# Artificial light and biological responses of broiler chickens: dose-response[2]

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**ABSTRACT:** Light intensity is an important aspect for broiler production. However, previous results do not provide a solid scientific basis for quantifying the response of broilers to light intensity. This study performed a meta-analysis to model the response of broilers to 0.1−200 lux of light intensity. Meta-analysis was used to integrate smaller studies and increase the statistical power over that of any single study and explore new hypotheses. The results indicated that light intensity <5 lux caused welfare concern ($P < 0.05$) and light intensity <1 lux induced productivity loss of broiler ($P < 0.05$), whereas greater level of light intensity >10 lux led to increased mortality ($P < 0.01$) and decreased uniformity ($P < 0.05$). Meta-regression showed that 30−200 lux light intensity was negatively related to BW ($P = 0.047$) and feed intake change ($P = 0.054$), whereas a quadratic relationship was observed between feed conversion ratio change and 50−180 lux light intensity ($R^2 = 0.95$). In addition, the majority of carcass characteristics (abdominal fat weight and wing weight) and metabolic indicators ($K^+$, $Ca^{2+}$, and T3) were affected by light intensity >5 lux. To conclude, this meta-analysis based on published data quantitatively identified that 5 lux of light intensity during grow-out period should be the minimum level to maintain a well productivity and welfare of broiler chickens.

**Key words:** dose-response, light intensity, meta-analysis, metabolism, productivity, welfare



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## INTRODUCTION

Because of the super visual systems of poultry (Kram et al., 2010), artificial light has been widely utilized to regulate poultry production and welfare. Artificial light consists of four aspects, including light source, light period, light color, and light intensity. Although the effects of light source (Ghuffar et al., 2009), light period (Yang et al., 2015), and light color (Pan et al., 2014, 2015; Yang, et al., 2016a) on broiler chickens response are well understood, the quantificational relationships between light intensity and the response of broiler chickens still have not been identified. Moreover, the results of the published studies are sometimes contradictory and inconclusive. The light intensity were thought to not affect BW, feed intake (FI), feed conversion ratio (FCR), footpad condition and mortality (Newberry et al., 1987; Skoglund and Palmer, 1962; Kristensen et al., 2006; Lien et al., 2007; Blatchford et al., 2009). However, other studies concluded that light intensity showed effects on those performances (Newberry et al., 1987; Barwick, 1962; Downs and Lien, 2006).

Those studies were conducted under different conditions, which is hard to draw general conclusions from the results. Meta-analysis is the reanalysis of data by compiling the data from all independent publications, providing a more precise overall estimate of effects (Lipsey and Wilson, 2001; Maltin et al., 2003). Increasing evidence in agricultural production (Challinor et al., 2014; Pittelkow et al., 2015) and animal production

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(Faridi et al., 2015; Remus et al., 2014) have confirmed that meta-analysis is a powerful tool to provide a solid scientific basis for quantifying the results. Therefore, to draw general conclusions, meta-analysis has been conducted to quantify the dose-response of broiler chickens to light intensity.

## MATERIALS AND METHODS

### *Literature Search Strategy*

A simple search strategy, implemented in May 2017, was conducted in Scopus (https://www.scopus.com/; 1998–2017) and Web of Science (http://webofknowledge.com/WOS; 1998–2017). The algorithm included three broad outcome, light*OR photoperiod* OR illumination*, and five broad terms: Chick* OR Chicken*OR Poultry* OR Broiler* OR Gallus*.

### *Eligibility Criteria and Literature Selection*

Assessment of literature eligibility for the meta-analysis was independently selected by two evaluators (Figure 1). Articles were included or excluded in present study based on a series of criteria developed by the authors. The main criteria used for literature selection were the following: full manuscripts of peer-reviewed journals, evaluation in broiler chickens; randomization of study groups; artificial light source; reported the intensity of light sources; the paper obtained sufficient data to determine the effect size for performance parameters (e.g., the number of broilers in each treatment, production performance, processing characteristics, metabolic indicators, and welfare indicators, a measure of variance (SE or SD) or *P* value for each effect estimate or treatment and control comparisons). Effect size is the weighted difference between treatment and control groups means using the SEs and broiler numbers of control and treatment groups. We comprehensively selected the peer-reviewed literature for publications (Barwick, 1962; Skoglund and Palmer, 1962; Dorminey and Nakaue, 1977; Newberry et al., 1987; Deaton et al., 1988; Newberry et al., 1988; Charles et al., 1992; Downs and Lien, 2006; Kristensen et al., 2006; Lien et al., 2007, 2008, 2009; Miller et al., 2007;

