Lighting pattern and photoperiod affect the range use and feather cover of native laying hens under free range condition

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ABSTRACT The study aimed to investigate the effects of lighting pattern and photoperiod on range use, feather cover and gait score of native laying hens. Six hundred and thirty 19-wks-old Beijing You Chicken (**BYC**) pullets were randomly allocated to 6 groups with 105 birds each, 3 replicates per group, reared in individually lit indoor pens with separate covered shed and outdoor areas. A 2 × 3 factorial experiment (2 lighting patterns: continuous and intermittent lighting; 3 photoperiods: 16 h, 14 h, 12 h) was arranged indoors, including 16L: 8D (6:00−22:00) for group 1; 12L:2D:4L:6D (6:00−18:00,20:00−24:00) for group 2; 14L:10D (6:00−20:00) for group 3; 10L:2D:4L:8D (6:00−16:00,18:00−22:00) for group 4; 12L:12D (6:00−18:00) for group 5, and 8L:4D:4L:8D (6:00−14:00,18:00−22:00) for group 6, respectively. The number of hens in indoor pen, covered shed and outdoor area were counted at 8:00, 9:00, 10:00, 11:00, 12:00, 13:00, 14:00 for consecutive 3 sunny days at 34 wks and 36 wks of age, feather cover and gait score of the laying hens were assessed at the end of 36 wks. The results showed that daily average hen percentage was the highest in continuous 12 h group (63.67%), and the lowest in intermittent 14 h group (58.36%) in indoor pen ($P < 0.05$); the daily average hen percentage was the lowest in continuous 12 h group (16.05%), and the highest in intermittent 14h group (21.22%) in outdoor area ($P < 0.05$). Lighting pattern significantly affected hen percentage in indoor pen and outdoor area, the hen percentage in indoor pen was higher in continuous lighting groups than in intermittent lighting groups (62.09% vs. 59.23%) ($P < 0.05$), the hen percentage in outdoor area was lower in continuous lighting groups than in intermittent lighting groups (16.60% vs. 19.95%) ($P < 0.05$). Photoperiod had no effect on the hen percentage ($P > 0.05$), but time of day affected the hen percentage in different areas ($P < 0.05$). The feather cover score was higher in intermittent lighting groups than in continuous lighting groups (17.43 vs. 15.04, $P < 0.05$). The average hen percentage in indoor pen is strongly negatively correlated with the feather cover score ($r = -0.880$, $P = 0.050$), and the hen percentage in outdoor area is strongly positively correlated with the feather cover score in intermittent lighting condition ($r = 0.811$, $P < 0.05$). The present study suggested that more range use is beneficial for the feather cover and physical health of laying hens under free range condition, and intermittent lighting is more conducive to range use and feather cover of native laying hens, which may be related to its affecting hens' rhythmic activities, increasing adaptation to outdoor environment, and reducing the incidence of feather pecking and parasites.

Key words: lighting pattern, photoperiod, range use, feather cover, laying hens

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INTRODUCTION

Recent years more and more consumers have begun to pay attention to animal welfare, and have been willing to pay for animal welfare products (Fredrik et al., 2007; Yang, 2018). Free range is regarded as a kind of natural and animal friendly system, it could provide hens with the choice between indoor and outdoor areas, the opportunity to access fresh air, and exhibit behaviors such as sun bathing and foraging (Knierim, 2006); Free range could meet behavioral domain (Mellor and Beausoleil, 2015), increase chicken health and welfare (Yilmaz Dikmen et al., 2016), product quality and taste, and agroecological biodiversity, etc. (Almeida et al., 2012; Taylor et al., 2020). However, the meteorological factors directly affect the use of the system mainly by not providing favorable conditions related to thermal comfort (Netto et al., 2018).

The range use of hens can be an important indicator of animal welfare affected by free range. The good range use will lower hen number in the house during the

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daytime, increase the usage of resources, provide the hens with enriched environment (Knierim, 2006), and reduce feather pecking (Nicol et al., 2003; Lambton et al., 2010). But usually there are only a small portion of hens outside, majority of hens remaining in the house or the area close to the house (Harlander-Matauschek et al., 2001; Zeltner and Hirt, 2003).

The range use of hens is affected by many factors, e.g. weather condition, number of popholes (Keeling et al.,1988), availability of cover (Grigor and Hughes, 1993), fear of predation (Grigor et al., 1995), cockerel presence and ratio (Bestman and Wagenaar, 2003; Hegelund et al., 2005), vegetation (Nicol et al., 2003), flock size (Hegelund et al., 2005), genetics (Icken et al., 2008), light intensity in the house and pophole availability (Gilani et al., 2014), outdoor-preferring of hens (Singh et al., 2016), outdoor stocking density (Campbell et al., 2017b).

Light plays an important role in providing rest and regeneration, and adjusting activities of poultry (Kristensen et al., 2007; Zawilska et al., 2007), such as egg-laying, feeding, etc. Increasing lighting time and altering circadian rhythms increases both wakefulness and mobility in broilers (Bradshaw et al. 2002). The broilers under 24h continuous light did not have a stable feeding rhythm (Ferrante et al. 2006), and the broilers under continuous 8h dark period can change their feeding patterns substantially (Duve et al., 2011). Manser (1996) reviewed the effects of lighting on the welfare of domestic poultry, and found that the preferences of birds for different lighting condition are lacking. Ma et al. (2016) reported that hens preferred to rest in dark intermittently throughout the day, averaging 25 min per hour, which differed from the typical commercial practice of providing continuous darkness at night, and the intermittent lighting strategies have the effect of minimizing heat stress (Lin et al., 2006).

