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The Implementation of Energy-Saving Lighting Systems for Poultry Houses

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Abstract

The provision of lighting in poultry shelters is an energy-intensive process in poultry farming, due to a lack of sunlight in closed facilities. Lighting plays an important role in the majority of organism biorhythms and it clocks the processes of vital activities of the birds. Lighting directly influences productivity, growth and sexual maturation of birds. A determining factor for the lifetime of an LED is the crystal heating temperature during its operation. It may be assumed that the LED lifetime is largely independent of the variation in the current passing through the LED (within the limits of its design values). The research objective was to conduct laboratory testing to compare the electricity consumption between the existing and a newly developed lighting system for poultry house no. 19 of the Kuchinsky Poultry Breeding Plant. In order to conduct the laboratory testing, the authors developed lighting fixtures consisting of sealed plastic bodies with an LED-carrying PCB inside. The testing continued for 113 days. The new system consumed 662 kWh, while the previous system consumed 783 kWh. Energy savings through the testing period amounted to 15%. During the testing, the new equipment was reliable; no failures of LED fixtures were recorded.

Keywords: LED lighting, energy conservation, poultry farming, microclimate

1. Introduction

Poultry farming is a developing area of agriculture, where a complex technological process of poultry raising is determined by its high energy consumption. Lighting is one of the most important and most energy consuming processes due to a lack of natural source of sunlight in poultry shelters. Light is an important element of environment that influences vitality and physiological state of the birds [1, 2].

Correct lighting is a universal synchronizer for most biorhythms in the body. Light is a factor that regulates productivity, growth and sexual maturation of the birds [3, 4].

For the birds raised in closed windowless quarters, artificial light sources with their lighting regimes are the only source for day-and-night cycle regulation [5, 6].

Design regulations for poultry farming enterprises [7] specify recommended illumination levels and its allowable non-uniformity with a maximum deviation of 20%. As per the Federal Law dated November 23, 2009, no. 261 [8] that introduces a number of new limitations, forcing poultry farms to forgo previously installed incandescent lamps (Figure 1), new energy efficient lighting systems shall be implemented in poultry houses. Thus, poultry farming enterprises shall begin modernizing their lighting systems, while researchers shall start developing new energy efficient lighting sources and methods. Thus, new energy efficient lighting systems shall be implemented in poultry houses.

Figure 1: Poultry houses

In 1986, Mark O. North (USA) used field research to obtain the following dependences between different wavelengths of light and poultry indicators (**Table** 1) [9]

Table 1: Influence of visible light onto poultry parameters [9]

Parameter	Visible light				
	red	orange	yellow	green	blue
Growth factor	-	-	-	+	+
Reduced feed consumption	-	-	+	+	
Delayed puberty	-	-		+	+
Stimulated puberty	+	+	+	-	-
Stress resistance	+	-	-	-	-
Reduced cannibalism	+	-	-	-	+
Increased productivity	+	+	-	-	-
Reduced productivity	-	-	+	-	-
Improved male fertility	-	-	-	+	+

From the data shown in Table 1, it is evident that the main colors for broiler farming shall be green and red, while laying birds require red, yellow and green. This observation was taken into account in the development of lamps.

Yu.B. Aizenberg's reference provides ratios between the electric power, light output and luminary efficiency for incandescent lamps, white light tubular luminescent lamps and the same lamps with in-built electronic control gear (ECG) (Table 2) [10]. Tubular luminescent lamps have competitive advantages over incandescent lamps, e.g., service life (up to 10 times longer), safety for maintenance personnel (about 0.01 mm of mercury) [11].

Table 2: Comparative table for electric power, light output and luminary efficiency [10]

	Power consumption, W	Light output, lm	Luminary efficiency, lm/W
Incandescent lamp	75	940	12.5
	150	2200	14.6
Luminescent lamp	15	720-800	53
	30	1800-2250	75
Luminescent lamp with in-built ECG	15	900	60
	30	1900	63

A feature of incandescent lamps is a large amount of thermal energy output, thus, their luminary efficiency is low [12]. These lamps are used for warming the growing birds.

Analysis of average values from the Table 2 shows that all these lamps are inefficient and are a bad match to our tasks. Thus, LED-based light sources were considered.

The authors previously conducted a research work [13], where a program was developed for an ARDUINO ATMEGA controller for broiler farming to control the day/night regime (23-hours day – 1-hour night during the first week, 18-hours day – 6-hours night from the second week up to slaughter). The controller additionally managed radiating units, analyzed main parameters of microclimate such as humidity, gas content, temperature and informed operator about any changes. In **Figure**. 2, testing of the controller is shown. After the experiment, all the parameters in **Table** 1 were improved to a varying degree.