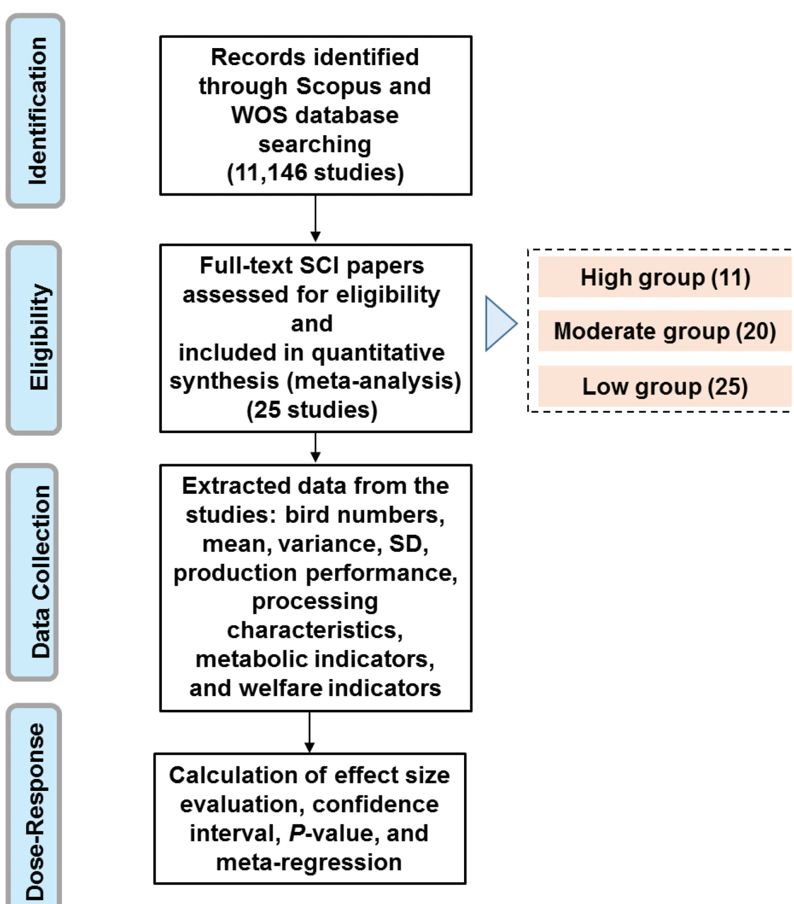


**Figure 1.** The number of studies included in quantitative analyses and statistical analyses process conducted to evaluate dose-response of light in broiler chickens in the present study.

Olanrewaju and Thaxton, 2008; Blatchford et al., 2009; Deep and Schwean, 2010; Olanrewaju, 2010; Ahmad et al., 2011; Olanrewaju et al., 2011, 2013, 2014a, 2014b, 2016; Blatchford et al., 2012; Deep et al., 2013) investigating the effects of light intensity on the responses of broiler chickens (11,146 observations).

### *Data Collection*

The extracted data included light intensity, number of broiler chickens in treatment groups, production performance, processing characteristics, metabolic characteristics, welfare performance, behavior evaluation, and measures of variance of responses (SE or SD), and *P* values (Figure 1). Other information extracted from relevant papers were journal name, publication year, authors, and length of experimental period. In cases where data were presented only in figures, values were extracted using Plot Digitizer (http://plotdigitizer.sourceforge.net/).

The light intensity levels extracted from those published studies were divided into three groups: 1) high level of light intensity treatment ($n$ = 11, 30−200 lux, high group), 2) moderate level of light intensity treatment ($n$ =25, 10−30 lux, moderate group), and 3) low level of light treatment as control group ($n$ = 25, <5 lux, low group).

Relative information was extracted from each light treatment in each study, including broiler chickens performance parameters, and the detailed value of light intensity. In addition, the performance parameters were also extracted, including production performance (BW [$n$ = 22], FI [$n$ = 8], FCR [$n$ = 16], mortality [$n$ = 11], and uniformity [$n$ = 6]), processing characteristics (carcass weight [$n$ = 8], breast weight [$n$ = 8], tender weight [$n$ = 7], fillet weight [$n$ = 6], abdominal fat weight [$n$ = 9], wing weight [$n$ = 6], leg weight [$n$ = 7], thigh weight [$n$ = 2], thigh meat weight [$n$ = 2], thigh bone weight [$n$ = 2], drum weight [$n$ = 2], drum meat weight [$n$ = 2], and drum bone weight [$n$ = 2]), metabolic characteristics ($Ca^{2+}$ [$n$ = 2], $HCO^{3-}$ [$n$ = 2], $Cl^-$ [$n$ = 4], pH [$n$ = 4], $pO_2$ [$n$ = 4], $pCO_2$ [$n$ = 4], GLU [$n$ = 3], corticosterone [$n$ = 3], total protein [$n$ = 2], T3 [$n$ = 2], T4 [$n$ = 2], and immune response [$n$ = 2]), and welfare performance (gait score [$n$ = 4], footpad score [$n$ = 3], activity [$n$ = 4], eye weight [$n$ = 7], and corneal diameter [$n$ = 4]).

### *Statistical Analysis*

Data extracted from included papers were exported into MS Excel 2013 spreadsheets and formatted for meta-analysis. Many literature reported multiple treatment-control comparisons, which were extracted as unique trials for meta-analysis. Stata was used (version 12; StataCorp, College Station, TX) to analyze performance outcomes by weighted mean difference (WMD), which was also called effect size analysis, in which the difference between treatment and control groups means was weighted using the SEs of control and treatment groups (Figure 1).

$$\mathrm{WMD} = \sum_{i=1}^{m} \left(X_t - X_c\right) \quad (1)$$

in which $X_t$ and $X_c$ represent mean for the treatment group (high group and moderate group) and the control group, respectively, and ω represents a weighting factor estimated by equation 2:

$$\omega = 1/v \quad (2)$$

in which $v$ is the variance. By giving greater weight (ω) to studies whose estimates have greater precision (lower $v$), the precision of the pooled estimate and the statistical power increased. The variance ($v$) is calculated by equation 3:

$$v = \frac{SD_t^2}{n_t X_t^2} + \frac{SD_c^2}{n_c X_c^2} \quad (3)$$

in which $SD_t$ and $SD_c$ are the SD for the treatment group and the control group, respectively, and $n_t$ and $n_c$ are the sample sizes for the treatment group and the control group, respectively.

