# The effects of LED lights in different colors on fattening performance, litter characteristics, meat properties, and some welfare parameters in broilers

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**ABSTRACT**

Light is important for broiler rearing which can affect economically significant performance traits. The purpose of this study was to investigate the effects of daylight (DL), warm white (WWL) and blue light (BL) on broiler fattening performance, carcass characteristics, meat quality, litter characteristics and welfare. In the study, 216 male chicks were used. Chicks were weighed and housed randomly in 3 light-controlled rooms (n=72), each containing 9 separate pens (8 chicks per pen). During the experiment body weight, weight gain, feed consumption, and feed-to-gain ratio were calculated weekly. Carcass yield and percentages of internal organs were determined. Tonic immobility duration, footpad, and breast burns of broilers, pH, and moisture of litter, cooking loss, and water-holding capacity of the breast meat were analyzed. At the end of six weeks of the experiment, the body weight ($P<0.001$), body weight gain ($P<0.001$), and total feed consumption ($P<0.01$) were lower, and feed-to-gain ratio ($P<0.01$) was higher for broilers reared under the BL. At the end of the fattening period, the tonic immobility duration, footpad & breast burns of broilers, and moisture & pH levels of the litter did not change according to the lighting groups ($P>0.05$). The differences among the groups in terms of, carcass yield, percentages of heart, liver, gizzard & abdominal fat, and examined meat properties were found as statistically insignificant ($P>0.05$). As a result, BL has a negative impact on the growth performance of broilers. However, carcass and carcass characteristics, litter parameters, meat quality and welfare characteristics were similar among examined light color groups.

## Introduction

To maximize broiler rearing efficiency, chicks must be exposed to optimal environmental factors. Light is important environmental factors for broiler rearing (12). It can affect broiler fattening performance, welfare, physiology and behavior (8). Light source, duration, color (wavelength), intensity and uniformity are considered as fundamental aspects of light (4). Since artificial light sources are used in broiler houses, these aspects of the light should be adjusted to the broilers (23). Bird eyes can perceive wavelengths up to 320 nm, with 562 nm being the most sensitive. Different colors can have different stimulatory effects on retinal and pineal cells in birds, leading to behavioral changes that affect growth, development and productivity (4, 29). Incandescent and compact fluorescent lamps are used as light sources in broiler fattening. In recent years, many new lighting technologies such as LEDs have emerged as an alternative to light sources, with energy saving at the forefront (19). LED-based light sources are characterized by their low consumption, small size, high efficiency, resistance to moisture, and long lifetime, and can provide light in the desired color (19). Because of all these advantages, LEDs have come to the fore as a new alternative for poultry house lighting, and the effects of light color on poultry has become one of the current research topics. However, the literature results are inconsistent. While DL affects the broilers in natural life, WL is used in commercial broiler rearing.

Light effect the behaviour and activity of broilers (25, 26). Activity is changed the litter properties such as moisture and pH (26). Footpad and breast burns are used as an indicator of litter quality and management practices. These parameters affect directly welfare because broilers live on the litter material during the whole life (7). Blue light leads to a positive impact on fear levels, demonstrated through various fear tests, including tonic immobility (8). The purpose of this study is to compare the color of LED light in natural light color, such as DL, with WWL and BL. This study investigated the effects of DL, WW and BL used in broiler rearing on broiler performance, carcass characteristics, meat quality, litter characteristics and broiler welfare.

## Materials and Methods

Experimental procedures were approved by the Ankara University Ethics Committee (2017-16-130). In the study, 216 male chicks (ROSS-308) were used. Chicks were randomly placed in 3 light-controlled rooms (n = 72), and in 9 separate pens (8 chicks per pen) with wood shavings litter in each room with dimensions of 117 × 61.5 cm (width x length). Ventilation was provided with a fan in each room. Chicks were exposed to DL, WWL, or BL using an LED bulb in each room. All light sources were exposed to an intensity of 20 lux with 23 hours of light per day (23L: 1D) until 7$^{th}$ day of the experiment, and then to 16 hours of light (16L: 8D) per day. Broilers were fed with a starter diet (3000 kcal/kg ME and 23.89% CP) until day 14, a grower diet (3125 kcal/kg ME and 22.61% CP) from day 14 to 28, and a finisher diet (3190 kcal/kg ME and 20.69% CP) from day 28 to 42. The temperature was 33 °C in the first 3 days and then it was decreased to 22 °C. The fattening period was terminated on the 42$^{nd}$ day.

