ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 10 (12): 921-926, 2011
ISSN 1682-8356
Asian Network for Scientific Information, 2011

Effect of Varying Light Intensity on Growth Performance and Carcass Characteristics of Broiler Chickens Grown to Heavy Weights

H.A. Olanrewaju, J.L. Purswell, S.D. Collier and S.L. Branton
[2]USDA, Agricultural Research Service, Poultry Research Unit, P.O. Box 5367,
Mississippi State, MS 39762-5367, USA

Abstract: This study investigated the effects of varying levels of light intensities (25, 10, 5, 2.5 and 0.2 lx) on growth performance and carcass characteristics of broiler chickens grown to heavy weights. Four identical trials were conducted with two replications per trial. In each trial, 600 1-d-old Ross 308 chicks were randomly distributed into 10 environmentally controlled chambers (30 male and 30 female chicks/chamber). Each chamber was randomly assigned one of five light intensities from d 22 to 56. Feed and water were provided *ad libitum*. Birds were provided a four phase-feeding program (starter, grower, finisher and withdrawal). Birds and feed were weighed on 0, 14, 21, 28, 42 and 56 d of age for growth performance. Also at 56 d of age, 20 birds (10 males and 10 females) from each chamber were randomly selected and processed to determine weights and yields. There was no effect of light intensity on growth performance, except significant ($p \leq 0.054$) difference in FCR on 28 d of age under 25 and 5 lx. Broilers reared under 5 lx had significantly higher live weight ($p \leq 0.046$) and carcass weight ($p \leq 0.026$) in comparison with 0.2 and 25 lx. Birds reared under 5 and 10 lx had significantly higher fillet ($p \leq 0.025$) and tender ($p \leq 0.034$) weights when compared with birds reared under 0.2 and 25 lx. Mortality was not affected by light intensity treatments. In addition, plasma corticosterone concentrations were not statistically affected by light intensity, suggesting an absence of physiological stress. These results indicate that the range of light intensity used in this study has no effect on most production performances of broilers reared up to 56 d of age, but did affect some carcass characteristics. Therefore, using lower lighting intensity may be beneficial to commercial poultry facilities that are using low lighting environment to reduce hyperactivity, pecking damage and energy costs without physiological stress effects on broiler welfare.

Key words: Light-intensity, welfare, growth, meat yield, broiler

INTRODUCTION

Management of lighting programs is an approach used to reduce the incidence of metabolic and skeletal disorders in broiler chickens. Light as an environmental factor consists of three different aspects: intensity, photoperiod (duration) and wavelength (color). Light intensity, color and the photoperiodic regime can affect the physical activity of broilers (Lewis and Morris, 1998). These lighting programs have a central purpose of slowing the early growth rate of broilers which allows birds to achieve physiological maturity prior to maximal rate of muscle mass accretion. Most of the research involving light management has focused on photoperiods (Renden *et al*., 1996; Lewis *et al*., 2009) light-intensity (Lien *et al*., 2008; Blatchford *et al*., 2009; Deep *et al*., 2010) or light-intensity in combination with other environmental factors (Lien *et al*., 2007; Olanrewaju *et al*., 2008; 2010). Our review article on lighting reported that light intensity influences bird activity, behavior, physiology, immune response, growth rate and has been used to alleviate mortality issues related to metabolic disease (Olanrewaju *et al*., 2006). It has been shown that high light intensity increases activities, while low light intensity reduces hyperactivity, minimizes skin scratches and limits early rapid growth resulting in decreased mortality and feed consumption and improved feed conversion (Gordon, 1994; Buyse *et al*., 1996; Manser, 1996).

