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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

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Influence of Photoperiod, Light Intensity and Their Interaction on Health Indices of Modern Broilers Grown to Heavy Weights

H.A. Olanrewaju[1], W.W. Miller[2], W.R. Maslin[3], S.D. Collier[1], J.L. Purswell[1] and S.L. Branton[1]
[1]USDA, Agricultural Research Service, Poultry Research Unit,
P.O. Box 5367, Mississippi State, MS 39762-5367, USA
[2]Animal Ophthalmology Clinic, 1067 Old West Point Road, Starkville, MS 39759, USA
[3]College of Veterinary Medicine, Mississippi State University,
Wise Center, Mississippi State, MS 39762, USA

Abstract: The effects of photoperiod, light-intensity and their interaction on health indices of broiler chickens grown to heavy weights under environmentally controlled conditions were evaluated in 2 trials. In each trial, 540 Ross x Ross 708 chicks were randomly distributed into 9 environmentally controlled chambers (30 male and 30 female chicks/chamber) at d of hatch, provided with 23L:1D with 20 lx of intensity from placement to 7 d and then subjected to the following treatments. The treatments consisted of 3 photoperiod (long/continuous (23L:1D) from d 8 to d 56; regular/intermittent (2L:2D) and short/non-intermittent (8L:16D) from d 8 to d 48 and 23L:1D from d 49 to d 56, respectively) and exposure to 3 light intensities (10, 5.0 and 0.5 lx) from d 8 through d 56 at 50% RH. All birds were fed the same nutritionally complete diet. Feed and water were provided *ad libitum*. Ocular health and general health assessments were performed on d 42 and 49, respectively, while foot pad score was evaluated on d 56 of age. There were only significant ($P < 0.05$) effects of photoperiod on live BW and eye weight, but no differences on ocular weight relative to BW. Food pad lesions quality was significantly decreased with decreasing in photoperiod. There were no differences among treatments on ocular assessments, gait scoring test or tonic immobility responses, suggesting that these treatments did not compromise welfare of the birds. These results indicate that long/continuous and regular/intermittent photoperiods equally improved broiler performance compared with short/non-intermittent photoperiod and no significant effect of light intensity treatments was observed in this study.

Key words: Photoperiod, light-intensity, broiler, eye, welfare

INTRODUCTION

Poultry welfare has generated concerns from the domestic and global market sectors. Consumer concerns relative to poultry welfare are becoming increasingly relevant in meat and egg markets. The economic goals of current poultry and animal production systems have embraced health, well-being and welfare of birds, since birds are constantly responding to climatic and environmental changes (Cheng, 2010). For instance, poultry that are reared under unsuitable environmental conditions are not able to express their maximum genetic potential (Downs *et al*., 2006; Olanrewaju *et al*., 2008, 2010a). Environmental and management modifications have been the methods of choice for meeting health and welfare needs of poultry. Chickens have the ability to adapt to these changing environments either natural or artificial (Cheng, 2010). Welfare of birds is regulated by various factors, among which lighting programs (intensity, color or wavelength, photoperiod, source) play a crucial role. Light is one of the most important microclimate factors for growing broilers, as it greatly influences broiler activity, growth development and physiological functioning. 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. Manipulation of lighting programs is a strategy used to reduce the incidence of metabolic and skeletal disorders in broiler chickens as well as to inhibit cannibalism. In addition, manipulation of normal light perception in birds has been shown to be associated with several eye conditions including avian glaucoma, which is induced by prolonged exposure to continuous bright light (Jensen and Matson, 1957) and avian macrophthalmos from prolonged exposure to darkness or dim light (Berkovitz *et al*., 1972; Lauber and Kinnear, 1979). Most of the research involving light management has focused on photoperiod (Lewis and Gous, 2009) light-intensity (Deep *et al*., 2010; Olanrewaju *et al*., 2011) or light-intensity in combination with other environmental factors (Lien *et al*., 2007; Olanrewaju *et al*., 2008, 2010 a, b). A previous study on the interactive effects of ammonia and light intensity indicated that light intensities alone yield no significant