Chicks were weighed every week with a scale sensitive to 0.01 g (Necklife JZC-TSC). Weight gain and feed consumption were measured in each pen and feed to gain ratio was calculated. On day 41 of the experiment, 2 selected broilers from each pen were restrained for 15 seconds, and the time until they moved was measured as tonic immobility duration (20). On day 42, all broilers were examined for footpad and breast burns. A 3-point visual score was used in the footpad burn. A score of 1 represents an intact footpad and an intact skin ridge within the mid-footpad surface. A score of 2 indicated footpads with mild lesions, and dermal ridges with oval or round ulcers covered with a crust (<7.5 mm); and a score of 3 indicated footpads with severe lesions, with a dark brown crust (>7.5 mm) adhering to the central plantar footpad (7). A 2-point visual score is used to score for breast burns, with a score of 1 meaning no lesion present and a score of 2 meaning lesion present (7).

On day 42 of the experiment, a total of 100 g litter samples were collected from each pen (4 corners and 1 center) and measured for pH and moisture. The pH was measured with a pH meter (Mettler Toledo) after mixing 20 g of substrate with 30 ml of distilled water and holding for 2 minutes. The litter mixture was weighed and placed in a drying oven at 105°C for 16 hours to measure the moisture content. They were then weighed again and moisture content was calculated from the difference between the first and last weightings (1).

Two broilers from each pen (total 18 broilers from each group) were selected for slaughter at 42 days of age. Carcass weight was determined and expressed as a percentage of body weight. Heart, liver, gizzard and abdominal fat weights were measured and expressed as a percentage of body weight. A breast sample (upper third of the pectoral muscle) was taken. pH meter (Mettler Toledo) was used to determine meat pH at first 15 min, 45 min, and 24 h after slaughter. To measure cooking loss, 5 g of breast meat was placed in a refrigerated bag. The samples were kept in a water bath at 80°C for 1 hour and then cooled. Cooking loss was calculated as the ratio of the difference in weight between the raw and cooked meat relative to the weight of the raw meat (21). To determine the water holding capacity, 5 g breast meat was divided into 5 pieces and kept for 5 minutes in filter papers placed between a glass layer with a weight of 2250 g. After the time was up, the pieces of meat were removed from the filter paper and the filter paper was weighed again. Water holding capacity was calculated as the ratio of the difference in weight between the initial and final weight relative to the initial weight (28).

***Statistical analysis:*** One-way ANOVA was used to identify among group differences for examined parameters except for food pad and breast burns. Duncan's multiple comparison test was used to determine significant differences among the groups. A chi-square test was used to control for the significance of differences among groups in footpad and breast burns (6). A value of $P<0.05$ was considered statistically significant.

## Results

The body weights at the end of the fattening period were determined as 3428, 3343, and 3219 g in the DL, WWL and BL groups, respectively (Table 1). Differences among the groups in terms of body weight were found to be statistically significant ($P<0.05$) except at the beginning of the trial and the 3$^{th}$ weeks of age. The level of importance among the groups increased from the beginning to the end of the research. When the body weight gains in the groups were examined from the beginning to the end of the experiment, the differences among the groups were found to be significant ($P<0.05$) at the 1$^{st}$, 4$^{th,}$ and 6$^{th}$ weeks of the fattening period. During the experiment, broilers reared under the DL, WWL and BL, total body weight

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gains were found as 3390, 3304, and 3180 g, respectively (P<0.001). Total feed consumption (Table 2) during the six-week experiment was calculated as 5131, 5032, and 4926 g in the daylight, warm white, and blue light groups, respectively (P<0.01). The total feed-to-gain ratio during the fattening period was 1.51, 1.52, and 1.55 in the DL, WWL and BL groups, respectively. The differences among the groups were found as significant (P<0.01).

At the end of the fattening period, the tonic immobility duration, footpad & breast burns of broilers, and moisture & pH levels of the litter did not change according to the lighting groups (P>0.05, Table 3 and 4). The tonic immobility duration was 163, 152, and 125 seconds in the DL, WWL and BL groups, respectively. On the 42nd day of the experiment, the pH and moisture of the litter in the DL, WWL and BL groups were calculated as 7.54 & 33.87%, 7.92 & 32.96%, and 7.71 & 33.21%, respectively. The differences among the groups in terms of carcass yield, and percentages of heart, liver, gizzard & abdominal fat were statistically insignificant (P>0.05, Table 5). In DL, WWL and BL groups, $pH_{24}$ (5.89, 5.91, and 5.93), cooking loss (25.07, 27.51, and 26.46%), and water holding capacity (17.43, 19.41, and 18.44%) of breast meat were found to be similar (P>0.05, Table 6).