Kristensen *et al*. (2006a) observed an increase in BW of broilers due to light intensity ranging from 5.4 to 6.45 lx and decrease in BW under light intensity ranging from 107.6 to 124.7 lx. However, no differences in BW of broilers reared under intensities of 0.1 to 107.6 lx and 6.45 to 194 lx (Newberry *et al*., 1986; 1988; Rahimi *et al*., 2005), It has been shown that Feed Intake (FI), Feed Conversion Ratio (FCR), as well as growth are maximal for broilers (2.5 kg) that are reared in lower light intensity, nearly continuous illumination or under alternative lighting schedules (Scheideler, 1990; Clark and Classen, 1995). Higher FI at 3.2 lx compared to that occurring at 0.7, 16, or 50 lx has been reported by Wathes *et al*. (1982). In addition, higher FI has been reported in broilers reared under 2.7 lx compared to 21.5 lx (Downs *et al*., 2006). In contrast, a transitory lower in

Corresponding Author: Hammed A. Olanrewaju, USDA-ARS Poultry Research Unit, P.O. Box 5367, Mississippi State, MS 39762

FI from 2 to 3 week was observed in broilers reared under 1.75 vs. 10.75 lx (Lien *et al*., 2007). It has also been suggested that lower intensities may improve FCR because of a reduction in activity (Downs *et al*., 2006). However, it has been reported that increasing light intensity from 5 to 51 lx has no effect on FCR in broilers (Buyse *et al*., 1996). Similarly, Charles *et al*. (1992) reported no effect of light intensity of 6 to 151 lx on FCR. Furthermore, Lien *et al*. (2008) reported that FCR is not affected by providing 1.75 vs. 162 lx. Most reports have shown no effect of intensity on mortality (Downs *et al*., 2006; Lien *et al*., 2008; Deep *et al*., 2010), but an increase in mortality due to light intensity ranging from 6.45 to 194 lx has been reported by Newberry *et al*. (1988). Lien *et al*. (2007) stated that mortality differences attributable to lighting programs are often not observed unless levels approach 10%. Deep *et al*. (2010) recently reported that light intensities (1, 10, 20 and 40 lx) did not affect broiler production and mortality, but affected carcass characteristics.

Results from most of the studies are inconsistent. Furthermore, most studies have not evaluated gradient levels of light intensity at ranges typically used in commercial practice with modern early- and late-developing broiler production systems designed to optimum growth and meat yield. To address this knowledge gap, the present study is aimed at investigating the effects of varying light intensity on growth performance, processing yield and carcass quality of modern heavy broiler chickens.

MATERIALS AND METHODS

Bird husbandry: A randomized complete block experimental design was utilized in the 4 trials conducted for this study. In each of 4 trials with 2 replicates per trial, 600 1-d-old Ross 308 chicks were purchased from a commercial hatchery (Aviagen, Inc., Huntsville, AL) and upon arrival, the chicks were sexed and group-weighed. All procedures relating to the use of live birds were approved by USDA-Agricultural Research Service Animal Care Committee. Chicks were vaccinated for Marek's, Newcastle and infectious bronchitis diseases at the hatchery. At 12 d of age, birds received a Gumboro vaccination via water administration. Chicks were randomly distributed into 10 environmentally controlled chambers (30 males and 30 females chicks/chamber). Each chamber was randomly assigned one of five light intensities (25, 10, 5, 2.5 and 0.2 lx). Each environmentally controlled chamber had a floor area of 6 m^2 (2.3 m width x 2.6 m depth) with a chamber volume of 15.3 m^3 (2.5 m height). Each chamber contained 7.62 cm depth of new pine shavings, tube feeders and a 7-nipple watering system. The chicks remained in their respective chambers from 1-d-old throughout the experimental period (56 d of age). Birds were provided a 4-phase feeding program (starter: 1 to 14 d; grower: 15 to 28 d; finisher: 29 to 42 d; withdrawal: 43 to 56 d). Diets were formulated to meet or exceed NRC (1994) nutrient recommendations. Starter feed was provided as crumbles and subsequent feeds were provided as whole pellets. Feed and water were offered *ad libitum*. Temperature and relative humidity were the same across all treatments. Chamber temperatures were 32°C at the initiation of experimentation and reduced by 2°C at weekly intervals until 15.6°C on d 49 of age with 50% RH.