If the selected literature reported separate estimates of measure of variance (SE or SD) for each group, these were recorded as such. If the selected literature reported a common SE or SD, the estimate was used for both control and treatment groups.

Based on the assumption that significant heterogeneity existed among the experiments, random-effects models were conducted for each performance outcome to estimate the effect size, 95% confidence interval (CI), and statistical significance of WMD. A positive value of WMD indicates that the treatment group provides a greater value than the control group. The pooled effect size was considered significant if it's associated 95% CI (upper and lower 95% CI) did not overlap with zero and randomization tests yielded *P* values <0.05.

Meta-regression is applied to test whether evidence exists of different effects in different subgroups of trials using the individual WMD for each experiment as the indicator and the associated SE as the measure of variance. The random-effects

meta-regression with one covariate and additional trial variance is given by the following equation, which is the regression of Y on X with weight $\omega = 1/v$:

$$Y \sim N(\alpha + \beta X, v) \quad (4)$$

where Y is the performance parameters of broilers, X is the value of trial-specific covariate, $v$ is the variance of effect size within trial, β (slope) represents the change in the performance parameters of broilers per unit of change in the covariate X, and α (intercept; i.e., $\alpha = 0$; Y | X), is the performance parameters of broilers if the covariate is equal to zero. Meta-regression analysis was conducted using light intensity as covariate and the BW as the parameter of interest. Data were screened for plausible linear relationship between light intensity and the BW. Based on the meta-regression, the quantificational relationship between light and broiler could be established, which indicates the relationship between the light dose and the quantity biological effects occurring in broilers.

The effects of light intensity on performance of broiler chickens were displayed in forest plots, using the estimated WMD of fat products (Y). Points to the left of the line represent a reduction in the parameter (Y), whereas points to the right of the line indicate an increase in the parameter. Each square represents the mean effect size for that study. The upper and lower limits of the line connected to the square represent the upper and lower 95% CI for the effect size. For ease of interpretation, all WMD were transformed and reported as percentage change in performance parameters for the treatment group relative to the control group.

## RESULTS

### *Production*

Significant effects were found in the BW in the broiler chickens raised with greater level of light intensity (>10 lux) in contrast with those raised with light intensity of 0.5 lux (2.08%; 95% CI: 0.76 to 3.40; $P = 0.002$; Figure 2) and 0.2 lux (3.18%; 95% CI: 1.80 to 4.55; $P < 0.001$; Figure 2). However, greater level of light intensity (>10 lux) had no statistically significant effect on the BW of the broiler chickens, when compared with 1 lux (0.10%; 95% CI: −0.44 to 0.63; $P = 0.737$; Figure 2) and 5 lux (0.5%; 95% CI: −0.02 to 1.02; $P = 0.059$; Figure 2), regardless of the broiler chickens raised

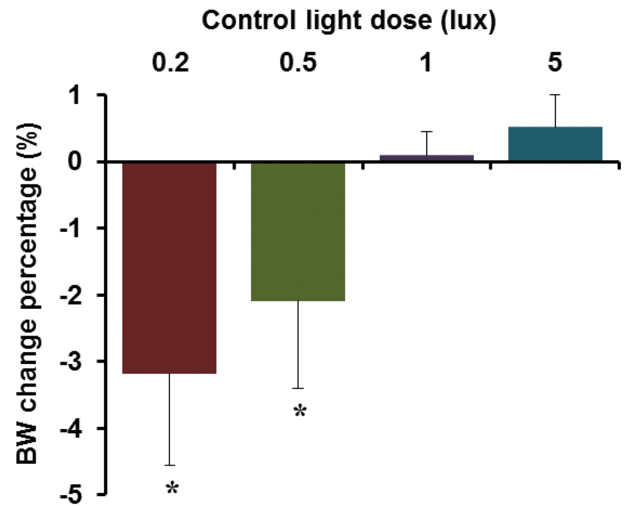


**Figure 2.** BW change percentage of broiler chickens reared under various levels of control light intensity (0.2, 0.5, 1, and 5 lux) compared with greater level of light intensity (>10 lux). Data are expressed as means ± 95% confidence interval. *$P < 0.05$.

with moderate level ([moderate group]; 0.4%; 95% CI: −0.54 to 0.62; $P = 0.892$; Figure 3) or high level ([high group]; −0.78%; 95% CI: −1.15 to 0.42; $P = 0.074$; Figure 3). Further, meta-regression showed a negative linear relationship between and the BW change percentage and the light intensity ranging from 30 to 200 lux ($P = 0.047$; Figure 4).

