Comparison of an intermittent, short-dawn/dusk photoperiod with an increasing, long-dawn/dusk photoperiod on broiler growth, stress, and welfare

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ABSTRACT Photoperiod has been shown to significantly affect broiler performance. However, the effects of the traditional 1-min dimming period on broiler growth and welfare are unclear. In this study, 4 consecutive trials were conducted to compare the effects of an intermittent, short-dawn/dusk photoperiod (**ISD**) to an increasing, long-dawn/dusk photoperiod (**ILD**) on broiler growth, stress, and welfare. Straight run day-of-hatch Ross 708 × Ross 708 broilers were placed in 1 of 4 commercial broiler barns (2 b of 26,200 birds each per treatment) and grown to 45 D of age. The photoperiod in the ISD treatment consisted of 24L:0D day 0 to 6, 16L:8D day 7 to 13, 12L:4D:2L:6D day 14 to 20, 12L:4D:3L:5D day 21 to 27, 12L:4D:4L:4D day 28 to 41, and 13L:3D:5L:3D day 42 to 45, with a 1-min transition between light and dark periods. The photoperiod in the ILD treatment consisted of 23L:1D day 0 to 7, 16L:8D day 8 to 21, 18L:6D day 22 to 32, and 20L:4D day 33 to 45, with a 1-min light/dark transition period day 0 to 7 and a 30-min transition period day 8 to 45. Treatments were rotated among the barns between trials. On day 45, blood samples were collected from 20 birds/barn (n = 40/treatment) to assess plasma corticosterone (**CORT**) and heterophil/lymphocyte (**H/L**) ratio. One hundred birds per barn (n = 200/treatment) were weighed individually and assigned scores for hock burn, foot pad dermatitis, and feather condition on day 45. Trial differences were observed for all measures ($P \leq 0.001$). Birds in the ISD treatment were heavier on day 45 ($P < 0.001$) and had lower hock burn ($P = 0.044$) and foot pad dermatitis ($P < 0.001$) scores. Birds in the ILD treatment had lower plasma CORT ($P < 0.001$) and H/L ratio ($P < 0.001$). No treatment differences were observed for feather condition ($P > 0.05$). Overall, birds reared under the intermittent, short-dawn/dusk photoperiod had higher day 45 live body weights and lower hock burn and foot pad dermatitis scores, whereas those reared under the increasing, long-dawn/dusk photoperiod had reduced measures of short-term and long-term stress.

Key words: broiler, photoperiod, dimming, growth, welfare

2020 Poultry Science 99:3908–3913
https://doi.org/10.1016/j.psj.2020.05.015

INTRODUCTION

Various components of the lighting program, including spectrum, intensity, and photoperiod, have been shown to influence economically important performance traits in commercial broilers (Andrews and Zimmermann, 1990). In recent decades, the introduction of shorter photoperiods and intermittent lighting schedules have been shown to reduce some of the negative effects of continuous lighting on broiler health while supporting growth performance (Buyse et al., 1996). For example, increasing day length over the course of the rearing period may reduce leg abnormalities in broilers compared with providing near-constant light (Classen and Riddell, 1989; Classen et al., 1991; Riddell and Classen, 1992). Increasing photoperiod has also been shown to increase plasma androgen levels (Charles et al., 1992) and to improve body weight gain and reduce mortality compared with constant light (Riddell and Classen, 1992). Downs et al. (2006) have suggested that increasing photoperiod results in lower initial body weight gain followed by compensatory growth later in the rearing period. Intermittent light has shown mixed effects on stress measures (Abbas et al., 2008; Olanrewaju et al., 2019) and leg abnormalities (Wilson

Received December 12, 2019.

Accepted May 22, 2020.

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et al., 1984; Classen et al., 1991; Renden et al., 1996; Balog et al., 1997). However, intermittent lighting has been implicated in improving growth and feed efficiency (Malone et al., 1980; Mahmud et al., 2011) in broilers compared with continuous light. Although continuous light may increase growth rate early in the bird's development, previous research has shown that exposing birds to multiple intervals of light throughout the day may ultimately improve feed conversion and overall growth (Dorminey and Nakaue, 1977).