Beijing You Chicken (BYC), a dual-purpose native chicken used for meat and egg production in northern part of China, was listed as one of the most important chicken breeds by Ministry of Agriculture (National Livestock and Poultry Genetic Resources Committee., 2011). Many BYC farms adopt free range system, using the orchards, hillsides, and woods for range area, the birds going outdoors during the day, and returning indoors to rest at night, and egg production in free range condition was generally to be lower than in cage condition (our survey result and Yang, et al., 2013), there could be many reasons: different thermal environment, air quality, and lighting condition, etc. Shen et al. (2011) studied the effects of 4 kinds of lighting regimes (16L:8D,6:00−22:00; 12L:2D:4L:6D, 6:00−18:00, 20:00−24:00; 8L:4D:4L:8D, 8:00−16:00, 20:00−24:00; 16L:8D, 3:00−19:00) on performance of BYC laying hens, and found that the intermittent 12 h lighting (8L:4D:4L:8D) had beneficial effects on performance for the prelaying and peak laying period. Our group adopted 6 kinds of lighting regimes to study the egg laying of BYC during 20 to 61wks, and found that the egg-laying rate was significantly higher in intermittent 16 h group than in continuous 16 h group (Geng et al., 2014). We further studied the effects of lighting pattern and photoperiod on egg production of BYC hens aged from 22 wks to 57 wks, and found that continuous lighting was better for the egg production during 44 to 57 wks, and intermittent lighting was better for egg quality of the native bird at 37 wks (Geng et al., 2018). It is not clear if indoor lighting regime affects the welfare of laying hens under free range condition, so this present study was to investigate the effects of lighting pattern and photoperiod alone and in interaction on range use, feather cover and gait score of native laying hens, in order to provide some reference for appropriate lighting regime.

MATERIALS AND METHODS

Experimental Design and Birds

The experiment was conducted at BYC breeding farm, Daxing district, Beijing. Six hundred and thirty 19-wks-old BYC pullets (1.66 ± 0.23 kg/hen) were randomly allocated to 6 experimental groups, 105 birds every group with 3 replicates, 35 birds per replicate. The birds were reared in individually lit indoor pens with covered shed and outdoor range area (the profile drawing of the system was seen in Figure 1). Each pen is 3 m width and 8 m length. The feed troughs were suspended in layers outside the wire mesh near the aisle, and two drinking fountains were used. Nest boxes, perches and rice hulls were provided in each pen. The outdoor area was covered with grass and enclosed with wire mesh. A covered plastic shed connected the indoor pen and the outdoor area. The hens could enter the covered shed through the popholes. A hand crank was used to control the rise and fall of a rolling curtain to control the access of hens to outdoor area. During the daytime, the chicken was free to stay in indoor pen, covered shed and outdoor

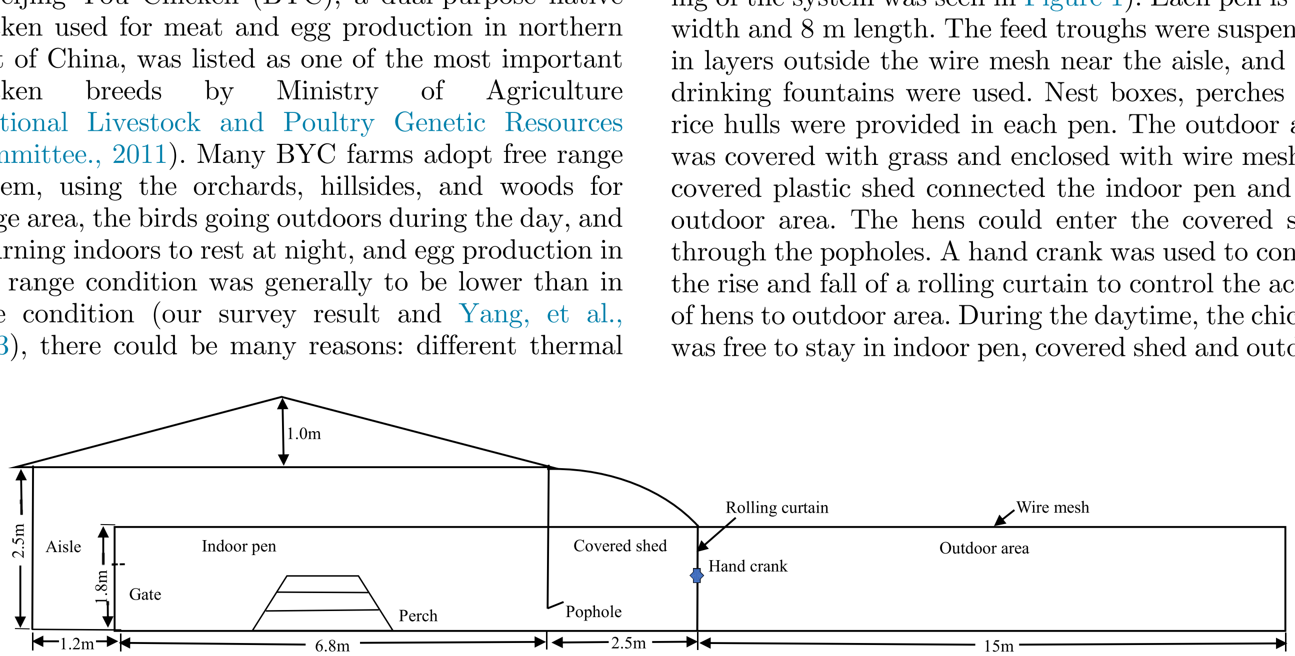

Figure 1. The profile drawing of the free-range system.

area. After the birds returning to the pen, the popholes were closed and the curtain was put down.