**Table 1.** The effect of light color on body weight (g) and body weight gain (g) of broilers.

| Light color | Body weight | | | | | | |
|---|---|---|---|---|---|---|---|
| | Initial | 1st week | 2nd week | 3rd week | 4th week | 5th week | 6th week |
| DL | 38.6±0.03 | 173±0.7$^{ab}$ | 507±3.7$^{a}$ | 1117±9.4 | 1873±15.2$^{a}$ | 2707±21.7$^{a}$ | 3428±35.4$^{a}$ |
| WWL | 38.8±0.05 | 178±2.7$^{a}$ | 515±5.6$^{a}$ | 1109±13.0 | 1848±20.3$^{a}$ | 2701±15.2$^{a}$ | 3343±32.4$^{a}$ |
| BL | 38.9±0.12 | 168±2.2$^{b}$ | 491±3.9$^{b}$ | 1086±12.4 | 1790±11.6$^{b}$ | 2631±6.8$^{b}$ | 3219±17.5$^{b}$ |
| P | - | * | ** | - | ** | ** | *** |
| **Light color** | **Body weight gain** | | | | | | |
| | 1st week | 2nd week | 3rd week | 4th week | 5th week | 6th week | Total |
| DL | 134±0.7$^{ab}$ | 334±3.5 | 610±6.0 | 756±12.5$^{a}$ | 835±21.5 | 721±25.8$^{a}$ | 3390±35.4$^{a}$ |
| WWL | 139±2.8$^{a}$ | 337±5.4 | 595±7.9 | 739±10.6$^{ab}$ | 853±19.2 | 642±25.4$^{ab}$ | 3304±32.4$^{a}$ |
| BL | 129±2.1$^{b}$ | 323±4.5 | 595±10.3 | 704±11.4$^{b}$ | 841±15.8 | 589±17.6$^{b}$ | 3180±17.5$^{b}$ |
| P | * | - | - | * | - | ** | *** |

DL: daylight, WWL: warm white light and BL: blue light. -: P> 0.05; *: P< 0.05; **: P< 0.01; ***: P< 0.001. a-b Different letters in the same column indicate statistically significant differences (P < 0.05).

**Table 2.** The effect of light color on feed consumption (g) and feed-to-gain ratio (g/g) of broilers.

| Light color | Feed consumption | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st week | 2nd week | 3rd week | 4th week | 5th week | 6th week | Total |
| DL | 142±0.7 | 382±4.3 | 724±3.3$^{a}$ | 1071±7.4 $^{a}$ | 1325±7.7 | 1488±35.8$^{a}$ | 5131±43.5$^{a}$ |
| WWL | 143±0.9 | 386±3.7 | 721±4.8$^{a}$ | 1047±11.2 $^{ab}$ | 1323±6.7 | 1413±33.8$^{ab}$ | 5032±41.0$^{ab}$ |
| BL | 142±1.3 | 377±2.9 | 703±4.7$^{b}$ | 1030±8.6 $^{b}$ | 1309±2.3 | 1365±24.2$^{b}$ | 4926±23.1$^{b}$ |
| P | - | - | ** | * | - | * | ** |
| **Light color** | **Feed-to-gain ratio** | | | | | | |
| | 1st week | 2nd week | 3rd week | 4th week | 5th week | 6th week | Total |
| DL | 1.06±0.01$^{b}$ | 1.14±0.01 | 1.19±0.01 | 1.42±0.02 | 1.59±0.03 | 2.07±0.05$^{b}$ | 1.51±0.01$^{b}$ |
| WWL | 1.03±0.02$^{b}$ | 1.15±0.02 | 1.21±0.01 | 1.42±0.01 | 1.56±0.03 | 2.21±0.04$^{a}$ | 1.52±0.01$^{b}$ |
| BL | 1.10±0.01$^{a}$ | 1.17±0.02 | 1.18±0.02 | 1.46±0.02 | 1.56±0.03 | 2.33±0.04$^{a}$ | 1.55±0.01$^{a}$ |
| P | ** | - | - | - | - | ** | ** |

DL: daylight, WWL: warm white light and BL: blue light. -: P> 0.05; *: P< 0.05; **: P< 0.01; a-b Different letters in the same column indicate statistically significant differences (P < 0.05).