Traditional lighting schedules typically provide a relatively short, 1-min dimming period between the light and dark phases of the photoperiod. Reductions in leg bone asymmetry have been observed in broilers with the introduction of dimming between light and dark periods, suggesting more even growth rate when birds are able to adjust to changing light intensity (van der Pol et al., 2015). However, the effect of an extended dawn/dusk period between photoperiod and scotoperiod on measures of stress and performance traits has not been measured. In addition, comparisons between intermittent and increasing photoperiods have not been thoroughly researched. Therefore, the aim of this study was to compare the effect of an intermittent, short-dawn/dusk photoperiod with an increasing, long-dawn/dusk photoperiod on broiler growth, stress, and welfare.

MATERIALS AND METHODS

Animal Husbandry

Day-of-hatch straight-run Ross 708 × Ross 708 broiler chicks were reared to 45 D of age in solid-side wall, tunnel-ventilated commercial barns measuring 13.1 × 152.4 m at the Stephen F. Austin State University Broiler Research Center in Nacogdoches, Texas. There were 4 consecutive flocks consisting of 104,800 birds each; 26,200 birds were placed in each of 4 barns, resulting in a stocking density of 0.076 m^2/bird. Birds were cared for in accordance with the Guide for the Care and Use of Agricultural Animals for Use in Research and Teaching (FASS. 2012), and protocols were approved by the Stephen F. Austin State University Institutional Animal Care and Use Committee (AUP#2016-004). Birds received *ad libitum* access to feed and water for the duration of the rearing period. Diets consisted of a crumbled starter (day 1–18), pelleted grower (day 19–35), pelleted finisher phase 1 (day 36–42), and pelleted finisher phase 2 (day 43–45). Each barn was fitted with 2 feeder lines with 428 feeders each, allowing for approximately 61 birds/feeder, and 4 drinker lines with 572 nipples each, allowing for approximately 11 birds/nipple. Birds were assigned to 1 of 2 treatments: an intermittent, short-dawn/dusk photoperiod (**ISD**) presented in Table 1, or an increasing, long-dawn/dusk photoperiod (**ILD**) presented in Table 2. The photoperiod in the ISD treatment consisted of 24L:0D day 0 to 6, 16L:8D day 7 to 13, 12L:4D:2L:6D day 14 to 20, 12L:4D:3L:5D day 21 to 27, 12L:4D:4L:4D day 28 to 41, and 13L:3D:5L:3D day 42 to 45, with a 1-min transition between light and dark periods. The photoperiod in the ILD treatment consisted of 23L:1D day 0 to 7, 16L:8D day 8 to 21, 18L:6D day 22 to 32, and 20L:4D day 33 to 45, with a 1-min light/dark transition period day 0 to 7 and a 30 min transition period day 8 to 45. Two barns were assigned to each lighting schedule for each flock (n = 52,400 birds/treatment), and treatments were rotated among barns between each flock. Each barn was equipped with 72 12-W Agrishift MLB lamps (Once Inc., Plymouth, MN) arranged in 3 rows along the length of the barn and placed at 6.1 m intervals.

Stress Measures

Blood samples were collected via the brachial vein from 20 birds/barn (n = 40/treatment) at the end of the rearing period: 1 to 2 mL of blood was collected from each bird and transferred to a lithium heparin separation gel vacutainer (36,7884, BD Medical, Franklin Lakes, NJ). One drop of blood from each sample was used to prepare a blood smear slide. Vacutainers were then inverted and stored on ice. Blood samples were centrifuged at 4,000 RPM for 15 min (Centrifuge 5,804, Eppendorf, Hamburg, Germany), and plasma was poured off into a microcentrifuge tube and stored at −20°C until analysis. Plasma was thawed overnight at 4°C and used to assess corticosterone (**CORT**) using a commercially available ELISA kit (ADI-901-097, Enzo Life Sciences, Inc., Farmingdale, NY). Absorbance was read at 450 nm using a microplate absorbance reader (Tecan Sunrise, Tecan Trading AG, Switzerland) and analyzed using the Magellan Tracker software program. Dry blood smear slides were stained with a neat stain hematology stain kit (Cat. #25034, Poly Sciences, Inc., Warrington, PA). Heterophil/lymphocyte (**H/L**) ratio was determined at 40× magnification under light microscopy (89,404-886, VWR International, Radnor, PA) by counting individual heterophils and lymphocytes until a

Table 1. Intermittent, short-dawn/dusk photoperiod applied to birds in the ISD treatment day 0 to 45.