A 2 × 3 factorial experiment was arranged (2 lighting patterns: continuous and intermittent lighting; 3 photoperiods: 16 h, 14 h, 12 h), including 16L:8D (6:00−22:00) for group 1; 12L:2D:4L:6D (6:00∼18:00, 20:00−24:00) for group 2; 14L:10D (6:00−20:00) for group 3; 10L:2D:4L:8D (6:00−16:00,18:00−22:00) for group 4; 12L:12D (6:00 −18:00) for group 5; and 8L:4D:4L:8D (6:00−14:00,18:00 −22:00) for group 6, respectively (see Table 1). In order to keep the same ranging time for all the birds, the groups were lighted at 6:00 in the morning, fed from 6:00 to 8:00, ranged freely from 8:00 to 14:00, and returned to the pens after 14:00 when the second feeding begins, the fluorescent lamps were used, and the bulbs were 2 m off the ground, and light intensity was 2.7 watt/m^2 at the level of the birds' heads. Special light-proof cloth and the automatic light controller were used in each pen.

The birds were fed commercial corn-soybean meal-based diets with 15.07% crude protein (CP), 11.20 MJ/kg metabolizable energy (**ME**), and 2.03% calcium during 19 to 21 wks, and with 15.51% CP, 11.08 MJ/kg ME, and 2.75% calcium during 22 to 36 wks (Table 2). Under severe weather conditions such as raining and thundering days, the birds were confined inside the pens to reduce the stress.

The study was performed in accordance with local ethical guidelines and met the requirement of the institutional animal care and use committee.

Measurement and Methods

The number of hens in indoor pen, covered shed and outdoor area were counted by the same two people at 8:00, 9:00, 10:00, 11:00, 12:00, 13:00, 14:00 for consecutive 3 sunny days at 34 wks and 36 wks of age, totaled 6 d. The hen percentage in each zone is the number of the hens at the time of day divided by the total hen number. The daily average hen percentage in each zone is the average of hen percentages at the 7 time points.

The ambient temperature, relative humidity, and ammonia concentration were measured at the same time of day during 34 and 36 wks of age, 5 sites were selected according to "Z" type in each zone, using the portable weather meter (Kestrel 3000; Kestrel Instruments, Boothwyn, PA) and ammonia meter (Smart Sensor AR8500, China).

Table 1. Experimental design and lighting treatments.

Group	Lighting pattern	Photoperiod/(h)	Lighting regimen
1	Continuous	16	16L:8D (6:00−22:00)
2	Intermittent	16	12L:2D:4L:6D (6:00 −18:00, 20:00−24:00)
3	Continuous	14	14L:10D (6:00−20:00)
4	Intermittent	14	10L:2D:4L:8D (6:00 −16:00, 18:00−22:00)
5	Continuous	12	12L:12D (6:00−18:00)
6	Intermittent	12	8L:4D:4L:8D (6:00 −14:00, 18:00−22:00)

Table 2. Composition and nutrient levels of the basal diet.

Ingredients,%	19−21 wks	22−36 wks
Corn	65.5	64.0
Soybean meal	21.5	23.2
Wheat bran	5.0	3.8
Limestone	4	5
Layer premix[1]	4	4
Total	100	100
Calculated nutrient level[2]		
ME/ (MJ/kg)	11.20	11.08
Crude protein/%	15.07	15.51
Calcium/%	2.03	2.75
Total phosphorus/%	0.51	0.51
Available phosphorus/%	0.29	0.29

[1]Layer premix provided per kilogram of diet: Vitamin A, 100-250 KIU; Vitamin D3, 60-80 KIU; Vitamin E, 0.5 KIU; Vitamin K3, 80 mg; Vitamin B1, 45 mg; Vitamin B2, 180 mg; Vitamin B6, 100 mg; Vitamin B12, 0.5 mg; D-Calcium-pantothenate, 220 mg; Nicotinamide, 720 mg; Folic acid, 20 mg; Biotin,2 mg; Copper, 0.2−0.8 g, Ferrous iron, 1.5−5 g; Zinc, 0.8 −2.4g; Manganese,1.5−3 g; Iodine, 10−30 mg; Selenium, 2−6 mg

[2]Calculated using NRC (1994) values.

The feather cover and gait score of the birds were assessed in the morning when all the birds stayed in the pen at the end of 36 wks, and the leg condition was observed. Five sites were selected in each pen according to "Z" type, and three hens were randomly selected at each site for observation and feather cover scoring, after which they were placed on ground for gait observation and scoring (at least 30 s), then immediately returned to the pen. The feather cover scoring was according to Tauson et al. (2005) and Heerkens et al. (2015), and the method was seen in Table 3.