No overall effects were observed in the FI of broiler chickens raised with greater level of light intensity (>10 lux) (0.04%; 95% CI: −0.39 to 0.47; $P = 0.857$) in comparison with those raised with lower light intensity (control group; <5 lux). However, greater level of light intensity (>10 lux) increased the FI by 2.80% (95% CI: 3.09 to 2.51; $P < 0.001$) in contrast with those raised in control group (<5 lux; Figure 3). Further analysis indicated that the FI increase in broiler chickens varied with

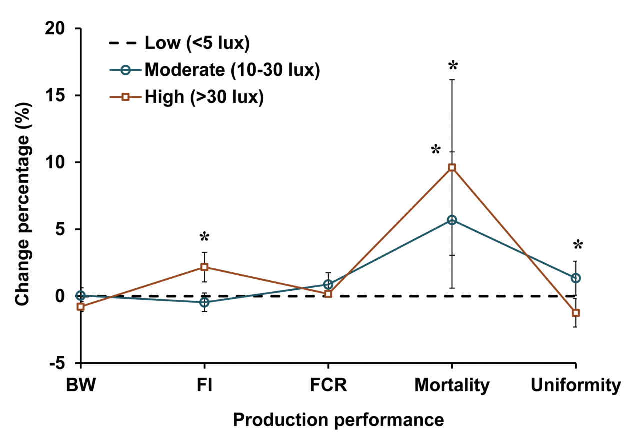


**Figure 3.** The BW, FI, FCR, mortality, and uniformity change percentage of broiler chickens raised with greater level of light intensity (>10 lux) in contrast with lower level of light intensity (<5 lux). Data are expressed as means ± 95% confidence interval and SE. *$P < 0.05$.

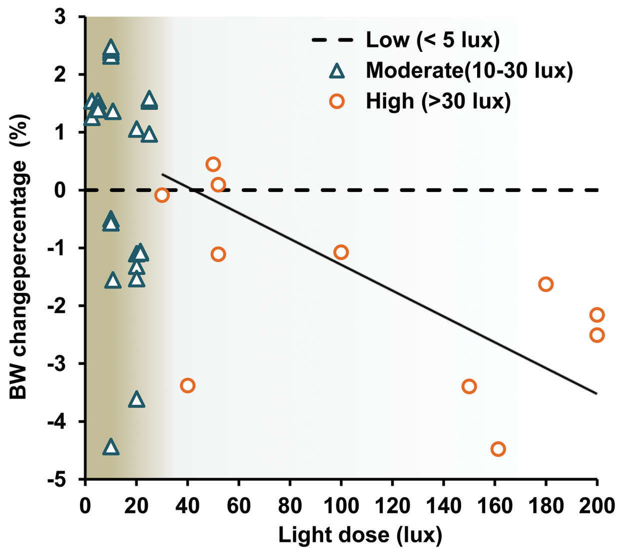


**Figure 4.** The negative linear relationship between BW change of broiler chickens and light intensity ranging from 30 to 200 lux.

the level of the light intensity. The FI of broiler chickens raised with high level of light intensity (high group) was significantly increased by 2.17 (95% CI: 1.06 to 3.27; $P = 0.011$; Figure 3), whereas broiler chickens raised with moderate level of light intensity (moderate group; −0.46%; 95% CI: −1.16 to 0.23; $P = 0.19$) showed no significant difference in FI (Figure 3). Moreover, meta-regression showed a negative linear relationship between the FI change percentage and the light intensity ranging from 10 − 30 lux (moderate group; $P = 0.037$; Figure 5) and a positive linear relationship between the FI change percentage and the light intensity ranging from 30 to 200 lux (high group; $P = 0.054$; Figure 5), suggesting that moderate level of light intensity depressed the FI of broiler chickens, whereas high level of light intensity promoted the FI of broiler chickens.

For the FCR, no significant effects were observed in broiler chickens raised with greater level of light intensity (>10 lux) in contrast with those raised in control group (<5 lux; 1.03%; 95% CI: −0.22 to 2.28; $P = 0.076$): nor moderate group (1.24% [95% CI: 0.40 to 2.15; $P = 0.45$] or high group (0.87% [95% CI: 0.66 to 1.07; $P = 0.89$]; Figure 3). However, meta-regression showed a quadratic relationship between the FCR change percentage and the light intensity ranging from 50 to 180 lux ($R^2 = 0.95$; Figure 6).

For mortality, the average mortality of broiler chickens raised with greater light intensity (>10 lux) was significantly increased by 7.47% (95% CI: 3.63 to 11.29; $P < 0.001$; Figure 3) in comparison with those raised in control group (<5 lux). Further analysis indicated that the mortality of broiler chickens raised with high level and moderate level of light intensity was significantly increased by 5.69% (95% CI: 0.60 to 10.77; $P = 0.028$) and 9.61% (95% CI: 3.06 to 16.16; $P = 0.004$), respectively (Figure 3). Further, meta-regression showed a positive linear relationship between the mortality change percentage and the light intensity ranging from 30 to 200 lux (high group; $P = 0.03$; Figure 7), suggesting that high level of light intensity increased the mortality of broiler chickens.