Growth day	Intensity (foot candles)	Transition (minutes)	Total hours of light	Cycle 1	Cycle 2
0–6	4.3 (100%)	0	24	0:00- 0:00	
7–13	2.5 (80%)	0	16	6:00-22:00	
14–20	0.42 (35%)	1	14	6:00-18:00	22:00-24:00
21–27	0.23 (28%)	1	15	6:00-18:00	22:00- 1:00
28–41	0.23 (28%)	1	16	6:00-18:00	22:00- 2:00
42–45	0.23 (28%)	1	18	5:30-18:30	21:30- 2:30

Abbreviations: ISD, short-dawn/dusk photoperiod.

Table 2. Increasing, long-dawn/dusk photoperiod applied to birds in the ILD treatment day 0 to 45.

Growth day	Intensity (foot candles)	Transition (minutes)	Total hours of light	Cycle 1
0–7	4.3 (100%)	0	23	0:00- 0:00
8	2.5 (80%)	30	16	6:00-22:00
9–11	1.9 (70%)	30	16	6:00-22:00
12–15	1.2 (60%)	30	16	6:00-22:00
16	0.52 (40%)	30	16	6:00-22:00
17–21	0.52 (40%)	30	16	6:00-22:00
22	0.49 (38%)	30	18	6:00-24:00
23	0.44 (36%)	30	18	6:00-24:00
24	0.39 (34%)	30	18	6:00-24:00
25	0.35 (32%)	30	18	6:00-24:00
26	0.31 (30%)	30	18	6:00-24:00
27–32	0.23 (28%)	30	18	6:00-24:00
33–45	0.23 (28%)	30	20	6:00-02:00

Abbreviations: ILD, long-dawn/dusk photoperiod.

total of 100 cells was counted for each slide. Blood was collected from a different subset of birds than that which was used to obtain body weight and welfare measures. In addition, mortality was recorded as it occurred.

Welfare Assessment

Welfare assessment was performed on 100 birds/barn (n = 200/treatment) on day 45 according to the procedures outlined by Arnould et al. (2009). Twenty birds were randomly selected from each of 5 30.48 m sections of each barn and assigned scores for hock burn and foot pad dermatitis. Hock burn and foot pad dermatitis were both scored on a scale of 0 to 4, where a score of 0 indicated normal coloration, and no visible lesions, a score of 1 indicated normal coloration and one lesion less than 0.5 cm in width, a score of 2 indicated 1 lesion 0.5 to 1.0 cm in width, a score of 3 indicated discoloration and one or more lesions larger than 1.0 cm in total width, and a score of 4 indicated severe discoloration and multiple severe lesions more than 1.0 cm in total width (Welfare Quality. 2009). Feather condition was scored on a scale of 0 to 3, where a score of 0 indicated clean plumage, a score of 1 indicated slightly dirty feathers, a score of 2 indicated noticeably dirty feathers, and a score of 3 indicated almost completely dirty plumage. Welfare assessment was performed on the same subset of birds which was used to obtain body weight measurements.

Body Weight

Live body weight was obtained from 100 birds/barn (n = 200/treatment) on day 45. Twenty birds from each of 5 30.5 m sections of each barn were weighed on a hanging scale with shackles (BW-2050, Weltech International, Ltd., Cambridgeshire, England).

Statistical Analysis

Data for body weight, plasma CORT, and H/L ratio were analyzed for the main effects of treatment (ILD vs. ISD), trial (flock 1-4), and trial × treatment interaction using the GLM procedure in Minitab 17.1.0 followed by mean separation using Fisher's LSD. Normality was confirmed using the Shapiro-Wilk test, and homogeneity of variances was confirmed using Levene's test. All assumptions for ANOVA were met without transformation of the data. Ordinal data from the welfare assessments were analyzed for main effects of treatment and trial in Minitab 17.1.0 using Kruskal Wallis, adjusted for ties. A significant difference was defined as $P \leq 0.05$.

