Fiber-optic light guides as secondary sources of light for hen keeping in cage batteries

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Abstract. The method of local illumination of cage batteries with LED lamps, previously developed by us, made it possible to increase the livability and productivity of hens in comparison with the traditional method. In this case, the placement of low-power LED sources directly in each cage requires a large number of rather complex electronic devices across the whole metal structure of the cage battery and extended power transmission lines. This work compares the efficiency of local LED lighting and fiber-optic light guides when keeping hens of the productive flocks of cross SP-789 in traditional cages. The 120-day-old hens were divided by the method of analogs in 2 groups of 100 heads. In the control group, LED lamps were used for local illumination of hens, and in the experimental group, fiber-optic light guides were used with LEDs as the primary source of illumination. The color temperature of light-emitting diodes was 3000 K. Up to 260 days of age, hens were kept in triple-tiered cage batteries, 5 animals per cage. The results of the study showed that in the control and experimental groups, the livability of the livestock was 95.0 and 99.0%, the egg production per initial hen was 99.2 and 102.5 pieces. The weight of eggs was 57.9 and 58.3 g, the yield of the egg weight per initial hen was 5.81 and 5.98 kg, feed consumption for 10 eggs and 1 kg of egg weight were 1.37, 2.35 and 1.30, 2.23 kg, respectively, without significant changes in the morphological and chemical qualities of eggs.

1. Introduction

At present, in the Russian Federation, egg hens of productive and breeding flocks are mainly kept in multi-tiered cage batteries. Having a number of significant advantages, this technology at the same time makes certain difficulties in ensuring the same conditions for the entire flock [1-5]. There are special technical and technological methods for a significant increase in the uniformity of the flock and, consequently, the livability and productivity of chickens [6-10]. Among these is the previously proposed method of local illumination of cage batteries with LED lamps of the white warm spectrum, which, in comparison with the traditional method, increases the livability and productivity of chickens while reducing the cost of feed and electricity per unit of production [11, 12].

It should be noted that although the placement of low-power LED lamps directly in each cage significantly improves electrical safety and reduces the risk of a fire hazard due to the low supply voltage of lamps (24-48 V), it requires a large number of rather complex electronic devices located across the whole metal structure of a cage battery (in case of 18x96 m there can be up to 6,000 LED lamps) and extended power transmission lines (up to several kilometers) [13].
Currently, for local illumination, remote primary light sources can be used, located a few tens of meters from the illuminated surface area. By using LEDs as primary light sources, all the advantages of LED lighting are retained, while the primary electrical light source can be moved outside the cage battery. To transmit light directly to each cage, fiber-optic cables (light guides) can be used as secondary light sources based on multiple reflections in a closed semitransparent medium, as implemented in the fiber-optic communication lines [14,15]. The use of fiber-optic technologies will significantly improve the electrical and fire safety of local LED lighting systems, especially during intensive cleaning of equipment, due to the removal of the light source and power lines from the metal structure of cage batteries. Moreover, using a combination of longitudinal and end-beam light guides [16], it is possible to significantly increase the uniformity of illumination even in comparison with existing local LED lighting systems.

This work aims to study the efficiency of using fiber-optic light guides based on LEDs for local illumination of hens of the productive flocks in multi-tiered cage batteries.

2. Materials and methods
The study was carried out in the vivarium of the Selection and Genetic Center "Zagorskoe Experimental Breeding Farm" using the chickens of the productive flocks of cross SP-789. The 120-day-old hens were divided into 2 groups of 100 heads each. In the control group, LED lamps were used for local illumination of the hens, and in the experimental group, fiber-optic light guides were used with LEDs as the primary light source. Hens up to 260 days of age were kept in three-tier cage batteries, 5 hens per cage with the 2L:5D:3L:2D:3L:9D intermittent illumination mode. The light sources were placed outside the cage batteries, above the feeders of each tier (under the egg-collection belt, except for the upper tier). In both groups, the color temperature of the light-emitting diodes was 3000 K, the illumination intensity at the level of the feeders was 10 lx.

3. Results and discussion
The study results (Table 1) showed that during the period of the study, the livability of the livestock in the experimental group was 4.0% higher than in the control.

The live weight of hens from the experimental group was 2.9% higher than that of the control group at the age of 240 days. The difference between groups in live weight was statistically significant (P <0.05).

A 50% Intensity of egg production in both groups was achieved at 140 days of age.

The groups did not practically differ in terms of egg production per average laying hen, however, due to the higher livability of the bird, the egg production per initial hen in the experimental group was 2.6% higher than in the control group.
The higher live weight of the experimental chickens contributed to an increase in the average weight of their eggs by 0.7%, although the difference between the groups was statistically insignificant. An increase in the weight of eggs in the experimental group made it possible to increase the yield of eggs of the first category by 7.1% and reduce the yield of eggs of the second category by 7.2%. The groups differed insignificantly in the egg yield of the rest of the category and the number of damaged eggs.

Due to the higher egg production and egg weight, the experimental group showed higher egg weight per initial and middle hen than the control group by 2.9 and 0.5%, respectively.

Feed consumption per head per day in the experimental group was 112.1 g, which is 4.7% lower than in the control, and along with higher egg production and egg weight yield per hen in this group, it resulted in the reduced feed consumption by 10 eggs and 1 kg of egg weight by 5.1%.