Experimental treatments: Light intensity treatments commenced on d 22. Lighting in each chamber was set to a light intensity typical of those found in commercial production (25, 10, 5, 2.5 and 0.2 lx). Each chamber was equipped with incandescent bulbs, which peak in the red portion of the visible spectrum (750 nm) and were controlled by a dimmer and digital timer for each chamber, typical of that used in commercial housing. Light intensity settings were verified at bird level using a photometric sensor with NIST-traceable calibration (403125, Extech Instruments, Waltham, Mass) for each intensity and adjusted weekly when necessary. The light fittings and tubes were cleaned weekly in order to minimize dust build-up, which would otherwise reduce the intensity. Photoperiod in each chamber consisted of continuous lighting (24L:0D) at 20 lx from placement to 7 d, 20L:4D at 10 lx from 8 to 21 d, 20L:4D from 23 through 53 d and 24L:0D from 54 to 56 d of age.

Measurements: Birds and feed were weighed on 0, 14, 21, 28, 42 and 56 d of age for the computation of growth rate and feed consumption. The incidence of mortality was recorded daily and feed conversion ratio was corrected for mortality. Necropsies and cause of death were performed on all birds that died during the trials.

Blood collections and chemical analyses: On d 55 (d before processing) of each trial, blood samples were collected between 0800 and 0900 h from wing veins of 6 (3 male and 3 female chicks/chamber) randomly selected birds from each chamber and the birds were then returned to the appropriate chambers by using our standard handling procedure (Olanrewaju *et al*., 2008). In addition, unnecessary discomfort to the birds was avoided by using proper housing and handling techniques, as described by the NRC (1996). Blood samples were collected directly into heparinized (50 IU/mL) monovette syringes. All bleedings were completed within 45 s after birds were caught. After all birds were bled, the iced samples were transferred to the laboratory, centrifuged at 4,000 x g for 20 min at 4°C. Two mL of each of the plasma samples from the syringes were stored in 2.0 mL graduated tubes at -20°C for later Corticosterone (CS) analyses. Plasma samples were removed from the freezer, thawed and

analyzed for CS using a universal microplate spectrophotometer (Bio-Tek Instruments Inc., Winooski, VT) with ELISA reagent assay test kits from Assay Designs (EIA-CS Kit, Assay Designs Inc., Ann Arbor, MI), according to the manufacturer's instructions. We have previously used this methodology of the kit as it relates to the manufacturer's instructions in broilers (Olanrewaju *et al*., 2008; 2010).

Growth performance and carcass characteristics: On d 56 of each trial, 20 (10 males/10 females) birds per chamber irrespective of their body weights were randomly selected for processing, weighed and subjected to a 12-h feed withdrawal period. This weight was used to calculate carcass and breast meat yield. Thereafter, the birds were placed in coops and transported to the processing plant. Birds were electrically stunned (5 s; 12.5 V), bled (80 s), scalded (150 s and 53°C) and mechanically picked (35 s) and eviscerated. Whole carcass (without neck, giblets, abdominal fat pad) and abdominal fat were weighed. Carcasses were split into front and back halves and placed on ice for 4 h. Afterward, the front halves were deboned to obtain weights of skinless, boneless, breast fillet (*pectoralis major* muscle) and breast tender (*pectoralis minor* muscle). Carcass yield, abdominal fat pad and total breast meat yields (sum of *pectoralis major* and *minor* muscles) were determined from live weights (post-feed withdrawal) of the broilers selected for processing.

