.55^{a}	10.48^{a}	6.66^{a}
LED-RL(4)	1.93^{b}	1.83^{c}	8.49^{c}	4.00^{c}
LED-GL(5)	2.04^{b}	2.22^{b}	9.13^{b}	5.16^{b}
LED-ML(6)	1.88^{b}	1.48^{d}	8.15^{c}	3.50^{cd}
SEM	0.10	0.11	0.19	0.32
Sig.	*	*	*	*
Effect of density (D):				
$10/m^2$	2.24^{a}	2.11^{a}	9.33^{a}	5.00^{a}
$12/m^2$	1.97^{b}	1.86^{b}	8.46^{b}	4.08^{b}
$14/m^2$	1.53^{c}	1.49^{c}	7.32^{c}	3.16^{c}
SEM	0.07	0.07	0.13	0.23
Sig.	*	*	*	*
Interaction (LC*D):				
ICL*10	1.94^{bcde}	1.47^{defg}	7.76^{cdef}	4.00^{def}
ICL*12	1.40^{efg}	1.37^{efg}	6.90^{fg}	2.00^{gh}
ICL*14	1.05^{f}	1.40^{efg}	6.23^{g}	1.50^{h}
LED-WL*10	2.14^{abcd}	1.83^{cdef}	7.60^{def}	3.50^{defg}
LED-WL*12	1.85^{cde}	1.45^{defg}	7.22^{efg}	2.00^{gh}
LED-WL*14	1.37^{efg}	1.07^{g}	6.23^{g}	2.50^{fgh}
LED-BL*10	2.64^{a}	2.92^{a}	11.09^{a}	8.00^{a}
LED-BL*12	2.43^{abc}	2.74^{a}	10.25^{ab}	7.00^{ab}
LED-BL*14	2.12^{abcd}	2.00^{bcde}	10.09^{ab}	5.00^{cd}
LED-RL*10	2.54^{ab}	2.07^{bcd}	10.01^{b}	4.50^{cde}
LED-RL*12	2.15^{abcd}	1.90^{cdef}	8.55^{cd}	4.00^{def}
LED-RL*14	1.10^{fg}	1.52^{defg}	6.90^{fg}	3.50^{defg}
LED-GL*10	2.26^{abcd}	2.59^{ab}	10.75^{ab}	6.00^{bc}
LED-GL*12	1.93^{bcde}	2.37^{abc}	9.73^{b}	6.00^{bc}
LED-GL*14	1.92^{bcde}	1.70^{defg}	6.90^{fg}	3.50^{defg}
LED-ML*10	1.95^{bcde}	1.82^{cdef}	8.76^{c}	4.00^{def}
LED-ML*12	2.06^{abcd}	1.36^{efg}	8.07^{cde}	3.50^{defg}
LED-ML*14	1.65^{def}	1.27^{fg}	7.60^{def}	3.00^{efgh}
SEM	0.18	0.19	0.33	0.56
Sig.	*	*	*	*

$^{a, b, c \dots}$ Means having different superscripts within columns in the same effect are significantly different (P≤ 0.05). 1-ICL= Incandescent light, 2- WL= White light, 3- BL= Blue light, 4- RL= Red light, 5-GL=Green light, 6- ML =Mix light

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الملخص العربى

الاستجابة الانتاجيه والفسيولوجية لدجاج التسمين المعرض لألوان مختلفه من اضاءه LED والمربى تحت كثافات مختلفه

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تهدف هذه الدراسة إلى تقييم تأثيرات ألوان الضوء المختلفة وكثافات التسكين على الأداء الإنتاجي والفسيولوجي لدجاج التسمين. تم استخدام عدد 648 كتكوت التسمين مختلط الجنس من سلاله الروس 308 حيث قسم هذا العدد عشوائيا الى سته معاملات وكل معامله احتوت على ثلاث مكررات لكل كثافه 10، 12، 14 طائر/ م2 عرضت هذه المعاملات الى الاضاءه العاديه المتوهجه (ICL) فى المعامله الكنترول بينما عرضت باقى المعاملات الأخرى لالوان مختلفه من اضاءه LED ذات اللون الأحمر (LED-RL) ،الضوء الأزرق (LED-BL)،الضوء الأخضر(LED-GL) ،الضوء الأبيض(LED-WL) ، والضوء المختلط (LED-ML) حيث كانت شده الإضاءه 5 وات / م 2 بمعدل 30 لوكس . اشارت النتائج إلى أن الطيور التي عرضت للضوء الازرق (LED-BL)والموجوده تحت الكثافه 10 طيور / م 2 أظهرت أداءآ إنتاجيًا اعلى من المجموعات المعرضة لألوان الاضاءه والكثافات الأخرى. كما لوحظ ان اعلى حيويه وأعلى قيمه لمعامل كفاءة الإنتاج الأوروبي كانت للطيور المعرضة للضوء الازرق (LED-BL) والمرباه تحت الكثافه 10 طيور / م 2 مقارنة بالمجموعات الأخرى. كما لوحظ ان الطيور المعرضة للضوء الازرق (LED-BL) والمرباه تحت الكثافة المنخفضة اظهرت إستجابه أقل للإجهاد وذلك بانخفاض مستوى هرمون الكورتيكوستيرون وزياده تركيز هرمون الميلاتونين. بالإضافة إلى ذلك تحسنت معنويا أوزان الأعضاء الليمفاوية والاستجابه المناعية بشكل ملحوظ عندما عرضت الطيور للضوء الازرق (LED-BL) والمرباه تحت الكثافه 10 طيور /م2 مقارنة بالمجموعات التجريبية الأخرى. وعموما فان هذه الدراسة اشارت الى أن استخدام الاضاءه الزرقاء (LED-BL) مع كثافه تسكين 10 طيور / م 2 فى مساكن دجاج التسمين اظهرت تاثيرآ إيجابياً على الأداء الإنتاجي والفسيولوجي مقارنة مع الألوان والكثافات الأخرى.