The uniformity increase in broiler chickens was dependent on the level of the light intensity. In contrast to control group (<5 lux), high level of light intensity was significantly decreased the uniformity

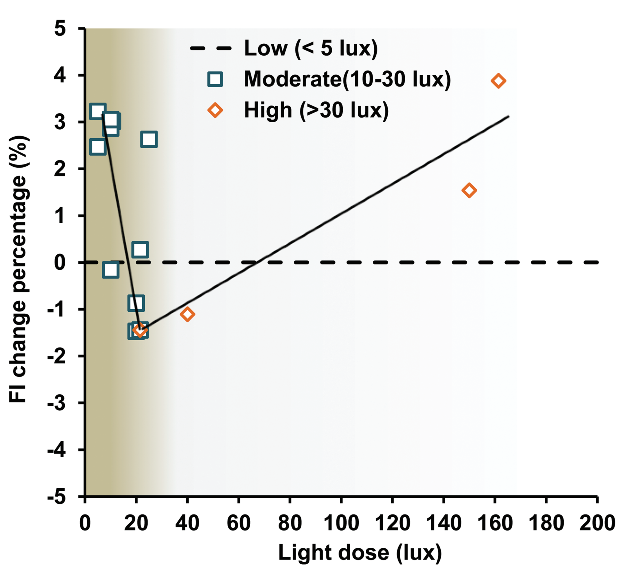


**Figure 5.** The negative linear relationship and positive between BW change of broiler chickens and light intensity ranging from 5−30 lux to 30−200 lux.

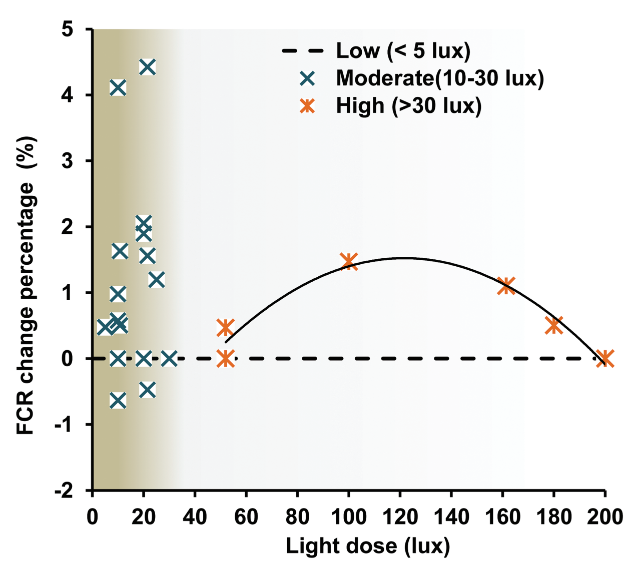


**Figure 6.** The quadratic relationship between BW change of broiler chickens and light intensity ranging from 50 to 180 lux.

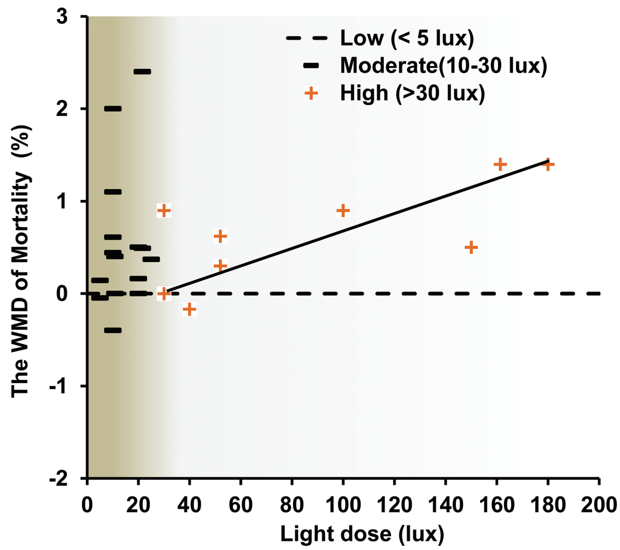


**Figure 7.** The positive linear relationship between BW change of broiler chickens and light intensity ranging from 30 to 200 lux.

by −1.25% (high group; 95% CI: −2.31 to −0.19; *P* = 0.021) (Figure 3). However, moderate level of light intensity could increase the uniformity by 1.34% (moderate group: 95% CI: 0.07 to 2.61; *P* = 0.039), compared with light intensity <5 lux.

### *Processing Characteristics*

For processing characteristics, no significant effects were observed in carcass weight (0.29%; 95% CI: −0.14 to 0.73; *P* = 0.189), tender weight (0.27%; 95% CI: −0.42 to 0.97; *P* = 0.436), thigh weight (−0.67%; 95% CI: −1.67 to 0.33; *P* = 0.19), thigh meat weight (−0.14%; 95% CI: −0.96 to 0.68; *P* = 0.733), thigh bone weight (−0.24%; 95% CI: −2.14 to 1.66; *P* = 0.805), and drum bone weight (−0.48%; 95% CI: −2.34 to 1.37; *P* = 0.607) in broiler chickens raised with greater level of light intensity (>10 lux) in contrast with those raised in control group (<5 lux) (Figure 8). However, significant effects were found in breast weight (4.81%; 95% CI: 1.46 to 8.17; *P* = 0.005), fillet weight (2.17%; 95% CI: 1.10 to 3.24; *P* < 0.001), abdominal fat weight (2.45%; 95% CI: 0.63 to 4.28; *P* = 0.008), wing weight (−2.21%; 95% CI: −2.60 to −1.84; *P* < 0.001), leg weight (−2.63%; 95% CI: −4.91 to −0.37; *P* = 0.023), drum weight (−1.01%; 95% CI: −1.58 to −0.44; *P* < 0.001), and drum meat weight (−1.62%; 95% CI: −2.91 to −0.32; *P* = 0.014) in broiler chickens raised with greater level of light intensity in contrast with those raised in control group (<5 lux) (Figure 8).