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

eye lesions, but levels of ammonia concentration induced eye lesions in broiler chickens (Olanrewaju *et al*., 2007). Continuous or near-continuous light affects the diurnal rhythm and has serious welfare effects including leg disorders (Manser, 1996; Sanotra *et al*., 2001) and has been proved to be stressful and result in greater mortality in broilers (Buckland *et al*., 1976; Freeman *et al*., 1981). On the other hand, moderate day length of 16 h is associated with potential welfare benefits such as lower physiological stress, increased sleep and improved leg health (Gordon, 1994; Davis *et al*., 1997). Tonic immobility and lameness have been widely used as a measure of fearfulness and lameness in poultry (Gallup, 1979; Jones and Faure, 1981; Vestergaard and Sanotra, 1999). Foot pad dermatitis (FPD) is a widespread problem of poultry health and welfare issues as not only the walking ability but also carcass quality are affected (Bradshaw *et al*., 2002). Foot pad dermatitis can be caused by many factors including litter moisture, which is the most significant factor since broilers spend the majority of their time lying on litter (Martland, 1985; Bessei, 2006; Shepherd and Fairchild, 2010). Lighting programs were also been shown to affect the incidence of foot pad disorders. For instance, it has been suggested that decreased activity and increased resting associated with dim light or short photoperiod resulted in a longer time of lying down on litter thereby leading to an increased incidence of foot pad erosions (Bessei, 2006; Blatchford *et al*., 2009). Based on the above information, the objective of the present study was to evaluate the effects of photoperiod, light intensity and their interaction on general health (ocular, tonic immobility (TI), gait score (GS) and footpad (FP) of modern broiler chickens grown to heavy weights (>3 kg).

MATERIALS AND METHODS

Bird husbandry: All procedures relating to the use of live birds in this study were approved by the USDA-ARS Animal Care and Use Committee at the Mississippi State location. In each of 2 trials, with each lasting 8 wk, a total of 540 1-d-old Ross x Ross 708 (Aviagen Inc., Huntsville, AL) chicks were purchased from a commercial hatchery and on arrival, the chicks were sexed and then group weighed. Chicks were randomly distributed into 9 environmentally controlled chambers (30 male and 30 female chicks/chamber). 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). 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. Each chamber contained fresh pine shavings at a depth of 10 cm, tube feeders and a 7-nipple watering system. 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 RH on d 1 were maintained at 32±1.1°C and 50±5%, respectively and RH was held constant across all treatments. Temperature was decreased as the birds progressed in age until 15.6°C was reached at 49 d of age.

Experimental treatments: Photoperiod consisted of continuous lighting (24L:0D) with 20 lx of intensity from placement to 7 d of age and then subjected to the following treatments. The treatments consisted of 3 photoperiods (long/continuous (23L:1D) from d 8-d 56; regular/intermittent (2L:2D) from d 8-d 48 and (23L:1D) d 49-d 56; short/non-intermittent (8L:16D) from d 8-d 48 and (23L:1D) from d 49-d 56, respectively) and exposure to 3 light intensities (10, 5.0 and 0.5 lx) from day 8 through d 56 at 50% RH. There were 3 different chambers for each photoperiod treatment along with 3 different chambers for each light intensity treatment, for a total of 9 chambers. Each of the 3 photoperiod treatments was paired with 1 of the 3 light intensity treatments so that each chamber represented a particular photoperiod:light intensity level combination. Each chamber was equipped with incandescent lighting, which is standard in US commercial broiler housing. Light intensity settings were verified at the bird level (30 cm) by using a photometric sensor with National Institute of Standards and Technology-Traceable Calibration (403125, Extech Instruments, Waltham, MA) for each intensity adjustment. The light fittings and tubes were dusted weekly to minimize dust buildup, which would otherwise reduce the intensity.