Statistical analysis: A randomized complete block design was used in this study with two replications per trial. Analyses were conducted using ANOVA followed by least significant difference test comparing treatment means by using the MIXED procedure of SAS software (SAS Institute, 2008). Regression analysis was also conducted to examine and compare both pre- and post-treatment application periods. Chambers used were switched within trials to remove chamber effects so that treatments are not confounded. Four trials were repeated over time where trial serves as the blocking factor. In addition to the treatment effect, the statistical model also incorporated the age and sex effects. Chamber was considered as the experimental unit and treatments were replicated in time. Means comparisons were assessed by least significant differences and the level of significance was fixed at $p \leq 0.05$ unless otherwise stated.

RESULTS

Data on the effects of varying levels of light intensities on growth performance (BW, BWG, FI, FCR) of broiler chickens grown to heavy weights are presented in Table 1. Body weight (BW) and BW gain (BWG) from d 0 to 56 d of age were not affected by varying light intensities of 25, 10, 5, 2.5 and 0.2 lx. However, Feed Conversion Ratio (FCR) was significant ($p \leq 0.054$) on d 28 and the major difference was between the 5 and 25 lx treatments.

The influence of varying levels of light intensities on carcass characteristics and yields of broilers at 56 d of age are presented in Table 2. Broilers reared under 5 lx had significantly higher live weight ($p \leq 0.046$) and carcass weight ($p \leq 0.026$) in comparison with 0.2, 2.5, 25 and 0.2, 25 lx, respectively. Furthermore, birds reared under 5 and 10 lx had significantly higher pectoralis major muscle ($p \leq 0.025$) when compared with 0.2 and

Table 1: Influence of varying light-intensity from 22 to 56 d of age on BW, BWG, feed intake and feed conversion of broilers[1]

	BW (kg)					BWG (kg)				
Item	14 d	21 d	28 d	42 d	56 d	14 d	21 d	28 d	42 d	56 d
Light-intensity treatment (lx)										
25	0.441	1.022	1.612	3.011	4.365	0.398	0.975	1.569	2.969	4.322
10	0.448	1.054	1.635	3.053	4.384	0.405	1.007	1.592	3.011	4.341
5	0.442	1.018	1.612	3.028	4.297	0.400	0.973	1.569	2.985	4.254
2.5	0.445	1.049	1.610	3.028	4.285	0.402	1.001	1.569	2.985	4.243
0.2	0.446	1.023	1.600	2.985	4.273	0.403	0.977	1.557	2.942	4.230
SEM[2]	0.022	0.013	0.041	0.060	0.064	0.020	0.012	0.040	0.059	0.064
p-value	0.999	0.087	0.983	0.950	0.654	0.999	0.071	0.980	0.945	0.654
	Cumulative feed intake (kg/bird)					Cumulative feed conversion ratio (kg of feed/kg of gain)				
Item	14 d	21 d	28 d	42 d	56 d	14 d	21 d	28 d	42 d	56 d
Light-intensity treatment (lx)										
25	0.544	1.224	2.311	4.906	8.447	1.324	1.357	1.450^{a}	1.642	2.086
10	0.547	1.224	2.333	4.928	8.504	1.311	1.339	1.440^{ab}	1.621	2.088
5	0.540	1.248	2.270	4.849	8.406	1.309	1.337	1.421^{b}	1.609	2.090
2.5	0.549	1.235	2.289	4.891	8.361	1.322	1.353	1.440^{ab}	1.632	2.098
0.2	0.544	1.250	2.267	4.782	8.199	1.308	1.357	1.425^{ab}	1.613	2.061
SEM[2]	0.012	0.066	0.046	0.174	0.320	0.016	0.010	0.009	0.060	0.055
p-value	0.990	0.998	0.831	0.978	0.970	0.908	0.418	0.054	0.995	0.991

[1]Means within a column and effect that lack common superscripts differ significantly ($p \leq 0.05$).

