The influence of the duration of the "subjective day" under intermittent LED lighting on the daily rhythm of oviposition and the productivity of hens

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Abstract. Lighting is the key factor affecting oviposition time. The oviposition time is directly related to ovulation, which occurs 5 hours after reaching the peak concentration of luteinizing hormone in the blood, which depends on the lighting regime. This paper studies the impact of the "subjective day" duration under intermittent LED lighting on the daily rhythm of oviposition and the productivity of hens of the productive flocks of cross SP-789. The "subjective day" lasted 16 hours per day for group 1, 15 h for group 2, 14 h for group 3 and 13 h for group 4. It was established that the shorter the duration of the “subjective day”, the earlier the hens begin and finish laying. So, in groups 1, 2, 3, and 4, hens began laying eggs at 4 a.m., 3 a.m., 2 a.m., and 1 a.m. and ended at 6 p.m., 4 p.m., 4 p.m., and 3 p.m. with an average time of laying eggs of 8.67; 7.36; 5.36 and 5.27 h, respectively. In groups 1, 2, 3, and 4 the livability of hens, weight of eggs, egg production and yield of egg weight per the initial laying hen, feed consumption for 10 eggs and 1 kg of egg weight were 98.0, 97.0, 99.0, 99.0%; 60.0, 59.9, 60.4, 59.7 g; 123.9, 124.1, 130.3, 126.1 pcs, 7.48, 7.47, 7.97, 7.63 kg; 1.37, 1.36, 1.32, 1.36, and 2.28, 2.26, 2.18, 2.26 kg, respectively.

1. Introduction

Lighting is a powerful exogenous factor that regulates many physiological and behavioral processes in poultry [1-4]. It is the most significant of all the factors influencing the oviposition time [5]. The oviposition time is directly related to ovulation, which occurs 5 hours after reaching the peak concentration of luteinizing hormone in the blood, which in turn depends on the lighting regime [6-9].

The authors [10] report that the "dawn" time (switch on the light) and the "dusk" time (switch off the light) have approximately the same impact on the oviposition time. However, according to later studies [11], the time of “dusk” has a more significant impact on the oviposition time than the time of “dawn”.

The oviposition time influences the egg quality indicators. The eggs laid in the morning were heavier than those laid later in the day. The best eggshell quality was observed in eggs laid during the day [12-15]. At the same time, eggs laid during the day, in comparison with the morning ones, contain slightly less yolk [13, 14] and much more protein [16].

At present, at the poultry farms aimed at egg production, intermittent lighting regimes are widely used. These conditions, in comparison with constant daylight hours, ensure not only the reduced
energy consumption for lighting, but also the increased livability of livestock and poultry productivity, the improved egg quality, feed conversion [17- 20], and vision, and the reduced stress-relatedness of hens [17, 18, 21, 22].

This work aims to study the daily rhythm of oviposition, the productivity and quality of eggs of hens of the productive flocks with different durations of the "subjective day" in the conditions of intermittent LED lighting.

2. Materials and methods
The study was carried out using the hens of the productive flocks of cross SP-789 in the vivarium of the Selection and Genetic Center "Zagorskoe Experimental Breeding Farm". The 124-day-old hens were divided into 4 groups of 100 heads each. Hens up to 290 days of age were kept in KOH cage batteries (5 animals per cage).

The lightning regimes were the following:

- 1L:6D:4L:2D: 3L:8D for the control group 1;
- 1L:5D:4L:2D:3L:9D for the experimental group 2;
- 1L:4D:4L:2D:3L:10D for the experimental group 3;
- 1L:3D:4L:2D:3L:11D for the experimental group 4.

The light was first turned on at 2 a.m. in all groups, and further the appropriate schemes were used. The duration of the “subjective day” (from the first light on to the beginning of the longest dark period of the regime) was regulated by the evening time. In groups 1, 2, 3, and 4, it was 16, 15, 14, and 13 hours, respectively, with equal duration (8 hours) and intensity (10 lux) of illumination in all groups.

The light sources were LED lamps of a white warm spectrum with a color temperature of 3000 K.

Feeding and housing conditions, which are not the subject of this study, were maintained in accordance with the current recommendations for the technology of poultry egg production [19].