Experimental measurements

Ocular assessments

Eye examination: On day 42 of each trial, eye scoring was evaluated by a veterinary ophthalmologist on 10 (5 males and 5 females) randomly selected chickens from each chamber. The ophthalmologist did not know the treatment origin of any bird examined. Biomicroscopy was performed using a Kowa SL-14 portable slit-lamp (KOWA Company Ltd., Tokyo, Japan). During the examination, signs of clinical keratoconjunctivitis and anterior uveitis were recorded, if present. Corneal lesions assessed by biomicroscopy were assigned injury scores similar to Thoft's classification (Thoft, 1979). The numerical scale for grading corneal lesions was 0 = normal cornea; 0.5 = not normal but less than 1; 1 = diffuse corneal edema generally over greater than three quarters of the corneal surface; 2 = 1 + a focal superficial corneal ulcer measuring less than one quarter of the corneal surface; 3 = 1 + a corneal ulcer of half or more of the corneal surface and extending into

the anterior chamber; 4 = 3 + deeper extension into the stromal layers and 5 = corneal perforation.

Ocular development and histopathologic examination: On d 42 of each trial, 6 (3 males and 3 females) randomly selected chickens from each chamber were weighed individually. Subsequently, chickens were euthanized by cervical dislocation according to the USDA Animal Care and Ethics Committee for organ collection procedures. The right eyeball was dissected out, trimmed of extraneous tissue and weighed to the nearest 0.01 g. Assuming bilateral symmetry, only the right eye was excised and its weight doubled to give an estimate of total eye weight and calculation of the total eyes weight to BW ratio was determined. The dissected right eyeball was placed inside 10% buffered formalin for gross anatomical anomalies and histopathological evaluation by a veterinary pathologist using Kristensen (1948) method. Briefly, after fixing for at least 72 h in formalin, the eyes were placed in Kristensen's decalcifying solution (1:1 mixture of 8 N formic acid and 1 N sodium formate) for 3 days. Two sections were prepared from each eye as follows. The eye was held in a normal postural position and cut vertically approximately 4 mm lateral to the center of the cornea. A second cut was made through the center of the cornea. Third cut was made approximately 4 mm medial to the center of the cornea. All cuts were made completely through the eye. The two trimmed sections were placed in a single cassette such that the center of the cornea was face-down for each section. Following this, the cassettes were washed in gently running tap water for 24 h to remove residual acid and then placed in 10% buffered neutral formalin until processed. All tissues were processed routinely, embedded in paraffin, sectioned at 6 μm and stained with hematoxylin and eosin (Olanrewaju *et al*., 2007). The examining pathologist was unaware of bird treatment origin. The iris and ciliary body were scored for the presence (+) or absence (-) of heterophils, diffuse lymphocytic infiltrates and nodular lymphocytic infiltrates. In addition, the presence (+) or absence (-) of increased cellularity along the rostral surface of the iris was also noted and the corneal epithelium was scored for the presence (+) or absence (-) of ulceration.

General well-being: Gait scoring (GS) test and tonic immobility (TI): On day 49, 10 (5 males and 5 females) birds from each chamber were randomly selected for assessment of their general welfare using three different protocols as described previously (Olanrewaju *et al*., 2007). Welfare locomotive ability was assessed using a modification of the Kestin Gait Scoring System as described in the American Humane Welfare Standard (Kristin *et al*., 1994). Fear and frustration were assessed by determining tonic immobility index time (American Humane Welfare Standard). In addition, unnecessary discomfort to the birds was also avoided by using proper housing and handling techniques (National Research Council, 1996).

Gait scoring (GS) test: On d 49 (morning), 10 (5 males and 5 females) randomly selected birds from each chamber, 2 (1 male and 1 female) chicks at a time, were allowed to walk freely (1.52 m) within an interior enclosed floor area of 1.83 x 3.66 m that contained new pine shavings. Gait score performance was evaluated according to the Kestin Gait Scoring System (Kristin *et al*., 1994) and modified by Dawkins *et al*. (2004) on a scale ranging from 0 to 2. Score 0 represented no detectable impairment of walking, score 1 indicated birds with no detectable walking impairment and able to walk at least 5 ft without sitting down, while score 2 indicated severe impairment of walking ability with birds being unable to walk 5 ft without sitting down again. Each bird was observed for 2 to 3 min. If the chick hesitated or remained immobile, it was touched with a long stick to encourage it to walk.