Statistical Analyses

The data were analyzed statistically using SPSS 25.0 Software for Windows (SPSS Inc. Chicago, IL). General linear model (GLM) was used to analyze the main effects of lighting pattern and photoperiod alone, and the interaction of lighting pattern by photoperiod. Duncan's test was used for multiple comparisons. The percentage was arcsine transformed before analysis. $P < 0.05$ was regarded as statistically significant. The relationship between the average hen percentage and the feather cover score was assessed with Pearson's correlation coefficient. Correlation coefficients of $r = 0.70$ or higher was regarded as having a strong positive correlation, and when $r = -0.70$ or lower the variable was regarded as having a strong negative relationship.

RESULTS

Temperature, Relative Humidity and Ammonia

Figure 2 showed that the change of ambient temperature, relative humidity, and ammonia concentration in indoor pen, covered shed and uncovered outdoor area. Figure 2A indicated that ambient temperature increased with the time of day, 26.5 °C at 8:00, 28.2°C at 10:00, reached the highest at 14:00 (33.5°C). The ambient

Table 3. The scoring method for feather cover and gait.

Score	Feather cover	Gait	Assessment
1	Fewer feather cover, >50% scratch marks and some were picked off	Very hesitantly move, did not take a few steps to stop, even squat down	Worse
2	Few feather cover, 20 to 50% scratch marks and some were picked off	Walk irregular, small steps, very unbalanced	Bad
3	General feather cover, <20% scratch marks	Walk regularly and balanced	General
4	Good feather cover, complete and smooth, no scratch marks	Walking easily, regular gait, even striding, well balanced	Best

temperature in indoor pen was numerically higher than in covered shed from 8:00 to 11:00, but lower than in covered shed from 12:00 to 14:00. The ambient temperature in covered shed was very close to outdoor area from 13:00 to 14:00 (>35°C). Figure 2B indicated that relative humidity in covered shed was higher than in indoor pen and outdoor area ($P < 0.05$). Figure 2c indicated that ammonia concentration in indoor pen was significantly higher than in covered shed and outdoor area at each time of day ($P < 0.05$).

Distribution of Laying Hens

Figure 3 showed the distribution of laying hens in indoor pen, covered shed and outdoor area, respectively. Figure 3A indicated the change of hen percentage in indoor pen, the hen percentage was lower from 9:00 to 11:00 (<53%), and higher from 12:00 to 14:00 (>68%). The daily average hen percentage was the highest in continuous 12 h (63.67%), and the lowest in intermittent 14 h (58.36%) in indoor pen ($P < 0.05$). Figure 3B indicated the change of hen percentage in covered shed, the hen percentage was higher from 9:00 to 11:00 (>21.9%), and lower from 12:00 to 14:00 (<17.1%), there had no differences in covered shed (20−22%, $P > 0.05$). Figure 3C indicated the change of hen percentage in outdoor area, the hen percentage was higher from 9:00 to 11:00 (>20%), and lower from 12:00 to 14:00 (<11.4%), the daily average hen percentage was the lowest in continuous 12 h group (16.05%), and the highest in intermittent 14 h group (21.22%) in outdoor area ($P < 0.05$).

Effects of Lighting Pattern and Photoperiod

Table 4 showed that lighting pattern didn't affect the hen percentage in covered shed ($P > 0.05$), but significantly affected the hen percentage in indoor pen and outdoor area ($P = 0.012$ and $P = 0.001$), the hen percentage in indoor pen was higher in continuous lighting groups than in intermittent lighting groups (62.09% vs. 59.23%) ($P < 0.05$), the hen percentage in outdoor area was lower in continuous lighting groups than in intermittent lighting groups (16.60% vs. 19.95%) ($P < 0.05$). Photoperiod had no effects on the hen percentage in indoor pen, covered shed, and outdoor area ($P > 0.05$), but time of day had significant effects on the hen percentage in these areas ($P < 0.05$), the hen percentage in outdoor area was the highest at 10:00 (34.60%), and the lowest at 14:00 (6.98%).

Table 5 showed that lighting pattern alone significantly affected the feather cover of laying hens, the feather cover score of hens was higher in intermittent lighting groups than in continuous lighting groups (17.43 vs. 15.04, $P < 0.05$), but photoperiod alone and the interaction of lighting pattern by photoperiod didn't affect the feather cover ($P > 0.05$). The gait score of birds were not affected by lighting pattern and photoperiod alone or in interaction ($P > 0.05$). The leg condition of all groups was good, no limp or poor walking was noticed.

Table 6 showed that the average hen percentage in indoor pen is strongly negatively correlated with the feather cover score ($r = -0.880$, $P = 0.050$), the hen percentage in outdoor area is strongly positively correlated with the feather cover, but not significantly ($r = 0.994$, $P > 0.05$); the hen percentage in outdoor area is strongly positively correlated with the feather cover score in intermittent lighting condition ($r = 0.811$, $P < 0.05$).