RESULTS

Data for day 45 live body weight, stress measures, and welfare assessment scores are shown in Table 3. There were no interaction effects observed for live body weight ($P > 0.05$), plasma CORT ($P > 0.05$), or H/L ratio ($P > 0.05$). There was an effect of treatment ($P < 0.001$) and trial ($P < 0.001$) on live body weight, which was higher in birds in the ISD treatment; body weight was higher in trial 3 and lowest in trial 1. Plasma CORT was affected by treatment ($P < 0.001$) and was higher in birds in the ISD treatment; CORT was also affected by trial ($P < 0.001$) and was higher in trial 1 and lower in trials 2 and 4, which did not differ from each other. Likewise, H/L ratio was higher in birds in the ISD treatment ($P < 0.001$) and was lowest in trial 2 and 3 and highest in trial 4. Hock burn scores were lower in the ISD treatment ($P = 0.044$) and were affected by trial ($P < 0.001$). Foot pad dermatitis scores were also lower in birds in the ISD treatment ($P < 0.001$) and were affected by trial ($P < 0.001$). Feather condition was affected by trial ($P < 0.001$) but not treatment ($P > 0.05$). There were no effects of treatment ($P > 0.05$), trial ($P > 0.05$) or the treatment × trial interaction ($P > 0.05$) on percent mortality. Mortality was 5.76% for ISD1, 5.58% for ILD1, 3.61% for ISD2, 2.28% for ILD2, 4.05% for ISD3, 4.04% for ILD3, 2.73% for ISD4, and 2.73% for ILD4.

DISCUSSION

Trials differed from each other in day 45 live body weight, probably because of differences in climate, where some flocks were reared during the summer/autumn and

Table 3. Main effects of treatment and trial and interaction effect on day 45 live body weight, stress, and welfare measures on broilers reared under an intermittent, short-dawn/dusk photoperiod (ISD) or an increasing, long-dawn/dusk photoperiod (ILD) day 0 to 45.

Measure	Day 45 body weight	Plasma CORT	H/L ratio	Hock burn	Foot pad dermatitis	Feather condition
Units	kg	pg/mL		04	0-4	0-3
ISD1	2.57	4,484.62	0.58	0.87	1.24	1.04
ILD1	2.67	3,312.46	0.39	0.58	1.27	1.01
ISD2	2.65	1,772.07	0.44	0.43	0.82	1.00
ILD2	2.77	1,202.34	0.28	0.73	1.48	1.03
ISD3	2.95	3,173.07	0.41	0.73	1.43	1.01
ILD3	2.97	1,483.71	0.28	1.06	1.79	1.00
ISD4	2.80	1,730.07	0.89	0.34	1.08	1.00
ILD4	2.90	904.72	1.12	0.27	0.90	1.00
Pooled SEM	0.01	140.80	0.02	0.02	0.03	0.00
Main effect treatment						
ISD	2.82[a]	2,789.97[a]	0.54[a]	0.60[b]	1.14[b]	1.01
ILD	2.74[b]	1,725.81[b]	0.37[b]	0.67[a]	1.36[a]	1.01
P-value treatment	<0.001	<0.001	<0.001	0.044	<0.001	0.616
Main effect trial						
1	2.62[d]	3,898.54[a]	0.49[b]	0.72	1.25	1.03
2	2.71[c]	1,487.20[c]	0.36[c]	0.59	1.15	1.01
3	2.96[a]	2,328.39[b]	0.35[c]	0.91	1.61	1.00
4	2.85[b]	1,317.41[c]	0.63[a]	0.30	0.99	1.00
P-value trial	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
P-value treatment × trial	0.191	0.430	0.913			

[a-c]Values within a column with different superscripts differ ($P < 0.05$).
Abbreviations: CORT, corticosterone; H/L, heterophil/lymphocyte.

others during the winter. Overall, however, birds in the ISD treatment were heavier on day 45 than those in the ILD treatment. Increasing photoperiod has been shown to improve early feed conversion compared with 14L:10D, 16L:8D, or 23L:1D light schedules (Renden et al., 1993). However, intermittent lighting for 2L:4D (Malone et al., 1980) or 1L:3D (Mahmud et al., 2011) has been shown to improve broiler growth and feed efficiency compared with continuous light. Providing intermittent light for 2L:2D has been shown to improve growth performance compared with 8L:16D (Olanrewaju et al., 2012) but not 23L:1D (Olanrewaju et al., 2019) photoperiods. Lien et al. (2007) proposed that the interaction of light intensity and photoperiod is more influential on body weight than photoperiod alone. However, intermittent light (2L:2D) has been shown to increase carcass, fillet, and tender weights compared with a short (8L:16D) photoperiod, regardless of light intensity (Olanrewaju et al., 2012). It has been proposed that intermittent lighting encourages short bursts of activity but low activity overall (Hester, 1994). This type of activity has been shown to improve body weight and feed efficiency (Balog et al., 1997). Finally, birds reared under intermittent light have more feed and fluid in the crop and gizzard at the end of the light period compared with those reared under continuous light, suggesting differences in feeding behavior under different light schedules (Hooppaw and Goodman, 1976). In this study, providing intermittent light with a short dawn/dusk period yielded heavier birds than did increasing daylength with a long dawn/dusk period, probably because of differences in feeding behavior and physical activity.