Tonic immobility (TI): On day 49 (afternoon), 10 (5 males and 5 females) birds from each chamber were also randomly selected for TI assessment. Tonic immobility was induced by inverting the bird on its back and restraining it for 10 s in a U-shaped wooden cradle covered with a layer of cloth. One hand was used to cover the birds head and the other hand was placed on the sternum, as described by Jones and Waddington (1992). Eye contact was completely avoided between the bird and the experimenter after the experimenter removed his hands from the cradle. A stopwatch was used to record latencies until the bird righted itself (getting to its feet again). The time was measured from withdrawal of the hand until the bird stood upright. If the bird righted itself in less than 10 s, then TI was not considered to have been induced. If TI was not induced after 3 attempts, the duration of TI was considered to be 0 s and the restraining procedure had to be repeated. If the bird did not show a righting response over the 10 s test period, then a maximum score of 600 was given for righting time. The number of inductions required to attain TI was also recorded for each bird.

Foot pad (FP) scores: On d 56 of each trail, 20 (10 males + 10 females) chickens were randomly selected from each chamber for foot pad scores following the procedure reported by Davis *et al*. (2010). Foot pad scores were assigned according to the following scale: 1 = no or minor visible lesions, 2 = lesion with area <1.5 cm and 3 = lesions with area >1.5 cm.

Statistical analysis: A 3 x 3 factorial arranged in a randomized complete design was used in this study. Data were replicated over time, with trial being the blocking factor. Chamber was considered the experimental unit. The 9 treatments consisted of 3 levels of photoperiod x 3 levels of light intensity. The main effects of photoperiod and light intensity and the interaction of these 2 factors on health indices were tested by using the MIXED procedure of SAS (SAS Institute, 2008). Chambers used were switched between trials to remove chamber effects so that treatments were not confounded. Chamber was considered as the experimental unit and treatments were replicated on time. Log transformation of the raw scores was used because of the large range among the data. Geometric means are presented (Table 1) for the corneal and anterior chamber scores. The histopathologic eye tissue evaluations (presented as percent of occurrence in Table 2) required arcsine transformation before analysis. For each of the eye tissue, the presence or absence of lymphocytic or heterophilic infiltrates in iris and ciliary body was given as a positive or negative score. If the number of samples with a positive score was 3 out of 4 for a particular treatment, the percentage of occurrence was 75%. Means comparisons were assessed by least significant differences and the level of significance was fixed at $P \leq 0.05$ unless otherwise stated.

RESULTS

Eye examination: Effects of the exposure of broiler chickens to photoperiod, varying light-intensity and their interaction at 42 d of age on live BW, eye weight, relative eye weight to BW and corneal lesion scores are summarized in Table 1. Short/non-intermittent photoperiod significantly reduced live BW ($p \leq 0.003$) and eye weights ($p \leq 0.002$) compared with those birds reared under either long/continuous or regular/intermittent photoperiods. However, there was no effect of treatments on the relative eye weight to live BW indicating that eye weight was directly proportional to the live BW. In addition, there was no significant difference among the treatments for corneal lesions scores. There were no statistically significant treatment differences due to light-intensity or photoperiod by light intensity interaction on any of the examined variables. Table 2 presents histopathologic examination due to photoperiod, varying light-intensity and their interaction on rostral surface, lymphocytes and heterophils in the iris stroma and ciliary body of broiler chickens at 49 d of age. There were no statistically significant treatment differences due to treatments or treatment interaction among iris and ciliary body lymphocytic and heterophilic infiltrates. Tonic immobility (TI) and gait scores (GS) were not significantly affected by photoperiod, varying light-intensity, or their interaction in broiler chickens at 49d of age (Table 3). The overall GS values were less than 1 and no birds were found to have GS≥2. As shown in Table 4, short/non-intermittent photoperiod significantly reduced final BW ($p \leq 0.000$) and significantly increased both left ($p \leq 0.000$) and right ($p \leq 0.001$) foot pad dermatitis (FPD) compared with those birds reared under long/continuous or regular/intermittent photoperiods. There was no main effect of light intensity on any of the examined variables. However, there was a photoperiod by light intensity interaction on BW ($p \leq 0.000$), left FPD ($p \leq 0.000$) and right FPD ($p \leq 0.001$).