Below we specify the indicators assessed during the study:

- The daily rhythm of oviposition was recorded using a video camera (color AHD-VIDEO CAMERA 720/960/1080P "Day/Night" with IR illumination and with a 4-channel hybrid AHD video recorder (TSr -HV0411 Forward) for 5 days, eggs laid by hens in groups, in the beginning, middle and end of the experiment;
- The egg production was determined by daily recording of laid eggs by groups;
- The livestock livability was determined by daily registration of dead poultry;
- The live weight of poultry was determined by individually weighing the entire population of the 124- and 290-day-old hens from each group;
- The feed consumption per head was determined by control accounting of the given feed and its residues for three days running in the middle of each month;
- Feed consumption per unit of production were calculated;
- Weight of eggs was determined by individually weighing all eggs from each group, laid by hens for 3 days running, in the middle of each month, starting from the 140-day age;
- The egg yield by category was determined from weighing and inspection of eggs laid by hens for 3 consecutive days monthly. The interstate standard GOST 31654-2012 “Edible hen eggs. Technical conditions ” was used;
- The weight of protein, yolk, and eggshell, the thickness of the eggshell were assessed according to the generally accepted methods (15 eggs from each group) for the 155-, 185-, 215-, 245- and 275-day-old hens;
- The content of carotenoids, vitamins A, E, and B2 in the yolk; the content of vitamin B2 in protein; the content of calcium in the eggshell were determined according to the generally accepted methods for the 155-, 185-, 215-, 245- and 275-day-old hens.
3. Results and discussion
The recorded daily rhythm of oviposition, presented in table 1, shows that with a decrease in the duration of the "subjective day" the hens started laying earlier and completed it earlier. Thus, in groups 1(c), 2, 3, and 4, with the simultaneous switching on the light at 2 a.m., hens began laying eggs at 4, 3, 2, and 1 a.m. and finished it at 6, 4, 4, and 3 p.m.

| Time, h | 1(c) | 2 | 3 | 4 |
|---------|------|---|---|---|
| 24-1    | -    | - | - | - |
| 1-2     | -    | - | - | 4.1|
| 2-3     | -    | - | 8.3| 8.2|
| 3-4     | -    | 1.5| 25.0| 21.4|
| 4-5     | 11.6 | 29.2| 22.6| 20.4|
| 5-6     | 8.7  | 20.0| 11.9| 18.4|
| 6-7     | 16.0 | 7.7 | 13.1| 12.3|
| 7-8     | 16.0 | 12.4| 7.1 | 5.1 |
| 8-9     | 7.3  | 4.6 | 4.8 | 1.0 |
| 9-10    | 1.4  | 1.5 | 2.4 | 1.0 |
| 10-11   | 16.0 | 3.1 | 2.4 | 4.1 |
| 11-12   | 10.1 | 7.7 | -  | 2.0 |
| 12-13   | 5.8  | 3.1 | 1.2 | -  |
| 13-14   | -    | 1.5 | -  | -  |
| 14-15   | 4.3  | 6.2 | -  | 2.0 |
| 15-16   | -    | 1.5 | 1.2 | -  |
| 16-17   | 1.4  | -  | -  | -  |
| 17-18   | 1.4  | -  | -  | -  |
| 18-19   | -    | -  | -  | -  |
| 19-20   | -    | -  | -  | -  |
| 20-21   | -    | -  | -  | -  |
| 21-22   | -    | -  | -  | -  |
| 22-23   | -    | -  | -  | -  |
| 23-24   | -    | -  | -  | -  |
| Total   | 100  | 100 | 100| 100|

Incl. for the period:
| From 2 to 10 a.m. | 61.0 | 76.9 | 95.2 | 91.9 |
| From 2 a.m. to 1 p.m. | 92.9 | 90.8 | 98.8 | 98.0 |
| From 1 p.m. to the end of the “subjective day” | 7.1  | 9.2  | 1.2  | 2.0 |

| light | 31.0 | 24.6 | 17.9 | 21.4 |
| darkness | 69.0 | 75.4 | 82.1 | 78.6 |

| The average time of oviposition, h | 8.67±0.38 | 7.36±0.41 | 5.36±0.26 | 5.27±0.26 |