DISCUSSION

Range use has been regarded as an important indicator of animal welfare under free range system (Knierim, 2006). Nicol et al. (2003) observed, on average, 14 to 22% of the birds on the range at any one time, and a lower percentage (9%) was found by Hegelund et al. (2005). Chielo et al. (2016) explored the range use of laying hens in commercial free-range flocks, they divided outdoor areas into 3 zones: apron, enriched belt and outer range based on distance from shed, and found that on average, 12.5% of hens were outside, and of these birds, 5.4% were in the apron, 4.3% in the enriched zone, and 2.8% were in the outer range. This present study used indoor pen, covered shed, and outdoor area, and showed that the hen percentage in different zones was different at different time of day, and daily average hen percentage was 58.36 to 63.67% in indoor pen, 20 to 21% in covered shed, and 16.05 to 21.22% in outdoor area, slightly higher than the 12.5% mentioned above, and close to Nicol et al. (2003) reported, further testified that the hens used much less outdoor area than indoor pen.

Some researchers found that more birds used the range in smaller flocks (Bestman and Wagenaar, 2003; Gebhardt-Henrich and Fröhlich, 2012). Gebhardt-Henrich et al. (2014) assessed the ranging behavior on a covered (veranda) and an uncovered run (free-range) in laying hens with small, medium and large size, and found that there had no association between the hen percentage

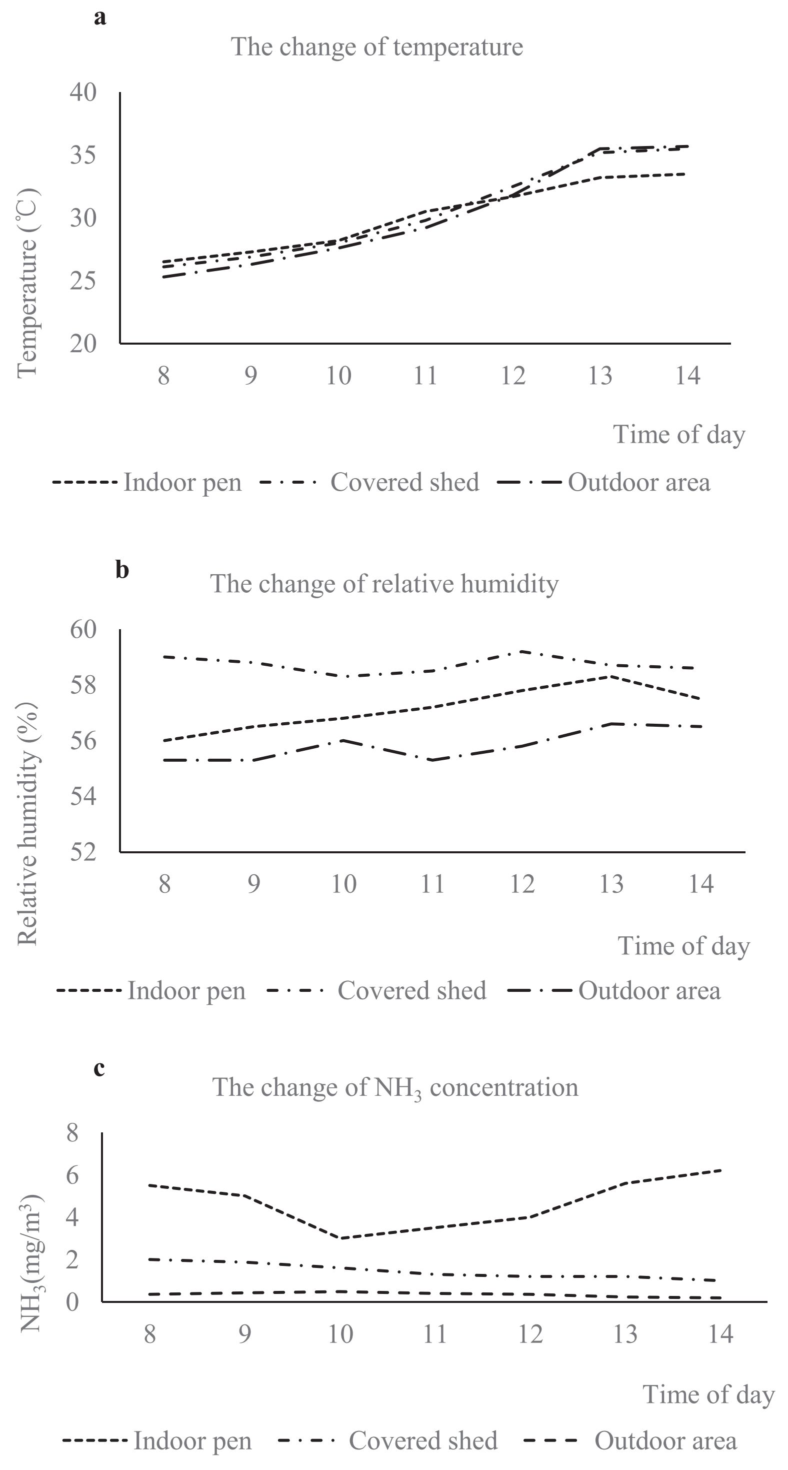

Figure 2. The Change of temperature, relative humidity and ammonia concentration. (a) The change of temperature for different zones. (b) The change of relative humidity at different zones. (c) The change of ammonia concentration at different zones.

outside the house and flock size, however, individual hens in small and medium sized flocks visited the areas outside the house more frequently and spent more time there than hens from large flocks. Campbell et al. (2017a) studied the range use of ISA Brown laying hens at one of 3 different outdoor stocking densities (simulating 2,000, 10,000, and 20,000 hens/ha), and found that the highest percentage of birds were observed on the range in 2,000 hens/ha density and the lowest percentage in 20,000 hens/ha density. They further observed that hens from the 2,000 hens/ha density were in visibly good condition (Campbell et al., 2017b), the footpad dermatitis and keel damage among the birds had minimal differences (Campbell et al., 2018). The present study used small sized flocks, the advantages are to conveniently count the number of hens in different zones at different time of day, and understand the change of hen percentage over time, the disadvantage is not reflecting the influence of large sized flocks.