Purina Mills [14, 15] is well-known for their Bio-MittentTM system of intermittent lighting used in poultry houses where laying birds are kept. The results showed a reduction in energy consumption by 75%, reduced egg breakage (by 10%), reduced feed consumption for the same egg productivity (by 5-7%); this system has been tested on a population amounting to 25 million hens through all the farms where the system had been implemented.

M. Zonov [16] used field research to identify opportunities for reducing the consumption of electricity by means of varying lighting regimes in poultry houses. The research

Figure 2: Lighting system testing

used three groups. The first group (control) were kept under the standard farm regime using 23G:1T regime up to slaughter and 18C:6T regime during the second and the thirds weeks. The second group had round the clock lighting; the third group was raised under the 23G:1T regime during the first week and then 3C: 3T up to slaughter. The regime of the third group (Table 3) provided savings of 34 kopecks per bird, live weight increased by about 0,5%, feed consumption reduced by 1%, mortality reduced by 0.2%, die-off did not exceed 0.8%.

Table 3: Field testing results

Indicators	Lighting regime		
	1 – control	2 – experimental	3 – experimental
Weight by Day 35, g	2008.5	2003.6	2012.8
Survival, %	97.6	97.5	97.7
Feed, kg	1.65	1.65	1.64
Total duration of lighting, hrs	740	805	797
Power consumption, kW	10,286	11189	6908
Lighting costs, rubles	15532	16895	10431

V.I. Fisitsin., Huber–Eicher B., Karakaya M. and other researchers propose to pay more attention to LED lighting, due to its high energy efficiency, low energy consumption, low operation costs, long service life, broad wavelength range [17-19].

At a poultry house of Agrotekhnopark of the Belgorod State Agrarian University, a testing of LED lighting manufactured by Gelan LLC under their own in-house lighting regime (Table 3) was conducted, the results are shown in Table 4 [20]. The experiment supports direct influence of light onto increased weight of birds, the most efficient type of light for increased weight gain was cold white fluorescent light.

TABLE 4: A ratio of electric consumption, light output and luminary efficiency [20]

Age, days	Illumination, lux	Lighting regime, hours (day/night)
0-5	60-40	24/0
5-10	25	23/1
10-15	20	18/6
15-20	15	18/6
20-40	10-5	18/6 (23/1)

TABLE 5: Testing results

Group no.	Type of lighting	Average weight
Experimental group 1	cold white fluorescent light	2435.9 ± 18.9 g
Experimental group 2	natural white light	2313.3 ± 26.4 g
Experimental group 3	warm white light	2328.8 ± 19.6 g

2. Methods and Materials

From analysis of literature [21-22], the principal factor influencing a LED's service life is its crystal heating temperature during operation.

The main factor influencing a LED's service life is the temperature of a p-n junction during its operation independent of duty of the irradiation facility, because during the operation of a LED fixture, the structure is heated due to the heat released by the p-n junction (Figure 3). LED manufacturers found the functions describing the service life depending on the temperature of the p-n junction. These functions differ between manufacturers. Studies show that the service life of a LED lamp depends on the temperature of crystal (p-n junction) and if the temperature is +70°C it may amount to 50,000 hrs with a reduction in light output by 30% and 100,000 hours if the temperature is under +55°C. Thus, in order to ensure long service life of LEDs in lamps, it is necessary to design a cooling system in such a way that the maximum temperature of LEDs never exceeds +70°C.[24]

Plots (Figure. 4) obtained by L.Yu. Yuferev and A.A. Mikhalev show the crystal temperature as a function of LED service life and current passing through it. From analyzed dependences, it may be assumed that the lifetime is almost completely independent of variation in current passing through the LED (within the limits of its design values).

L.Yu. Yuferev and A.A. Mikhalev propose predicting the crystal heating by means of a verification calculation in ANSYS/CFX software package. Figure 5 shows the results of thermal camera survey and software simulation. From the data in Figure 5, it is evident