### *Metabolic Characteristics*

No significant difference was observed in pH (−0.06%; 95% CI: −0.11 to 0.014; *P* = 0.708), $pCO_2$ (0.14%; 95% CI: −0.20 to 0.407; *P* = 0.407), GLU (2.57%; 95% CI: −1.71 to 6.84; *P* = 0.239), corticosterone (1.01%; 95% CI: −7.60 to 9.61; *P* = 0.818), total protein (0.122%; 95% CI: −1.01 to 1.28; *P* = 0.891), T4 (−2.00%; 95% CI: −4.40 to 0.40; *P* = 0.099), and immune response (1.07%; 95% CI: −2.60 to 4.76; *P* = 0.569) of broiler chickens raised with greater level of light intensity (>10 lux), in contrast with control group (<5 lux) (Figure 9). However, greater level of light intensity (>10 lux)

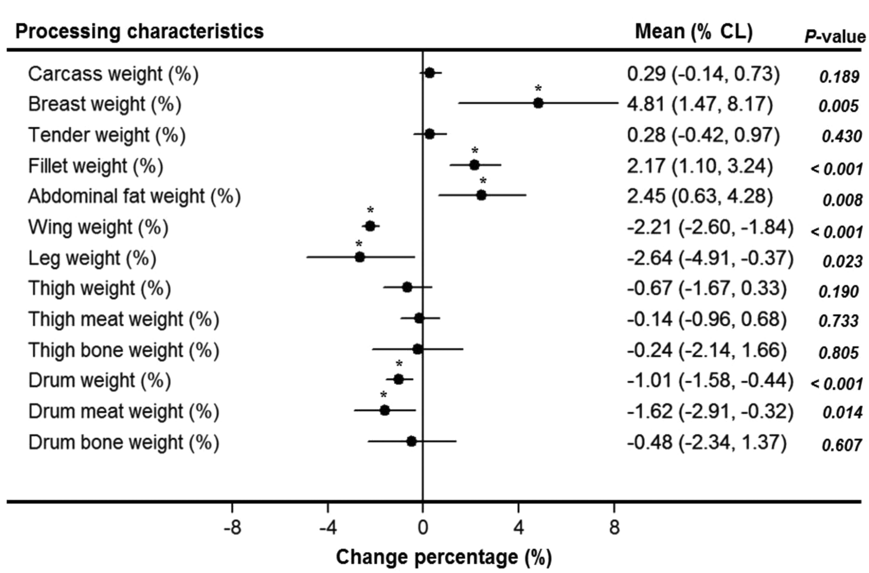


**Figure 8.** The processing characteristics change percentage of broiler chickens raised with greater level of light intensity (>10 lux) in contrast with lower level of light intensity (<5 lux), including carcass weight, breast weight, tender weight, fillet weight, abdominal fat weight, wing weight, leg weight, thigh weight, thigh meat weight, thigh bone weight, drum weight, drum meat weight, and drum bone weight. Data are expressed as means ± 95% confidence interval and SE. **P* < 0.05.