Chielo et al. (2016) found that hens in outer range and enriched belts had better feather condition than those from

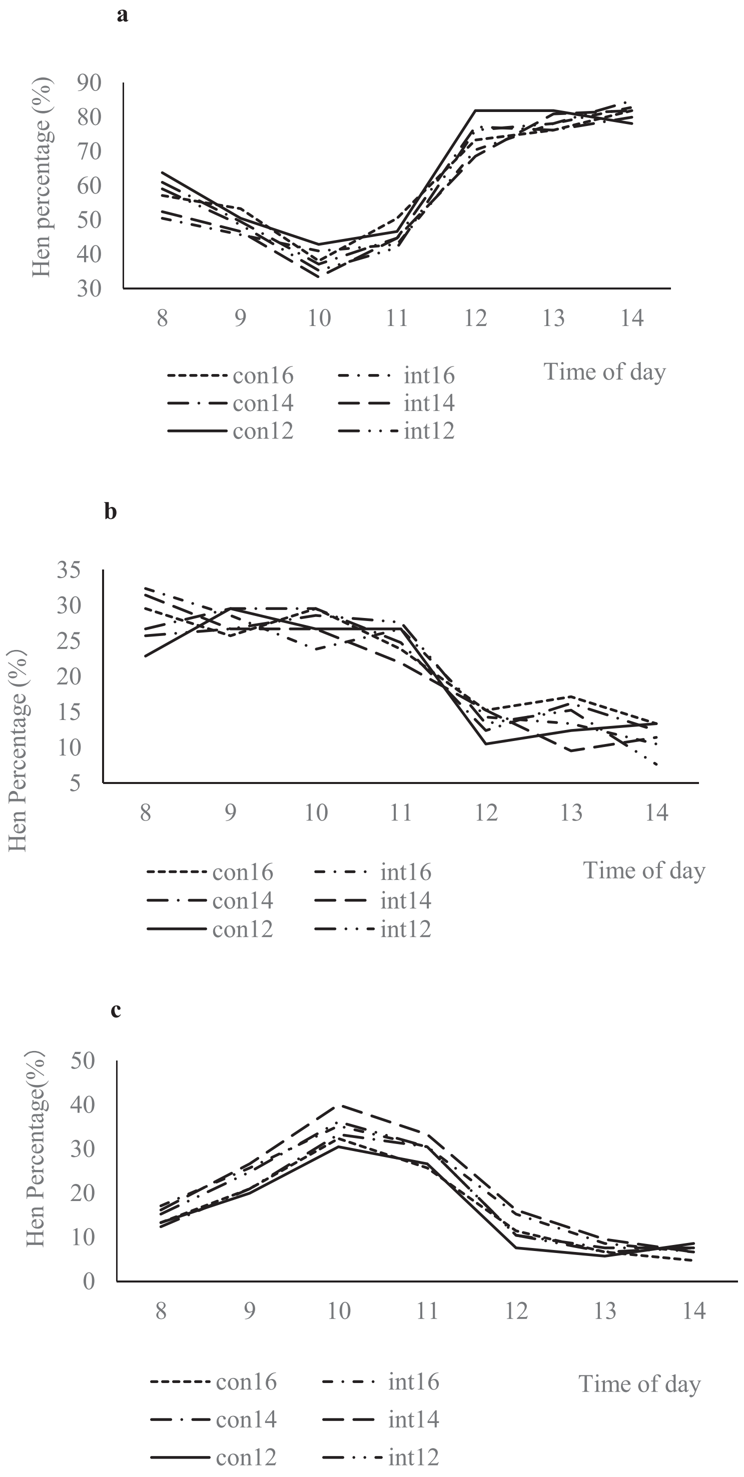

Figure 3. The hen percentage in indoor pen, covered shed and outdoor area. (a) The hen percentage in indoor pen. (b) The hen percentage in covered shed. (c) The hen percentage in outdoor area. Note: con16: 16L:8D, 6:00−22:00; int16: 12L:2D:4L:6D, 6:00−18:00. 20:00−24:00; con14: 14L:10D, 6:00−20:00; int14: 10L:2D:4L:8D, 6:00−16:00,18:00−22:00; con12: 12L:12D, 6:00−18:00; int12: 8L:4D:4L:8D, 6:00−14:00,18:00−22:00.

the apron, and suggested positive relationships between range use, feather condition and increased behavioral opportunities and decline in the range use in cold and/or damp condition. In this present study we found that the average hen percentage in indoor pen is strongly negatively correlated with the feather cover score, the hen percentage in outdoor area is strongly positively correlated with the feather cover score, which testified that more range use of laying hens benefits for the feather cover, and the range use of hens also declined under the high temperature. Temperature varied with the time of day and influenced the range use with fewer hens out of indoor pen as temperature rose at noon.