**Table 3.** The effect of light color on food pad and breast burns (%) of broilers.

| Light color | Footpad burn | Breast burn |
|---|---|---|
| DL | 6.9 | 3.0 |
| WWL | 5.6 | 2.9 |
| BL | 2.8 | 5.7 |
| $X^2$ | 1.341 | 0.931 |
| P | - | - |

DL: daylight, WWL: warm white light and BL: blue light. -: P> 0.05

**Table 4.** The effect of light color on tonic immobility duration (second) of broilers and pH & moisture levels (%) of the litter.

| Light color | Tonic immobility duration | pH | Moisture |
|---|---|---|---|
| **DL** | 163±37 | 7.54±0.11 | 33.87±0.58 |
| **WWL** | 152±30 | 7.92±0.09 | 32.96±0.91 |
| **BL** | 125±29 | 7.71±0.18 | 33.21±1.19 |
| **P** | - | - | - |

DL: daylight, WWL: warm white light and BL: blue light. -: P> 0.05.

**Table 5.** The effect of light color on carcass yield (%) and some internal organ weights (%) of broilers.

| Light color | Carcass yield | Heart | Liver | Gizzard | Abdominal fat |
|---|---|---|---|---|---|
| **DL** | 75±0.3 | 0.53±0.02 | 1.65±0.05 | 0.87±0.04 | 1.32±0.05 |
| **WWL** | 77±0.4 | 0.48±0.02 | 1.73±0.05 | 0.83±0.03 | 1.20±0.05 |
| **BL** | 76±0.9 | 0.49±0.02 | 1.67±0.08 | 0.87±0.03 | 1.34±0.07 |
| **P** | - | - | - | - | - |

DL: daylight, WWL: warm white light and BL: blue light. -: P> 0.05.

**Table 6.** The effect of light color on pH, cooking loss (%), and water holding capacity (%) of breast meat.

| Light color | $pH_{15}$ | $pH_{45}$ | $pH_{24}$ | Cooking loss | Water holding capacity |
|---|---|---|---|---|---|
| **DL** | 6.34±0.03 | 6.02±0.03 | 5.89±0.02 | 25.07±1.01 | 17.43±0.45 |
| **WWL** | 6.30±0.03 | 6.04±0.02 | 5.91±0.03 | 27.51±1.18 | 19.41±0.75 |
| **BL** | 6.36±0.03 | 6.05±0.03 | 5.93±0.03 | 26.46±1.09 | 18.44±0.73 |
| **P** | - | - | - | - | - |

DL: daylight, WWL: warm white light and BL: blue light. -: P> 0.05.

## Discussion and Conclusion

Broilers collect visual data and decide on activities such as feeding and drinking (27). In this study, chicks reared under the WWL had greater body weight gain than those reared under the BL in the first week of the growth. This showed WWL facilitated the chicks' adaptation to the poultry house in the first week. Considering the whole fattening period, the body weight gain of broilers in the BL group was lower than the others. It was seen that the DL and WWL groups were superior due to these broilers consumed more feed. It can be said that the lowest body weight gain in broilers reared under the BL may be due to their more inactivity and less feeding behavior during the day. Solimon and Sabrout (26) reported that the feeding and drinking frequencies were lower in broilers reared under BL. Jie et al. (12) indicated that daily weight gain of broilers reared under the BL was lower than that under the WL. Franco et al. (8) declerated that when the broiler is reared under the BL as a shorter wavelength, behavioral expression may be affected due to the visual ability. They indicated that BL has a calming effect and this makes the broilers at 33 and 34 days of age less active and less feeding behaviors. However, this significant difference was not seen in broilers at 11-12 days of age. They also indicated that there was an interaction among light, genotype, and sex about feeding behavior. However, Rozenboim et al. (22) showed that BL increased the body weight of broilers significantly more than white or red light on later stages of the growth. Ibrahim et al. (11) indicated that body weight gains of broilers reared under the WL and BL were similar. The differences among the studies may be due to the duration of light applied during the day. Previous studies have shown different results regarding feed consumption and feed-to-gain ratios. Rosenboim et al. (22) found that feed-to-gain ratio during the rearing period did not differ among groups. In our study, although broilers reared under the BL consumed less feed and gained less body weight, feed-to-gain ratios were higher than other groups because they provided less body weight gain than they consumed.