[2]Pooled SEM for main effects (n = 8)

Table 2: Influence of varying light-intensity from 22 to 56 d of age on live weights and yields of broilers carcasses and parts

		Carcass		Fat		Fillet		Tender	
Item	Live weight (kg)	Weight (Kg)	Yield (%)	Weight (kg)	Yield (%)	Weight (kg)	Yield (%)	Weight (kg)	Yield (%)
Light-intensity treatment (lx)									
25	4.26^{b}	3.11^{b}	73.00	0.111	3.57	0.760^{b}	24.44^{b}	0.185^{ab}	5.82
10	4.42^{ab}	3.24^{ab}	73.30	0.114	3.52	0.816^{a}	25.19^{a}	0.191^{a}	5.90
5	4.45^{a}	3.26^{a}	73.30	0.113	3.47	0.820^{a}	25.15^{a}	0.191^{a}	5.86
2.5	4.25^{b}	3.14^{ab}	73.90	0.110	3.50	0.782^{ab}	24.90^{ab}	0.184^{ab}	5.86
0.2	4.26^{b}	3.11^{b}	73.00	0.108	3.47	0.759^{b}	24.41^{b}	0.182^{b}	5.85
Pooled SEM[3]	0.060	0.048	0.301	0.003	0.025	0.015	0.173	0.003	0.044
p-value	0.046	0.026	0.317	0.592	0.216	0.025	0.033	0.034	0.812
Sex									
Male	4.87^{a}	3.59^{a}	73.76^{a}	0.103^{b}	2.87^{b}	0.893^{a}	24.87	0.201^{a}	5.60^{b}
Female	3.81^{b}	2.77^{b}	72.81^{b}	0.119^{a}	4.30^{a}	0.697^{b}	25.16	0.172^{b}	6.21^{a}
Pooled SEM[3]	0.038	0.030	0.010	0.002	0.002	0.009	0.110	0.002	0.028
p-value	0.000	0.000	0.004	0.000	0.025	0.000	0.826	0.000	0.000

[1]Means within a column and effect that lack common superscripts differ significantly ($p \leq 0.05$).
[2]Carcass without giblets, necks and abdominal fat are expressed as a percentage of live weight, while Pectoralis major and minor, breast muscles and abdominal fats are expressed as a percentage of carcass weight.
[3]Pooled SEM for main effects (n = 8)

Table 3: Influence of light intensity on mortality and Corticosterone (CS) of broilers grown to heavy weights

	Mortality (%)				CS (pg/mL)
Item	14 d	28 d	42 d	56 d	56 d
Light-intensity treatment (lx)					
25	1.44	2.6	3.52	4.91	2121.2
10	0.86	2.59	2.92	4.80	2481.6
5	1.45	2.29	2.66	4.01	2362.5
2.5	0.86	1.70	2.16	4.57	2245.3
0.2	0.29	1.44	2.66	3.43	2202.2
SEM[1]	0.232	0.760	1.013	1.128	830.2
p-value	0.419	0.752	0.801	0.876	0.792

[1]Pooled SEM for main effects (n = 8)

25 lx and pectoralis minor muscles ($p \leq 0.034$) when compared with birds reared under 0.2 lx. On the other hand, relative carcass yield and tender yield did not differ among treatments. In addition, fat weight and yield were unaffected by light intensity. Most of the examined parameters were influenced by gender, except for fillet yield. Light intensity treatments did not significantly affect mortality, but were rather variable (Table 3). Furthermore, as shown in Table 3, plasma CS concentrations were not significantly affected by treatments on any of the sampling days in this study.