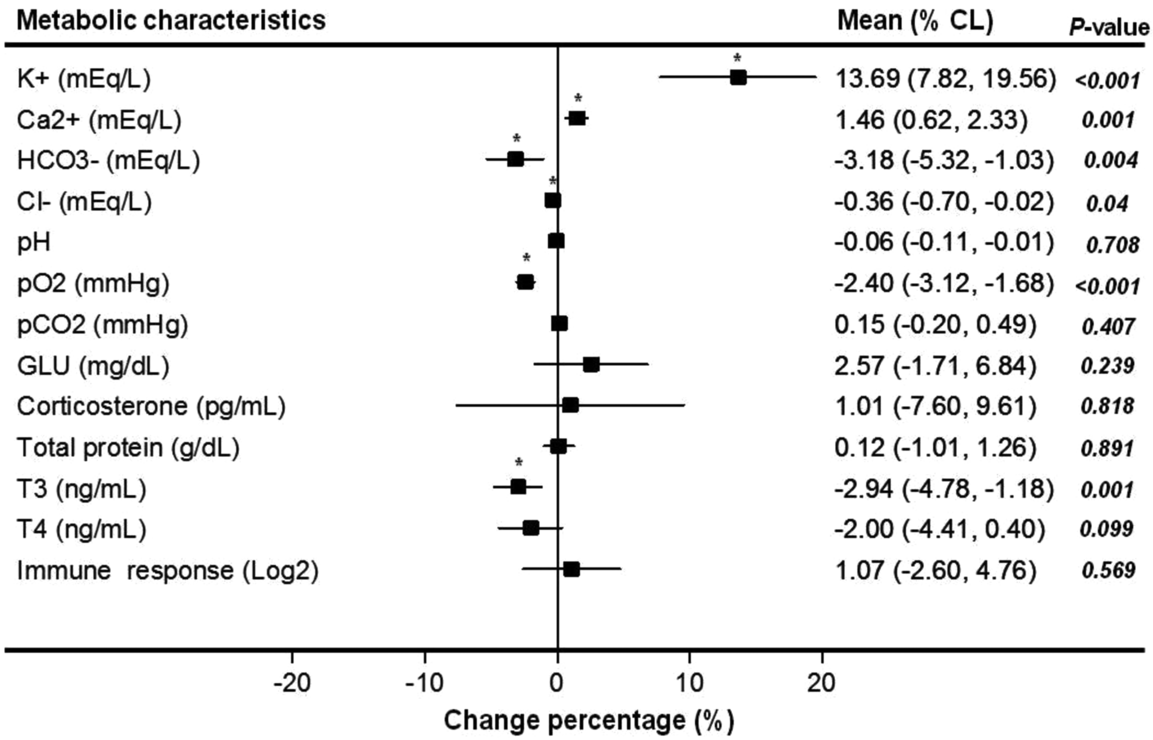


**Figure 9.** The metabolic characteristics change percentage of broiler chickens raised with greater level of light intensity (>10 lux) in contrast with lower level of light intensity (<5 lux), including $Ca^{2+}$, $HCO^{3-}$, $Cl^{-}$, pH, $pO_2$, $pCO_2$, GLU, corticosterone, total protein, T3, T4, and immune response. Data are expressed as means ± 95% confidence interval and SE. $^*P < 0.05$.

caused a positive response to $K^+$ (13.69%; 95% CI: 7.82 to 19.56; $P < 0.001$), and $Ca^{2+}$ (1.46%; 95% CI: 0.62 to 2.33; $P = 0.001$), whereas greater level of light intensity (>10 lux) caused a negative response to $HCO_3^-$ (−3.18%; 95% CI: −5.32 to −1.03; $P = 0.004$), $Cl^-$ (−0.36%; 95% CI:−0.70 to −0.02; $P = 0.04$), and T3 (−2.94%; 95% CI:−4.78 to −1.18; $P = 0.001$) in contrast with those raised in control group (<5 lux) (Figure 9).

### *Welfare*

The gait scores 0 and gait scores 2 of broiler chickens raised with greater level of light intensity (> 10 lux) was significantly increased by 18.77% (95% CI: 10.25 to 27.29; $P < 0.001$) and decreased by −7.04% (95% CI: −10.10 to −3.98; $P < 0.001$), whereas greater level of light intensity (> 10 lux) showed no significant difference in other gait scores (gait scores 1: 3.77% [95% CI: −22.89 to 30.44; $P = 0.781$]; gait scores 3: −18.51% [95% CI: −38.78 to −1.74; $P = 0.073$]) (Figure 10).

Greater level of light intensity (>10 lux) exhibited a significant effect on the footpad score (footpad score 1: 9.11% [95% CI: 6.11 to 12.10; $P < 0.001$]; footpad score 2: −35.27% [95% CI: −46.88 to −23.66; $P < 0.001$]) (Figure 10). The same situation was also observed for eye weight (−7.36%; 95% CI: −7.86 to −6.89; $P = 0.005$) and corneal diameter of eye (−1.23%; 95% CI: −2.04 to −0.44; $P = 0.002$) (Figure 10) in contrast with those raised in control group (<5 lux). Moreover, greater level of light intensity (>10 lux) further to decrease the corneal diameter of eye by −4.18% (95% CI: −7.06 to −1.30; $P = 0.005$) in contrast with those raised in control group (<5 lux).

In addition, the activity was significantly increased by 20.22% (95% CI: 14.13 to 26.31; $P < 0.001$), in broiler chickens raised with greater level of light intensity (>10 lux) in comparison with those raised in control group (<5 lux) (Figure 10).

## DISCUSSION

Meta-analysis is the reanalysis of data by compiling the data from all relevant publications for the purpose of quantitatively quantifying the response of broiler chickens to various level of light intensity. Present study used a meta-analysis to model the dose-response of the broiler chickens to various level of light intensity. The results indicated that the effect sizes of the BW response to various light intensity were dependent on the minimum light intensity used in the comparison. When compared with light intensity >10 lux, 0.2 lux, or 0.5 lux significantly decreased the BW of