Light is an important microclimate factor affecting broiler behavior and well-being (18). In our study, tonic immobility test results showed that there was no difference in broilers reared under DL, WWL, and BL. Previous studies have shown that broilers reared under BL have low levels of fear. The difference between the studies may be due to the duration and intensity of light applied during the day. For example, Mohamed et al. (18) declared that broilers reared under high light intensity (20 lux) showed higher fear levels compared to those reared under low light intensity (5 lux).

Footpad, hock and breast burns are summarised as “contact dermatitis”. They are characterised by hyperkeratosis and necrosis of the epidermis of the affected sites. Contact dermatitis causes pain and thus is a matter of welfare (3, 14). Pain negatively affects the

feeding and drinking behavior of broilers (3, 5). In this study, the application of different light colors during the fattening period did not affect the incidence of footpad and breast burns. The similar frequency of footpad and breast burns in broilers reared under the different light colors may be due to the similar litter characteristics of the groups. Since broilers spend their lives in contact with litter, there is a significant risk of broilers developing contact dermatitis if litter conditions are not optimal (14). Although the feed consumption was lower in broilers reared under the blue light, this situation did not change the litter characteristics. This shows that the difference in feeding behavior among the groups was not at a level that would affect the litter characteristics.

In studies on different light sources and colors, it has been reported that carcass yields at 6 weeks of age range from 71 to 76% in broilers (17, 27). Similarly, in this study, the carcass yield was calculated as 75, 77 and 76% in the DL, WWL, and BL groups, respectively. When the slaughter characteristics were examined, it was observed that the effects of different colors of light on carcass yield and percentages of heart, liver, gizzard, & abdominal fat were similar in broilers. Although the slaughter weights were different, the carcass yields were similar in broilers reared under different light colors. This situation may be due to the different metatarsus weights of the broilers reared under the different light colors. Examining bone properties in the future studies will help to discuss the studies more comprehensively. Similarly, Bayraktar et al. (2) reported that light color and source did not affect the carcass yield. Mohamed et al. (16) found a significant increase in weights of liver, spleen, and Bursa Fabricius in broilers reared under WL. The variations in results among studies may be due to differences in the duration of light exposure during the day.

In addition to broiler performance, meat quality is an important aspect, especially for consumers. Therefore, in our study, we investigated the possible effects of light color on breast meat quality attributes such as pH, cooking loss and water holding capacity. The pH of meat is generally thought to directly reflect the lactic acid level in the muscle and is an important property that influences the shelf life of meat. This study showed that pH level of breast meat was not affected by LED light in different colors. Ke et al. (13) determined that different LED lights were effective on the pH value of breast meat after slaughter and the pH value was higher in the blue and green color groups than in the red and white color groups. The water-holding capacity of meat affects the weight of poultry products and, consequently, their economic value. About 88–95% of the water in the muscle is held intracellularly within the space between actin and myosin filaments and rest is located between the myofibrils. Increase in the water content of muscles, enhancing tenderness, juiciness, firmness, and appearance, improve the quality and economical value of meat (15). For technological and economic reasons, it is desirable to keep the water in the meat as much as possible. Since broiler meat is used as whole carcasses or processed products, the water-holding capacity of meat quality is great importance. In this study, it was determined that the application of different colors of LED light during the fattening period did not make a statistically significant difference about the water-holding capacity of breast meat. The pH of meat affects its water-holding capacity. In this study, it can be said that the water-holding capacity of breast meat was similar in color groups and was effective in the similarity of pH values. The amount of cooking loss can describe the potential for loss of nutritional value of meat during the cooking process. The low cooking loss value of broiler meat can indicate good meat quality (24). This study showed that the application of different colors of LED light during the fattening period didn't create a significant difference among the groups in terms of breast meat cooking loss. Similar to the present study, it was reported that the application of red, green, yellow & blue LEDs and fluorescent light did not make a significant difference in terms of cooking loss in breast meat during the fattening period (9, 10).

As a conclusion, BL is not suitable in terms of fattening performance; however, carcass yield, percentages of some internal organs, breast meat quality, fear level, burns of footpad & breast, and pH & moisture of litter were found to be similar with DL and WWL. Broiler rearing should be done by taking this result into consideration while choosing the light color in the broiler house.

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## Ethical Statement

Experimental procedures were approved by the Ankara University Ethics Committee (2017-16-130).

## Conflict of Interest

The authors declared that there is no conflict of interest.

## Author Contributions

Study conception, design, material preparation, data collection, data analysis and writing of the manuscript were performed by M.T.D., N.Ü. and E.E.O.

## Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

## Animal Welfare

The authors confirm that they have adhered to ARRIVE Guidelines to protect animals used for scientific purposes.

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