Table 1: Influence of Photoperiod, light-intensity and their interaction on live body weights, eye weights, relative eye weight to BW and clinical corneal lesion (CLS) at 42 d of age[1,A]

Treatments	Live BW (Kg)	Eye WT (g)	Eye WT:BW (g/kg)	CLS[4]
Photoperiod				
Long	3.340[a]	7.378[a]	2.174	0.01
Reg-Inter	3.400[a]	7.616[a]	2.250	0.01
Short-Non-Inter	3.080[b]	6.378[b]	2.078	0.02
Intensity				
0.5 lx	3.238	7.585	2.345	0.00
5.0 lx	3.284	6.681	2.046	0.00
10.0 lx	3.294	6.935	2.111	0.01
SEM[2]	0.081	0.286	0.112	0.012
Photoperiod-light intensity				
Long-0.5 lx	3.290	7.483	2.286	0.01
long-5.0 lx	3.324	6.823	2.078	0.00
Long-10.0 lx	3.407	7.317	2.158	0.00
Reg-Inter-0.5 lx	3.290	8.567	2.599	0.01
Reg-Inter-5.0 lx	3.521	7.157	2.046	0.00
Reg-Inter-10.0 lx	3.376	7.123	2.106	0.01
Short-Non-Inter-0.5 lx	3.134	6.703	2.149	0.02
Short-Non-Inter-5.0 lx	3.227	6.065	2.016	0.01
Short-Non-Inter-10.0 lx	3.099	6.365	2.070	0.02
SEM[3]	0.140	0.499	0.194	0.014
Source of variation	---------- p-value ----------			
Photoperiod	0.003	0.002	0.329	0.359
Light intensity	0.765	0.066	0.395	0.682
Photoperiod × light intensity	0.457	0.431	0.487	0.463

[1]Means within a column and effect that lack common superscripts differ significantly ($P \leq 0.05$)
[2]Pooled SEM for main effects (n = 6)
[3]Pooled SEM for interaction effect (n = 2)
[A]The numerical scale for grading corneal lesions was 0 = normal cornea; 0.5 = not normal but less than 1; 1 = diffuse corneal edema generally over greater than three quarters of the corneal surface; 2 = 1 + a focal superficial corneal ulcer measuring less than one quarter of the corneal surface; 3 = 1 + a corneal ulcer of half or more of the corneal surface and extending into the anterior chamber; 4 = 3 + deeper extension into the stromal layers and 5 = corneal perforation

DISCUSSION

It is known that light intensity can affect many aspects of avian physiology, health, welfare and behavior that include skeletal, blood chemistry, blood gases, ocular development and behavioral rhythms (Nelson and Demas, 1997; Reiter, 2003; Olanrewaju *et al*., 2006). There are conflicting reports on the effects of lighting programs on the welfare and performance of birds. The present results indicate significant effects of photoperiod and low light intensity on eye weights are similar to the

Table 2: Influence of photoperiod and light-intensity on histological changes noted in the iris and ciliary in broiler chickens at 49 d of age[A]

	Iris			Ciliary body	
Treatments	Rostral surface[B]	Diffuse lymphocytic infiltrates[C]	Heterophilic infiltrates[D]	Diffuse lymphocytic infiltrates[C]	Heterophilic infiltrates[D]
Photoperiod					
Long	52.31	42.12	20.25	20.13	20.31
Reg-Inter	54.12	42.98	21.02	22.16	21.58
Short-Non-Inter	59.65	58.56	32.01	26.32	24.69
Light Intensity					
0.5 lx	44.23	42.06	20.23	20.34	20.10
5.0 lx	51.37	45.86	21.11	21.56	21.05
10.0 lx	60.23	48.97	31.21	24.95	21.05
SEM[1]	8.442	7.956	6.345	3.231	3.156
Photoperiod-light intensity					
Long-0.5 lx	44.80	43.30	21.11	21.53	20.01
long-5.0 lx	49.50	45.10	21.21	21.73	20.10
Long-10.0 lx	48.90	44.51	22.01	22.43	20.21
Reg-Inter-0.5 lx	58.60	46.20	24.43	22.60	21.16
Reg-Inter-5.0 lx	53.20	50.57	24.89	23.47	21.41
Reg-Inter-10.0 lx	62.50	52.40	25.22	23.51	21.71
Short-Non-Inter-0.5 lx	60.07	54.41	35.21	23.30	23.15
Short-Non-Inter-5.0 lx	63.40	54.87	36.31	24.14	24.59
Short-Non-Inter-10.0 lx	64.70	55.10	36.67	24.61	24.61
SEM[2]	9.235	7.232	6.035	4.56	4.325
Source of variation	p-value				
Photoperiod	0.359	0.521	0.297	0.654	0.653
Intensity	0.459	0.349	0.168	0.621	0.516
Photoperiod × Light intensity	0.238	0.328	0.684	0.358	0.463