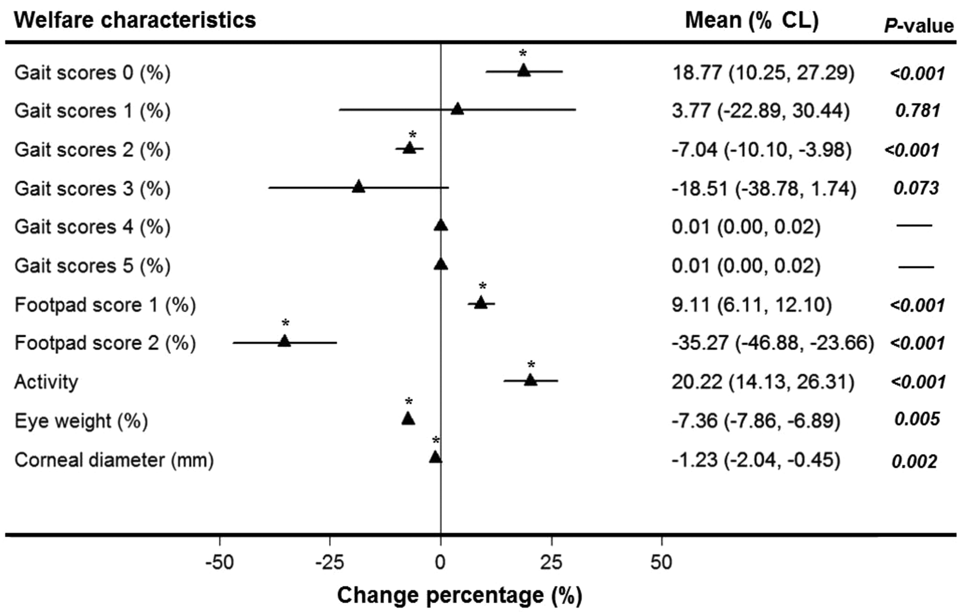


**Figure 10.** The welfare performance change percentage of broiler chickens raised with greater level of light intensity (>10 lux) in contrast with lower level of light intensity (<5 lux), including gait score, footpad score, activity, eye weight, and corneal diameter. Data are expressed as means ± 95% confidence interval and SE. **P* < 0.05.

broiler chickens, whereas 1 lux of light intensity showed no significant difference in the BW of broiler chickens. Therefore, 1 lux during grow-out period should be regarded as the minimum light intensity to reduce the BW loss of broiler chickens. However, some welfare problem could be caused by the 1 lux of light intensity. For example, the 1 lux of light intensity could increase the corneal diameter of eye, whereas no negative effects were found in 5 lux.

In general, greater level of light intensity (>10 lux) have no significant effect on BW, FI, and FCR, whereas mortality, and uniformity were significantly increased by greater level of light intensity (>10 lux) in contrast with lower level of light intensity (<5 lux). Moreover, regression showed that the light intensity ranging from 30 to 200 lux was negatively related to BW and FI change of broiler chickens, whereas a quadratic relationship was observed between the FCR change percentage and the light intensity ranging from 50 to 180 lux. The mechanisms through which light might affect the growth of broiler chickens were not fully understood. However, several pathways could be concluded from the previous studies. Light signals were perceived by the avian retinas and the suprachiasmatic nucleus and accompanied by many biological responses (Yang et al., 2016b), including immune response (Liu et al., 2011), mucosal mechanical barriers (Xie et al., 2008), and hormones serotonin (Cassone et al., 2009). Indeed, the present study found that greater level of light intensity (>10 lux) caused a significant response to T3 level in contrast with those raised with lower level of light intensity (5 lux). Besides the above pathways, the present study also found another potential pathway through which the diurnal physiological rhythms to affect the growth of broiler chickens. On one hand, 1 lux in scoto-phase and 5 lux in photo-phase might not be sufficient to entrain diurnal behavioral and physiological rhythms, while even 1 lux was capable of inducing strong melatonin and behavioral rhythms when the dark period light intensity was 0 lux (Deep et al., 2012). Disruption of diurnal physiological rhythms can result in abnormal BW (Kooijman et al., 2015) and ocular growth (Rada and Wiechmann, 2006). Therefore, disrupted diurnal rhythms might be responsible for the damaged ocular size and loss of BW of broiler chickens raised with light intensity less than 1 lux. On the other hand, as described above, the lower light intensity can increase the eye dimension and eye weight. When the broiler chicken was exposed to the poor light environment, the corneal diameter must be enlarged to get more light energy to find the feed and adapt to the environment. This was also confirmed by the previous study, which demonstrated that the abrupt decrease in light intensity resulted in broiler chickens not finding feed and water for 1 wk. As soon as light intensity was increased, chicks ate and drank frantically.

Greater level of light intensity had no statistically significant effect on the BW of the broiler

chickens, regardless of the broiler chickens raised with moderate level (10−30 lux) or high level of light intensity (30−200 lux). The same situation was also observed in the FCR in the broiler chickens. However, the high level of light intensity increased the FI of the broiler chickens. This phenomenon may be related to the different activity expression caused by various level of light intensity. The present study found that the averaged activity was significantly increased by 20.22% (95% CI: 14.13 to 26.31; $P < 0.001$), in broiler chickens raised with greater level of light intensity (>10 lux) in comparison with those raised with lower level of light intensity (5 lux), which suggest that though broiler chickens raised with greater level of light intensity ate more than those raised with lower level of light intensity, a considerable part of intake energy was useless and converted into activity expression. In addition, the present study indicated that lower level of light intensity significantly decreased the gait score (2) and footpad score (2).The greater occurrence of erosions in broiler chickens raised with lower level of light intensity may be related to their decreased activity, creating longer contact time with the litter (Hester, 1994).

The metabolic indicator T3 acts on different target tissues and stimulates oxygen utilization in the cells of the body. In the present study, we found a decreased of T3 companioned with a decreased of blood oxygen. In addition, T3 hormones increased the basal metabolic rate to make more glucose available to cells to stimulate protein synthesis, increase lipid metabolism, and simulate cardiac and neural functions (Todini et al., 2007). Moreover, plasma thyroid hormone concentrations are correlated with FI in broiler chickens. The previous study suggested that broiler chickens were significantly heavier and ate more when raised with long light periods (≤22 and 20 h) rather than shorter light periods (Yang et al., 2015). However, though greater level of light intensity could stimulate broiler chickens eat more, a reduction of T3 hormones was observed in the present study.

## LITERATURE CITED


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