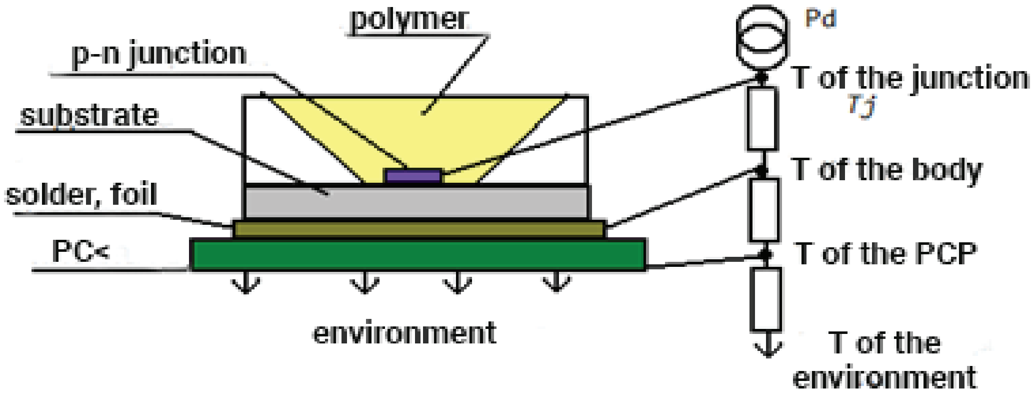


Figure 3: A model of thermal resistance of a LED

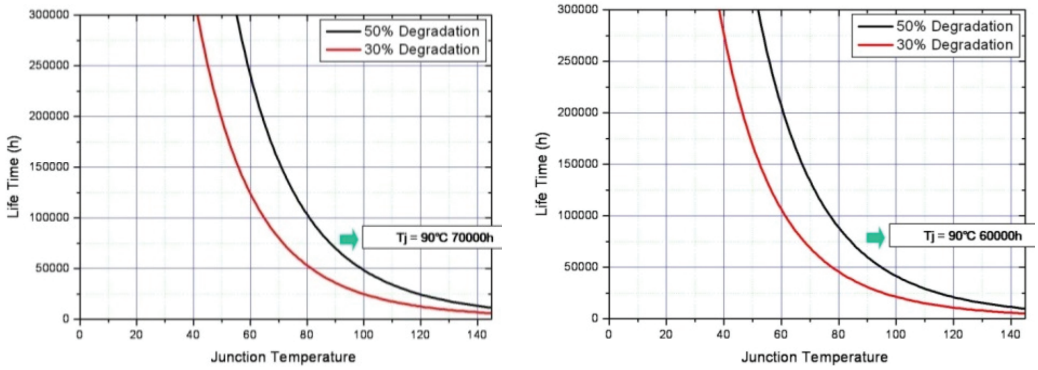
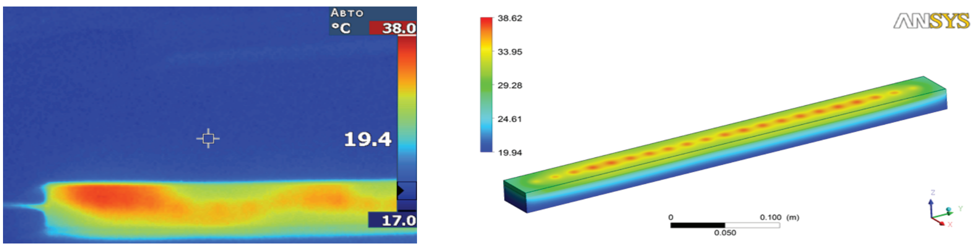


Figure 4: Changes in LED service lifetime for current values of 350 mA and 700 mA and crystal heating temperature.

that simulation provides sufficient accuracy of predicting heating distribution due to a high degree of correlation of the output values.



a b

(a) -thermal camera photograph; (b) - calculated.

Figure 5: Temperature distribution through the surface of plastic body

Figure 6 shows the maximum temperature of LEDs depending on ambient temperature obtained by modeling and by field research [25, 26]. According to the dependence, a plastic was selected; in further studies, the lamp body was plastic in order to reduce LED heating and the weight of the structure.

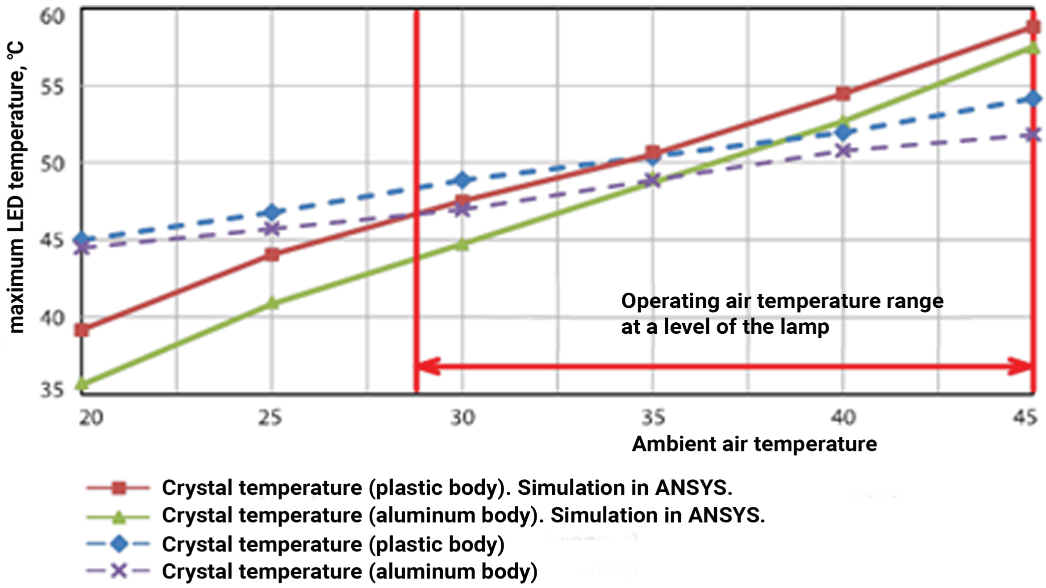


Figure 6: LED temperature as a function of ambient temperature [25, 26]