It should be noted that in experimental groups 3 and 4, from the first switch on until 8 a.m., 88.0 and 89.9% of the daily amount of eggs were laid. These indicators are 17.2–35.7 and 19.1–37.6% higher than in groups 1 and 2, respectively. From 2 a.m. to 10 a.m. and from 2 a.m. to 1 p.m., the largest number of eggs (95.2 and 98.8%) was laid in experimental group 3, which is 3.3–34.2 and 0.8–8.0% higher than in the other groups.
After 1 p.m., in experimental group 3, 1.2% of the daily yield was laid versus 7.1, 9.2 and 2.0% in groups 1, 2 and 4, respectively. In experimental group 3, 82.1% of eggs from the daily yield were laid in the darkness, which is 3.5-13.1% more than in other groups. The average oviposition time in groups 1, 2, 3, and 4 was 8.67, 7.36, 5.36, and 5.27 h, or 14.67, 14.36, 13.36, and 14.27 h after the last switch off. The difference in this indicator is significant between groups 2 and 1 (P <0.05); 3, 4, and 1 (P <0.001); 3, 4, and 2 (P <0.001).

Data from Table 2 show that during the period of the experiment, the livability of the livestock in all groups was high and amounted to 97.0-99.0%, with some lagging behind the experimental group 2. The loss of hens in all groups was not associated with the studied factor.

At 290 days of age, the hens of experimental group 3 were 2.0-3.3% superior in terms of live weight, to their peers from other groups, the excess over group 2 was with certainty (P <0.05).

The change of the daily rhythm of oviposition with a shift to the morning time (up to 10 a.m.) in group 3, allowed to obtain the maximum egg production and the yield of egg weight for the initial and middle hens by 3.3-5.2; 3.2-5.2 and 4.5-6.7; 3.1-4.6 % higher than in other groups, while the feed consumption for 10 eggs and 1 kg of egg weight were reduced by 2.9-3.6 and 3.5-4.9%, respectively.

| Indicator                                      | Group 1 | Group 2 | Group 3 | Group 4 |
|------------------------------------------------|--------|--------|--------|--------|
| Livability of livestock for the period of 124-290 days, % | 98.0   | 97.0   | 99.0   | 99.0   |
| Live weight (g) at the age of the hen, days: |        |        |        |        |
| 124                                           | 1280±14.4 | 1267±11.8 | 1288±13.9 | 1273±13.5 |
| 290                                           | 1664±19.4 | 1660±18.9 | 1714±19.2 | 1681±20.4 |
| Egg production (pcs.) per a hen:               |        |        |        |        |
| initial                                       | 123.9  | 124.1  | 130.3  | 126.1  |
| average                                       | 125.0  | 127.4  | 131.5  | 126.1  |
| Egg weight yield (kg) per a hen:               |        |        |        |        |
| initial                                       | 7.48   | 7.47   | 7.97   | 7.63   |
| average                                       | 7.55   | 7.66   | 7.90   | 7.63   |
| Feed consumption:                             |        |        |        |        |
| per 1 head per day, g                         | 114.5  | 115.4  | 115.8  | 115.1  |
| per 10 eggs, kg                               | 1.37   | 1.36   | 1.32   | 1.36   |
| per 1 kg of egg weight, kg                    | 2.28   | 2.26   | 2.18   | 2.26   |

The daily rhythm of oviposition had a certain impact on the weight of eggs (Table 3). Thus, in experimental group 3, where the maximum (95.2%) number of eggs was laid from 2 to 10 a.m., the egg weight was 0.7–1.2% higher than in the other groups. However, the difference was statistically significant only in comparison with the experimental group 4 (P <0.05), where this indicator was minimal. A clear dependence of the egg weight on the duration of the "subjective day" or on the average oviposition time was established in our experiment.