Trial differences were also observed for plasma CORT and H/L ratio, but overall birds in the ILD treatment had lower plasma CORT and H/L ratio than ISD birds. These results differ from Abbas et al. (2008), who reported higher plasma CORT and H/L ratio in broilers reared under a 12L:12D photoperiod compared with an intermittent (2L:2D) photoperiod. Similarly, previous research has shown that birds reared under near-continuous light had higher plasma CORT levels than broilers reared under intermittent light, although exposure to high intensity light on an intermittent schedule also increased CORT (Buckland et al., 1976). The key difference between findings reported by Abbas et al. (2008) and Buckland et al. (1976), and this study could be the extended dawn/dusk period in the ILD treatment. Extending the dimming period may allow birds to adjust melatonin production (van der Pol et al., 2015). Thus, allowing birds to adjust to the dark period may be more important in regulating stress than altering the relative length of light and dark periods.

Despite trial differences in all welfare assessments, the ISD treatment yielded lower hock burn and foot pad scores. Previous research has been inconclusive in comparing incidence of leg abnormalities under continuous, intermittent, or increasing photoperiods. For example, Sørensen et al. (1999) reported reduced prevalence of foot pad dermatitis and hock burn and improved walking ability in broilers reared under a longer photoperiod. However, in this study, ILD birds had higher hock burn and foot pad dermatitis scores than ISD birds. On the other hand, Renden et al. (1996) showed no differences in leg abnormalities between birds reared under increasing or intermittent photoperiod. Yet Wilson et al. (1984) found that birds reared under intermittent photoperiod were more active and showed reduced incidence and severity of leg abnormalities than those reared under continuous lighting. Changes in walking activity could explain why broilers in the ISD treatment had lower hock burn and foot pad dermatitis scores than birds in the ILD treatment.

The interaction of trial and treatment was not significant for day 45 body weight. Day 45 body weight, hock burn, and foot pad dermatitis scores were all higher in trial 3 than other trials, which suggests a relationship between body weight and welfare scores. However, overall ISD had heavier day 45 body weight but lower hock burn and foot pad dermatitis scores than ILD. Indeed, Sørensen et al. (1999) found that birds with lower body weight had poorer gait score. Thus, conflicting results make it difficult to conclude that day 45 body weight contributed to hock burn and foot pad dermatitis scores in this study.

Environmental conditions could have contributed to trial differences in body weight and welfare assessment scores, particularly because trials 1 and 2 were reared during the summer and autumn, whereas trials 3 and 4 were reared during the winter. Feather score has been correlated with foot pad dermatitis but not hock burn (Haslam et al., 2006). Foot pad dermatitis and hock burn scores were lower in trials 2 and 4; however, feather condition was lower in trials 3 and 4. Additionally, feather score was only affected by trial, whereas foot pad dermatitis and hock burn scores were affected by both trial and treatment. Therefore, barn conditions such as litter moisture content and seasonal changes in temperature and humidity, rather than lighting program, may have affected feather condition.

Providing an extended dimming period between light and dark periods may have been beneficial in reducing stress by allowing birds to adjust to changes in light intensity. On the other hand, intermittent lighting may have affected bird feeding behavior and walking activity, resulting in differences in body weight gain and welfare measures. In conclusion, rearing broilers under an increasing, long-dawn/dusk photoperiod reduced measures of both short-term and long-term stress, whereas providing an intermittent, short-dawn/dusk photoperiod yielded higher day 45 live body weight and reduced hock burn and foot pad dermatitis scores.

ACKNOWLEDGMENTS

Conflict of Interest Statement: The authors did not provide a conflict of interest statement.

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