Kjaer and Sørensen (2002) used 3 genotypes, two levels of light intensity (3 or 10 lx) and early versus late (4 wks old or 16 wks old) access to the range area, and found that age at access to the range and light intensity during rearing did not affect the plumage condition of the birds at 35 wks. The birds are reluctant to go outside

Table 4. Effects of lighting pattern and photoperiod on hen percentage at different time of day (%).

Lighting pattern	Photoperiod/(h)	Time of day	Indoor pen	Covered shed	Outdoor area
Continuous	16	8	57.14 ± 2.86	29.52 ± 4.36	13.33 ± 1.65
		9	53.33 ± 8.25	25.71 ± 7.56	20.95 ± 1.65
		10	38.10 ± 8.73	29.52 ± 5.95	32.38 ± 4.36
		11	52.38 ± 6.60	23.81 ± 7.19	23.81 ± 9.18
		12	73.33 ± 7.19	15.24 ± 6.60	11.43 ± 2.86
		13	76.19 ± 8.25	17.14 ± 4.95	6.67 ± 3.30
		14	81.90 ± 4.36	13.33 ± 3.30	4.76 ± 1.65
Continuous	14	8	60.95 ± 3.30	26.67 ± 3.30	12.38 ± 3.30
		9	49.52 ± 5.95	29.52 ± 4.36	20.95 ± 1.65
		10	37.14 ± 7.56	29.52 ± 6.60	33.33 ± 8.25
		11	44.76 ± 10.03	24.76 ± 4.36	30.48 ± 5.95
		12	77.14 ± 4.95	12.38 ± 4.36	10.48 ± 1.65
		13	76.19 ± 1.65	16.19 ± 4.36	7.62 ± 3.30
		14	80.0 ± 2.86	12.38 ± 3.30	7.62 ± 1.65
Continuous	12	8	63.81 ± 1.65	22.86 ± 4.95	13.33 ± 3.3
		9	50.48 ± 1.65	29.52 ± 4.36	20.0 ± 5.71
		10	42.86 ± 7.56	26.67 ± 1.65	30.48 ± 8.25
		11	46.67 ± 9.18	26.67 ± 5.95	26.67 ± 4.36
		12	81.90 ± 9.18	10.48 ± 5.95	7.62 ± 4.36
		13	81.90 ± 5.95	12.38 ± 3.30	5.71 ± 2.86
		14	78.1 ± 1.65	13.33 ± 3.30	8.57 ± 2.86
Intermittent	16	8	50.48 ± 8.25	32.38 ± 8.73	17.14 ± 2.86
		9	45.71 ± 8.57	28.57 ± 4.95	25.71 ± 4.95
		10	40.95 ± 4.36	23.81 ± 3.30	35.24 ± 7.19
		11	42.86 ± 5.71	26.67 ± 4.36	30.48 ± 4.36
		12	70.48 ± 5.95	14.29 ± 2.86	15.24 ± 5.95
		13	78.10 ± 5.95	13.33 ± 3.30	8.57 ± 2.86
		14	82.86 ± 2.86	10.48 ± 3.30	6.67 ± 1.65
Intermittent	14	8	52.38 ± 10.03	31.43 ± 5.71	16.19 ± 4.36
		9	46.67 ± 1.65	26.67 ± 3.30	26.67 ± 1.65
		10	33.33 ± 4.36	26.67 ± 4.36	40.0 ± 7.56
		11	44.76 ± 8.25	21.9 ± 4.36	33.33 ± 4.36
		12	68.57 ± 7.56	15.24 ± 3.3	16.19 ± 4.36
		13	80.95 ± 5.95	9.52 ± 1.65	9.52 ± 4.36
		14	81.90 ± 4.36	11.43 ± 2.86	6.67 ± 1.65
Intermittent	12	8	59.05 ± 1.65	25.71 ± 2.86	15.24 ± 4.36
		9	48.57 ± 8.57	26.67 ± 3.3	24.76 ± 5.95
		10	35.24 ± 4.36	28.57 ± 7.56	36.19 ± 4.36
		11	41.90 ± 8.73	27.62 ± 8.73	30.48 ± 8.73
		12	76.19 ± 4.36	13.33 ± 1.65	10.48 ± 3.30
		13	78.10 ± 6.60	15.24 ± 5.95	6.67 ± 1.65
		14	84.76 ± 1.65	7.62 ± 1.65	7.62 ± 1.65
Main effects					
Lighting pattern	Continuous		62.09 ± 16.56^{a}	21.32 ± 8.16	16.60 ± 10.25^{b}
	Intermittent		59.23 ± 18.25^{b}	20.68 ± 9.12	19.95 ± 11.63^{a}
P value			0.012	0.564	0.001
Photoperiod	16		60.27 ± 16.73	21.7 ± 8.49	18.03 ± 10.62
	14		59.59 ± 17.84	21.02 ± 8.37	19.39 ± 11.66
	12		62.11 ± 17.97	20.48 ± 8.67	17.41 ± 11.0
P value			0.170	0.510	0.137
Time of day	8		57.30 ± 6.75^{c}	28.10 ± 5.65^{a}	14.60 ± 3.38^{d}
	9		49.05 ± 6.06^{d}	27.78 ± 4.36^{a}	23.17 ± 4.37^{c}
	10		37.94 ± 6.34^{e}	27.46 ± 4.91^{a}	34.60 ± 6.57^{a}
	11		45.56 ± 7.75^{d}	25.24 ± 5.48^{a}	29.21 ± 6.32^{b}
	12		74.60 ± 7.26^{b}	13.49 ± 4.14^{b}	11.90 ± 4.52^{d}
	13		78.57 ± 5.57^{ab}	13.97 ± 4.37^{b}	7.46 ± 2.96^{e}
	14		81.59 ± 3.43^{a}	11.43 ± 3.25^{b}	6.98 ± 2.01^{e}
P value			0.001	0.001	0.001
Lighting pattern × Photoperiod *P* value			0.966	0.733	0.860
Lighting pattern × Time of day *P* value			0.188	0.347	0.581
Photoperiod × Time of day *P* value			0.687	0.684	0.864
Lighting pattern × Photoperiod × Time of day *P* value			0.810	0.750	0.987