Morphological analysis of eggs showed (Table 2) that, on average, throughout the experiment, the groups differed insignificantly in the absolute and relative weight of yolk, protein and eggshell, eggshell thickness and the ratio of the absolute weight of protein to yolk. There was a tendency to an increase in the relative weight of the yolk and eggshells in the experimental group, a decrease in the relative weight of protein and the ratio of protein to yolk.

Also, there were no significant differences between the groups in the content of calcium in the eggshell; carotenoids, vitamins A and B₂ in yolk, and vitamin B₂ in protein.

Table 1.

| Indicator                                                                 | Control   | Experimental |
|---------------------------------------------------------------------------|-----------|--------------|
| Livability of hens for the period 120–260 day, %                          | 95.0      | 99.0         |
| Live weight (g) at the age of (days):                                      |           |              |
| 120                                                                       | 1240±16.2 | 1247±11.3    |
| 240                                                                       | 1597±17.5 | 1644±11.9    |
| Age of chickens upon reaching 50% intensity of egg production, days      | 140       | 140          |
| Egg production (pcs.) per a hen:                                          |           |              |
| initial                                                                   | 99.9      | 102.5        |
| average                                                                   | 103.2     | 103.3        |
| Intensity of egg production, %                                            | 85.9      | 86.1         |
| Average weight of eggs, g                                                 | 57.9±0.21 | 58.3±0.20    |
| The yield of eggs (%) by categories                                       |           |              |
| Higher (>75 g)                                                            | 1.0       | 0.5          |
| Selected (65-74.9 g)                                                      | 8.0       | 8.5          |
| 1 (55-64.9 g)                                                             | 56.8      | 63.9         |
| 2 (45-54.9 g)                                                             | 29.0      | 21.8         |
| 3 (<45 g)                                                                 | 0.4       | 0.2          |
| Broken and cracked                                                        | 4.8       | 5.1          |
| Egg weight yield (kg) per a hen:                                          |           |              |
| initial                                                                   | 5.81      | 5.98         |
| average                                                                   | 6.00      | 6.03         |
| Feed consumption:                                                         |           |              |
| per 1 head per day, g                                                     | 117.6     | 112.1        |
| per 10 eggs, kg                                                           | 1.37      | 1.30         |
| per 1 kg of egg weight, kg                                                | 2.35      | 2.23         |
Table 2. Morphological and chemical characteristics of eggs.

| Indicator                  | Control          | Experimental     |
|----------------------------|------------------|------------------|
| Weight:                    |                  |                  |
| yolk, g                    | 14.6±0.42        | 14.7±0.37        |
| %                         | 24.6             | 25.0             |
| protein, g                 | 38.3±0.45        | 37.6±0.48        |
| %                         | 64.6             | 63.8             |
| eggshell, g                | 6.4±0.10         | 6.6±0.10         |
| %                         | 10.8             | 11.2             |
| Eggshell thickness, μm     | 368±0.38         | 369±0.38         |
| Protein to yolk ratio      | 2.62             | 2.56             |
| Content:                   |                  |                  |
| Calcium in eggshell, %     | 36.56±0.17       | 36.57±0.16       |
| In yolk, μg/g:             |                  |                  |
| carotenoids                | 12.32±0.68       | 12.24±0.70       |
| vitamin A                  | 4.67±0.13        | 4.43±0.11        |
| vitamin E                  | 64.07±5.41       | 66.47±5.29       |
| vitamin B2                 | 5.22±0.12        | 4.98±0.19        |
| vitamin B2 in yolk, μg/g   | 4.18±0.14        | 4.17±0.16        |

As the data in Table 3 show, at the age of 240 days, the experimental group was insignificantly inferior to the control group in terms of the absolute and relative weight of the heart and liver. At the same time, it prevailed in the development of reproductive organs: by 2.8 g and 0.12% for absolute and relative ovary weight, by 5.0 g and 0.25% for oviduct, and by 3.3 cm or 6.7% for oviduct length. However, the differences between the groups for all indicators were statistically insignificant and had the character of a trend.

Table 3. Results of anatomical butchering of 240-day-old chicken carcasses.

| Indicator                  | Control          | Experimental     |
|----------------------------|------------------|------------------|
| Weight:                    |                  |                  |
| heart, g                   | 7.9±0.30         | 7.5±0.13         |
| %                         | 0.49             | 0.46             |
| liver, g                   | 26.6±0.99        | 25.7±0.79        |
| %                         | 1.66             | 1.57             |
| ovary, g                   | 40.6±3.45        | 43.4±4.57        |
| %                         | 2.53             | 2.65             |
| oviduct, g                 | 52.7±3.93        | 57.7±3.92        |
| %                         | 3.28             | 3.53             |
| Oviduct length, cm         | 49.4±3.8         | 52.7±4.42        |

4. Conclusion

Thus, according to the results of the study, it can be concluded that when keeping egg chickens of the productive flocks in multi-tiered cage batteries, the use of fiber-optic light guides for local illumination as secondary light sources in comparison with LED lamps makes it possible to increase the livability of the livestock by 4.0%, egg production by the initial laying hen by 2.6%, the weight of eggs by 0.7%, the yield of the egg weight for the initial hen by 2.9%, the yield of eggs of the first category by 7.1% with a decrease in feed consumption by 10 eggs and 1 kg of egg weight by 5.1%, respectively.
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