[A]Means within column that lack common superscripts differ significantly by LSD at $P \leq 0.05$ on arcsine transformed values

[B]Observed increased cells along the roatral surface of the iris, which may have been the result of epithelial/endothelial hyperplasia, lymphocytic infiltrates, or both

[C]Indicates the presence of lymphocytes in the iris stroma or ciliary body but does not include lymphocytes that may be present in a nodular aggregate. There were no observations of nodular aggregates of lymphocytes in the iris or ciliary body.

[D]Indicates the presence of heterophils in the iris stroma or ciliary body.

[1]Pooled SEM for main effects (n = 6); [2]Pooled SEM for interaction effect (n = 2).

Table 3: Influence of photoperiod, light-intensity and their interaction on tonic immobility (TI) and gait-score (SC) in broilers at 49 d of age[1]

Treatments	TI (s)	CS (%)
Photoperiod		
Long	168.7	20.21
Reg-Inter	170.4	20.24
Short-Non-Inter	176.8	20.65
Light Intensity		
0.5 lx	176.3	10.52
5.0 lx	172.1	15.52
10.0 lx	175.3	15.65
SEM[1]	4.442	2.645
Photoperiod-light intensity		
Long-0.5 lx	178.9	15.23
long-5.0 lx	177.8	15.41
Long-10.0 lx	181.4	15.40
Reg-Inter-0.5 lx	185.2	15.80
Reg-Inter-5.0 lx	183.6	15.42
Reg-Inter-10.0 lx	181.9	20.10
Short-Non-Inter-0.5 lx	189.4	20.75
Short-Non-Inter-5.0 lx	191.1	20.55
Short-Non-Inter-10.0 lx	189.6	20.67
SEM[2]	5.235	2.735
Source of variation	p-value	
Photoperiod	0.452	0.623
Intensity	0.651	0.765
Photoperiod × Light intensity	0.684	0.686

[1]Means within column that lack common superscripts differ significantly by LSD at $P \leq 0.05$

[2]Pooled SEM for main effects (n = 6)

[3]Pooled SEM for interaction effect (n = 2)

studies reported by others (Harrison *et al*., 1968; Blatchford *et al*., 2009; Deep *et al*., 2010), except that increased eye weight was not evaluated in proportion to the bird BW in those prior studies. The increased eye weights observed in this study due to photoperiods are proportional to their BW. Broilers reared under long/continuous or regular/intermittent photoperiods had heavier eyes weights than broilers reared under short/non-intermittent photoperiod; however, these differences in eye weights were neutralized when reported on a BW basis.

Kristensen *et al*. (2006b) reported that leg health was unaffected using two levels of light intensity (5 and 100 lx). In addition, Olanrewaju *et al*. (2007) found that broilers exposed to light levels of 0.2 to 20 lx have similar skeletal health as demonstrated by gait-score. Blatchford *et al*. (2009) also reported that gait score was unaffected by three levels of light intensity (5, 50 and 200 lx). Results on both GS and TI in the present study were generally normal with no significant differences occurring among treatments. It has generally been accepted that a $GS \geq 2$ is a welfare concern, because behavioral differences are observed between lame and normal chickens and pathological changes are more obvious (Sorensen *et al*., 2000). The walking ability and fear of broiler chickens in this study were unaffected by