DISCUSSION

The present study examined the effects of varying light intensity on broiler production and carcass characteristics. The overall growth performance (BW, BW gain, FI and FCR) of broilers from d 0 to 56 d of age was unaffected by light intensity, which indicate no effects of light intensity according to age in this study, except a significant ($p \leq 0.05$) decrease in FCR on d 28 of age under 5 lx in comparison with 25 lx. The results of the present study are in agreement with other reports (Kristensen *et al*., 2006a,b; Lien *et al*., 2007; Blatchford *et al*., 2009; Deep *et al*., 2010; Olanrewaju *et al*., 2010; Ahmad *et al*., 2011). Cherry and Barwick (1962) also found no adverse effect of light intensities on BW from 1 to 107.6 lx. Similarly Newberry *et al*. (1988) found no influence of light intensity treatments (180 and 6 lx) on BW. Results of the present study are also in agreement with the finding of Hullet *et al*. (1992) who reported no effect of light intensity on BW and BWG. However, other studies documented that the BW of broilers were greater under intensities of 10.75 to 54 lx, relative to 63 to 1290 lx (Skoglund and Palmer, 1962; Wathes *et al*., 1982). Downs *et al*. (2006) also found a transitory effect of light intensity on BW. The present results indicated that light intensity has no effects on FI of broilers throughout the experimental period. These insignificant effects of light intensity on FI observed in this study are in agreement with the studies of Scheideler (1990) who observed that light intensities ranging from 4 to 20 lx did not affect FI in broilers. Charles *et al*. (1992) also found no effect of light intensity of 5 to 150 lx on FI. In addition, Kristensen *et al*. (2006a) reported no effects of light intensity ranging from 5 to 100 lx on FI in broilers. Contrary to the present study, Lien *et al*. (2008) found that FI increased proportionally by providing 1.75 vs. 162 lx of light intensity.

The present data showed significant ($p \leq 0.054$) difference in FCR only at 28 d of age under 25 and 5 lx. These results of are in agreement with the findings of Cherry and Barwick (1962) who observed an improved FCR as intensities were decreased from 107.5 to 1.75 lx. It has been suggested that lower intensities may improve FCR because of a reduction in activity and stimulating muscular growth (Newberry *et al*., 1986; Downs *et al*., 2006). However, Buyse *et al*. (1996) reported that increasing light intensity from 5 to 51 lx has no significant effect on FCR. In addition, it has been reported that FCR was not influenced by providing 1.75 vs. 162 lx (Lien *et al*., 2008). In contrast, Charles *et al*. (1992) reported no effect of light intensity on FCR when

broilers exposed to 6 to 151 lx. Furthermore, results from the present study indicated that light intensity had no effect on the BWG of the broilers from d 0 to 56 d of age. This lack of difference between light intensity treatments on BWG is similar to that found in other studies examining light intensity effects on BW and feeding activity (Downs *et al*., 2006; Kristensen *et al*., 2006b).

Light intensity influenced most of the processing characteristics (live, carcass, fillet, tender) weights and fillet yield, while relative carcass and tender yields did not differ among treatments. In addition, fat weight and yield were unaffected by light intensity. This effect between light intensity treatments on processing characteristics is similar to that reported by others (Lien *et al*., 2008; Deep *et al*., 2010).

Broiler mortality was not affected by light intensity in this present study, which is in agreement with other reports (Downs *et al*., 2006; Kristensen *et al*., 2006a,b; Lien *et al*., 2007; Deep *et al*., 2010; Ahmad *et al*., 2011). The highest mortality (4.91%) was observed in broilers reared under 25 lx on d 56 of age. Based on the lack of effect of varying light intensity on corticosterone in this study, varying light intensities of 25, 10, 5, 2.5 and 0.2 lx had no effect on broiler welfare.

In conclusion, these results indicate no effects of varying light intensity of 25, 10, 5, 2.5 and 0.2 lx on broilers growth performance parameters (BW, BW gain, FI and mortality), but did affect FCR on 28 d of age under 25 and 5 lx and processing parameters including carcass weight and yields of broilers reared up to 56 d of age. In addition, treatments did not affect plasma corticosterone, suggesting that these levels of light intensity may not have negative effect on the welfare of modern broilers grown to heavy weights. Therefore, using lower lighting intensity may be beneficial to commercial poultry facilities that are using low lighting environment to reduce hyperactivity, pecking damage and energy costs without adverse effects on FI and on broiler welfare.

ACKNOWLEDGMENTS

The authors thank Larry N. Halford and M. Robinson both of the USDA poultry research Unit for their contributions to this study.

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