[a-e]Values with different letter superscripts in the same column mean significant difference ($P < 0.05$).

when the light intensity inside the house is very different from the one outside the house (Bestman and Keppler, 2005). Rearing young birds with natural light can counteract the tendency of older birds to avoid bright daylight (Gunnarsson et al., 2008).

The lighting pattern and duration of the lighting allows the hen to establish a circadian rhythm (Dawson et al., 2001). Wang (2010) showed that the intermittent lighting can affect daily peak period of feeding and egg-laying of Hyline Grey laying hens. Our latest research indicated that light regimes affected the frequency and duration of feeding, egg-laying in BYC laying hens (Geng et al., 2022). In this present study, the hen percentage in indoor pen was higher in continuous lighting groups than intermittent lighting groups (62.09% vs. 59.23%), the hen percentage in outdoor area

Table 5. Effects of lighting pattern and photoperiod on feather cover and gait score.

Lighting pattern	Photoperiod/(h)	Feather cover	Gait score
Continuous	16	15.14 ± 0.71	3.54 ± 0.09
	14	15.04 ± 0.75	3.43 ± 0.14
	12	14.95 ± 0.29	3.47 ± 0.13
Intermittent	16	17.94 ± 0.61	3.68 ± 0.21
	14	17.88 ± 0.49	3.45 ± 0.12
	12	16.47 ± 0.65	3.51 ± 0.06
Main effects			
Lighting pattern	Continuous	15.04 ± 0.54[b]	3.48 ± 0.11
	Intermittent	17.43 ± 0.88[a]	3.55 ± 0.16
P value		0.001	0.297
Photoperiod	16	16.54 ± 1.65	3.61 ± 0.16
	14	16.46 ± 1.66	3.44 ± 0.12
	12	15.71 ± 0.95	3.49 ± 0.09
P value		0.067	0.111
Lighting pattern × Photoperiod *P value*		0.141	0.712

[a,b]Values with different letter superscripts in the same column mean significant difference ($P < 0.05$).

Table 6. Relationship between the average hen percentage and the feather cover score.

Item	Correlation Coefficient (r)	*P* value
Indoor pen	−0.880	0.050
Covered shed	−0.277	0.081
Outdoor area	0.944	0.228
Continuous lighting, outdoor area	0.223	0.314
Intermittent lighting, outdoor area	0.811	0.014

was lower in continuous lighting groups than in intermittent lighting groups (16.60% vs. 19.95%), indicating that the birds in intermittent lighting groups were more likely to go outside, which may be related to the fact that hens living under intermittent lighting condition are more adaptable to the changing outdoor environment, and possibly with greater total antioxidant capacity and lower malondialdehyde content for the birds as reported by Farghly et al.(2019).

Feather cover and gait score can partly reflect the welfare status of poultry. Nicol et al. (2003) reported a beneficial effect of increased range use of hens, with a 9-fold decrease in feather pecking when more than 20% of hens used the range on sunny days. Increased range use was associated with low injurious feather pecking in free-range laying flocks (Bright et al., 2011; Lambton et al., 2010). They suggested that providing 5% cover within 20 to 25 m from the hen house is beneficial to improve feather condition and when a higher proportion of hens use the range, that damaging feather pecking was reduced.

Greater use of the outdoor range has also been correlated with lower incidences of footpad dermatitis (Rodriguez-Aurrekoetxea and Estevez, 2016) and less plumage damage (Chielo et al., 2016), but Hartcher et al. (2016) found no association between range use and plumage damage. In this present study, a higher feather cover score was found in intermittent lighting groups than in continuous lighting groups (17.43 vs. 15.04), which is partly due to reduced feather pecking as described above, and partly due to intermittent lighting that limits the number of D. *gallinae* (poultry red mite) by disturbing its feeding pattern (Zoons, 2004; Stafford et al., 2006), was regarded as a promising alternative for controlling D. *gallinae* invasion in all kinds of production system, while the gait score did not differ, the birds in all groups maintained good leg condition, no limp or poor walking was noticed.

CONCLUSION

The present study suggested that more range use is beneficial for the feather cover and physical health of laying hens under free range condition, and intermittent lighting is more conducive to range use and feather cover of native laying hens, which may be related to its affecting hens' rhythmic activities, increasing adaptation to outdoor environment, and reducing the incidence of feather pecking and parasites.

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DISCLOSURES

The authors declared that we have no conflicts of interest to this work.

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