Table 4: Influence of photoperiod, light-intensity and their interaction on body weight (BW) and footpad of broilers grown to heavy weights at 56 d of age[1]

	Kg	-------- Food pad --------	
Treatments	BW	Left	Right
Photoperiod			
Long	4.204[a]	1.33[c]	1.33[b]
Reg-Inter	4.262[a]	1.62[b]	1.52[b]
Short-Non-inter	3.710[b]	2.58[a]	2.60[a]
Light Intensity			
0.5 lx	4.058	1.88	1.90
5.0 lx	4.142	1.92	1.88
10 lx	3.974	1.73	1.67
SEM[2]	0.069	0.120	0.113
Photoperiod-light intensity			
Long-0.5 lx	4.185[b]	1.55[de]	1.50[d]
Long-5.0 lx	4.373[a]	1.10[e]	1.20[d]
Long-10 lx	4.053[c]	1.35[de]	1.30[d]
Reg-Inter-0.5 lx	4.226[b]	1.75[cd]	1.75[cd]
Reg-Inter-3.0 lx	4.396[a]	1.65[de]	1.45[d]
Reg-Inter-20 lx	4.164[bc]	1.35[de]	1.35[d]
Short-Non-inter-0.5 lx	3.765[c]	2.35[bc]	2.45[ab]
Short-Non-inter-5.0 lx	3.659[c]	3.00[a]	3.00[a]
Short-Non-inter-10 lx	3.710[c]	2.40[ab]	2.35[bc]
SEM[3]	0.039	0.208	0.196
Source of variation	---------- p-value ----------		
Photoperiod	0.000	0.000	0.001
Light Intensity	0.672	0.268	0.074
Photoperiod × light intensity	0.041	0.004	0.008

[1]Means within a column and effect that lack common superscripts differ significantly ($P \leq 0.05$)
[2]Pooled SEM for main effects (n = 6)
[3]Pooled SEM for interaction effect (n = 2)

either photoperiod, light intensity or their interaction. Kristensen *et al.* (2006a) and Blatchford *et al.* (2009) found no effects of lighting treatments on lameness in broilers. The lack of effect of photoperiods, or levels of light intensities used in this study is in agreement with industry awareness (Classen *et al.*, 2003, 2004). Kristensen *et al.* (2006b) also reported that broiler leg health was unaffected by light intensity. It can be concluded that neither photoperiod, intensity nor their interaction as used in this study had a major effect on birds' health as indicated by the GS<1.

Unlike the present results, the incidence of leg problems has been shown to be influenced by light intensity (Newberry *et al.*, 1988), photoperiod (Wilson *et al.*, 1984) and light color (Prayitno *et al.*, 1997). Lighting treatments had no effects on gait scores, which signify that the levels of light intensity in the present study had no impact on overall leg health. Leg abnormalities and fear in broilers are both economic and welfare concerns in poultry production. The economic costs associated with leg weakness include culling and condemnations or downgrading at processing plant. However, recent reports indicated that gait scores (GS) and the incidence of leg weakness may have improved over time (Classen *et al.*, 2004). The duration of TI was similar for all the treatments. Duration of TI has been described as a good predictor of the level of fearfulness in domestic chickens (Jones, 1986).

Foot pad dermatitis is a major problem associated with various factors including litter quality, which is the most important factor because of its direct contact with the foot. The light program has also been shown to affect the incidence of foot pad disorders. It has been suggested that decreased activity and increased resting associated with dim light results in an increased incidence of foot pad erosions (Blatchford *et al.*, 2009). Decreased activity with dim light was suggested to result in increased contact time between the foot and litter, leading to greater foot pad erosions.

The present data indicates that a short, non-intermittent photoperiod negatively affects live BW and footpad condition when compared to either regular/intermittent or long/continuous (23L:1D) photoperiods. The findings in this investigation suggest that exposure to the treatments of photoperiod, light-intensity and their interaction had no significant effect on most health indices evaluated in broilers grown to heavy weights, suggesting that these levels of treatments did not negatively affect welfare of these chickens. In addition, using regular/intermittent photoperiod instead of long/continuous photoperiod will save energy utilization thereby reducing the total cost of production.

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