To calculate the heating temperature of the p-n junction by the method of series thermal resistance [24], it is necessary to introduce LED efficiency ηсд into equation

$$Tj - Ta = Pd \cdot (\Theta jc + \Theta cb + \Theta ba) \cdot \left(1 - \eta_{A4}\right), \quad (1)$$

where Tj is the temperature of the p-n junction; Ta is the ambient temperature; Θjc is a thermal resistance between the p-n junction and the body; Θcb is a thermal resistance between the body and its environment (PCB); Θba is a thermal resistance between the PCB and the environment; ηсд is the efficiency of a LED; *Pd* is the consumed power, *Pd* = (Iсд · Vсд), where Iсд is forward current; Vсд is forward voltage.

3. Results and Discussion

In order to conduct the laboratory testing, the authors developed lighting fixtures consisting of sealed plastic bodies with a LED-carrying board inside. Lamp characteristics: color temperature – 3000 K, dimensions – 510x50x35 mm, minimum light output - 520 lm, design power – 5.5 W, number of LEDs – 20 pcs (Figure 8).

The research objective of the laboratory testing was to compare electricity consumption between the existing and newly developed lighting system for a poultry house no. 19 of the Kuchinsky Poultry Breeding Plant.

Table 4 reflects the results of the testing conducted in two boxes of the Kuchinsky Poultry Breeding Plant; the most efficient one is compared to the new system. Exposure

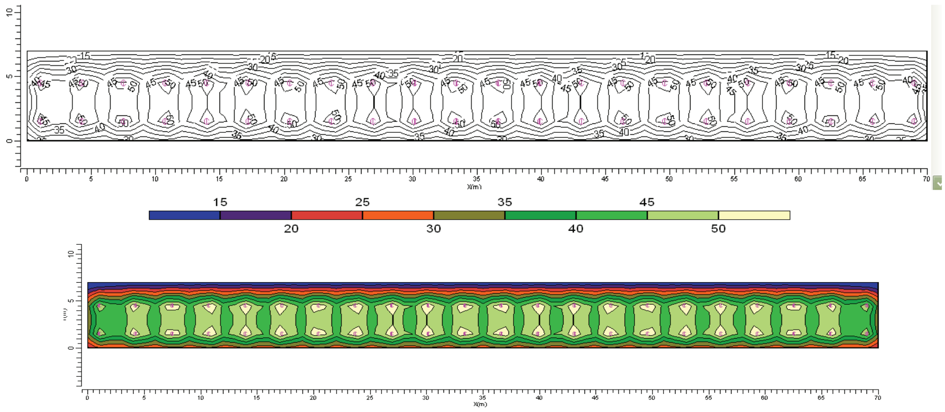


Figure 7: Design illumination in the facility

and the number of lamps during the laboratory testings was the same as during the on-site tests in the poultry house no. 19.

Figure 8: Testing a lighting system connected to an electric meter

Table 6: Testing results

Day	Value / power consumption Poultry house no. 18	Value / power consumption Proposed system, Poultry house no. 19	Value / power consumption during the laboratory testing
1	8005	481	407
11	8137/132	519/38	439/32
32	8500/495	688/207	582/175
113	9813/1808	1219/783	1031/662

As a result of laboratory testing of the developed lighting system, the following results were obtained: through the testing period of 113 days, the new lighting system consumed 662 kW h, the existing system consumed 783 kW h, energy savings through the testing period amounted to 15%. During the testing, the new equipment was reliable; no failures of LED fixtures were recorded.

4. Conclusion

The research has shown that the service life of LEDs does not depend on changes in current passing through the LED within the nominal range; in order to ensure prolonged operation of LED lamps it is necessary to design a cooling system to ensure that the maximum crystal temperature of the LEDs never exceeds +70°C. Simulation allows for a sufficiently accurate prediction of heating distribution; thus, there is no need for field-testing, as correlation is high. Through the testing period of 113 days, the new lighting system consumed 662 kW h, energy savings through the testing period amounted to 15%.

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Conflict of Interest

The authors have no conflict of interest to declare.

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