The higher egg weight in experimental group 3 resulted in an increase in the yield of eggs of the highest category by 1.9–2.5% in comparison with other groups. The maximum egg yield of the selected category was in experimental groups 2 and 4, and the maximum yield of eggs of the first category was in control group 1. The groups differed insignificantly in the yield of eggs of the third category and the number of damaged eggs (broken and cracked).
Table 3. Morphological, chemical, and market properties of eggs.

| Indicator                  | Group 1(c) | Group 2 | Group 3 | Group 4 |
|----------------------------|------------|---------|---------|---------|
| The average egg weight, g  | 60.0±0.19  | 59.9±0.19 | 60.4±0.20 | 59.7±0.19 |
| The yield of eggs (%) by categories |            |         |         |         |
| Higher (>75 g)             | 1.4        | 1.3     | 3.3     | 0.8     |
| Selected (65-74.9 g)       | 18.9       | 21.5    | 18.4    | 21.0    |
| 1                          | 53.5       | 49.7    | 51.1    | 50.0    |
| 2                          | 21.1       | 23.0    | 22.0    | 23.2    |
| 3                          | 0.6        | 0.7     | 0.3     | 0.5     |
| Broken and cracked         | 4.5        | 3.8     | 4.9     | 4.5     |
| Weight:                    |            |         |         |         |
| protein, g                | 38.2±0.20  | 38.4±0.26 | 38.1±0.23 | 37.9±0.27 |
| %                         | 63.8       | 64.4    | 63.8    | 63.7    |
| yolk, g                   | 15.0±0.26  | 14.7±0.26 | 15.0±0.27 | 15.1±0.27 |
| %                         | 25.0       | 24.7    | 25.1    | 25.4    |
| eggshell, g               | 6.7±0.05   | 6.5±0.06 | 6.6±0.05 | 6.5±0.06 |
| %                         | 11.2       | 10.9    | 11.1    | 10.9    |
| Eggshell thickness, μm     | 368±2.36   | 366±3.28 | 362±2.89 | 358±2.55 |
| Protein to yolk ratio     | 2.55       | 2.61    | 2.54    | 2.51    |
| Content:                  |            |         |         |         |
| Calcium in eggshell, %    | 36.86      | 37.14   | 36.76   | 37.17   |
| In yolk, μg/g:            |            |         |         |         |
| carotenoids               | 6.18       | 6.41    | 7.14    | 6.64    |
| vitamin A                 | 4.87       | 5.06    | 5.50    | 5.10    |
| vitamin E                 | 115.31     | 119.90  | 140.69  | 135.60  |
| vitamin B2                | 4.89       | 5.25    | 5.46    | 5.46    |
| vitamin B2 in yolk, μg/g  | 3.84       | 3.67    | 3.74    | 3.89    |

On average, over the period of the experiment, the groups differed insignificantly in the absolute and relative weight of protein, yolk, and eggshell. However, there was a tendency towards an increase in the absolute and relative weight of protein and a decrease in the absolute and relative weight of yolk in experimental group 2, exposed to the “subjective day” of 15 hours. As a result, this group had the highest ratio of protein to yolk (2.61), which was 2.4–4.0% higher than in other groups, which indicates a lower nutritional value of eggs in this group.

In terms of eggshell thickness, control group 1 was 0.5–2.8% superior to other groups, but the difference was statistically significant (P <0.01) only in comparison with group 4. However, this indicator did not affect the number of damaged eggs in this group. This proves that increasing the thickness of the eggshell does not always lead to an improvement in its strength. There was a tendency to a decrease in the thickness of the eggshell with a decrease in the duration of the "subjective day" from 16 to 13 hours per day.

In terms of calcium content in the eggshell and vitamin B2 in protein, the groups differed insignificantly. The maximum contents of carotenoids, vitamins A and E in yolk were recorded in experimental group 3, which was 7.5–15.5, 7.8–12.9, and 3.8–22.0 % higher than in the other groups. The lowest content of vitamin B2 in yolk was in the control group 1, which was 6.9–10.4% lower than in experimental groups 2–4, which differed insignificantly.
4. Conclusion
Thus, according to the results obtained, we can conclude that when the egg-laying hens of productive flocks are grown under intermittent LED lighting, the daily rhythm of oviposition depends on the duration of the “subjective day”. The shorter the “subjective day”, the earlier the hens begin and finish oviposition. A clear dependence of the morphological, chemical, and marker indicators of eggs on the duration of the "subjective day" was not established. The 14-hour "subjective day", in comparison with other studied options, makes it possible to increase the weight of eggs, the content of carotenoids, vitamins A and E in yolk, as well as egg productivity of hens, while reducing feed consumption per unit of production. By changing the duration of the "subjective day", one can adjust the oviposition circadian rhythm in the desired direction.

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