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APPLICATION OF INTENSIVE TECHNOLOGIES FOR IMPROVED PRODUCTION PROCESSES IN POULTRY FARMS

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One of the important problems in the modern world is to provide the population with high-quality food. So, today the agricultural sector faces the main task of increasing the production of agricultural products, as well as the use of agricultural waste. Poultry farming is one of the main branches of the agricultural sector. The main task facing farmers is to improve the conditions and technology for feeding and keeping farm birds, and one of the important tasks is the state of indoor air in this regard, the problem remains open. Therefore, the main way to solve this problem is the preferred transition to intensive technologies in order to realize the efficiency potential in poultry farming. However, the intensification of the area increases the anthropogenic load on the environment. The main source of environmental risk is the systems of disposal of bird droppings. Our research has shown that 85 % of the negative impact on the environment is caused by poultry and animal husbandry waste. Lighting also plays an important role in poultry farming. Thus, lighting is the basis for electricity consumption. Both natural and industrial lighting is important for the physiology of birds and their development, but, unfortunately, it is quite energy-intensive. In this regard, the idea of solving this problem is being created, it is the development and application of new, efficient, inexpensive and environmentally friendly technologies that are important for large-scale research. Therefore, it is necessary to take into account that most poultry farms are equipped with simple mechanical ventilation systems without cooling. So, an increase in productivity is possible through the introduction of intensive technologies, while the economic assessment of the use of evaporation plants, the disposal of bird droppings and LED lighting can be of practical importance

Keywords: poultry building, ventilation, cooling system, evaporator, fermentation of poultry droppings

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1. Introduction

One of the most pressing challenges facing humanity is producing the necessary amount of high-quality food products. Our republic is one of the countries in the world with natural and climatic conditions and sufficient natural resources for the production of high-quality agricultural products. The potential of our country allows not only ensuring food security but also exporting agricultural products to other countries. This area is one of the most important non-oil sectors and has always been supported by the state. At the last meeting of the Cabinet of Ministers, President Ilham Aliyev emphasized the importance of agricultural development under the current conditions. The Head of State noted that agricultural sectors should be developed. Therefore, the development of poultry farming, one of the main areas of agriculture, draws special attention. Poultry farming is one of the oldest areas of agriculture having history and traditions and it is also known that poultry is most commonly used in Azerbaijani cuisine.

This area is always in the spotlight of the state, with its dynamic development. 98 million AZN concessional loans have been issued over the past years to expand the production capacity of 39 poultry factories with an annual production capacity of 55,000 tonnes of poultry and 248.5 million eggs, plus the commissioning of 5 breeding, 1 commodity, and 9 broiler factories. Production of industrial poultry farming in 2017 exceeded the predicted limits for 2015.

81.3 thousand tonnes of live weight bird meat and 762.7 million eggs were produced in poultry factories. The total number of birds in factories was 12,343.2 thousand. On average, 177 eggs were obtained from each egg-laying chicken.

A distinctive feature of the modern stage of poultry development is the dynamic provision of the population with dietary foods and the increase of efficiency in this area by the use of resource-saving technologies. That is why egg produc-

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tion in the world has increased by 30 % and poultry production by 44 % in recent decades.

According to official statistics, the average American consumes 49.4 kg of poultry annually. But we consume 10.2 kg, which is 50 % of the country's demand [1]. Poultry consumption is expected to increase in the world over the next decade, according to the US Department of Agriculture [2].

The specific weight of bird meat in total meat reserves in our country is 31 %. In cities, this number reaches 50–60 %. It should be noted that the energy consumption of the production in our country is 1.5–2 times higher, the cost price of poultry products is 12–16 %, and the feed share is 60–80 % [3–5]. In Europe, the cost price of the energy consumption of poultry products is 3–5 %.

Therefore, the main task of this area is to find the energy and resource-saving elements differing in technology, physiology that will help to save feed and electricity and do not affect negatively the productivity and health of birds. However, the genetic potential of the birds' productivity depends to a great extent on the conditions that are created during their feeding and breeding. But modern technology leads to the loss of the adaptive capacity of the organism [5–7]. As a result, productivity, feeding effect, and resistance are reduced.

On the other hand, it is necessary to use electrophysical disinfectants – bactericidal lamps to purify the air from microorganisms that can cause respiratory diseases. The development of highly effective bactericidal devices is also an important issue. Therefore, scientific and practical tasks emerge, such as the development of technical equipment based on resonant feeding systems and modern sources of optical radiation. In this regard, the scientific validation of poultry-based energy resource-saving lighting and radiation equipment is also relevant. In general, the development and application of new, effective, low-cost and environmentally friendly technologies are essential for large-scale research.

2. Literature review and problem statement

Modern feeding and keeping technologies of agricultural birds are based on using special buildings. The keeping of birds in cage batteries is explained by the most efficient use of each cubic meter of the manufacturer's useful space.

Under these conditions, the physical state and productivity of birds are determined not only by important measures such as breeding and proper feeding but also by the climatic condition in the building. It is known that this factor has a very significant effect on the physiological state of birds and can change their fertility by 20–30 % [7]. Micro-climatic indicators, which affect birds more, include temperature and humidity of the indoor air, its dustiness, and pollution with gas, as well as air conditioning and airspeed.

The search for new solutions to resource-saving tasks used in broiler farming is of great interest. An analysis of the literature on this issue shows that, despite the large selection of technical means for artificial humidification of industrial premises, the approbation of their use in poultry farming is extremely limited. The lack of knowledge of the literature can be explained by the effectiveness of such equipment in poultry farming. Therefore, one of the tasks of the upcoming research was to determine the effect of artificial humidification on the microclimate in the poultry house, as well as the impact on the productivity of broilers in the hot climate of Azerbaijan. Of course, it is impossible to check all known mechanisms of artificial humidification. Therefore, the choice of technology and equipment for humidifying the air for research is based on the following requirements:

– to be more effective than known technologies and methods according to literature data;

– to get a wider distribution, already tested in industrial poultry farming;

– to have a performance that ensures normalization of the humidity regime of the air in the poultry house intended for industrial broiler farming.

Excess temperature causes both the worsening of physiological conditions and decreased productivity. For example, when keeping 5–8-week-old broilers, a temperature drop from 18 to 10 degrees causes a 48 % decrease in weight, which is 6 % for each degree. When the temperature increases from 23 to 32 degrees, this index is 26 % or 3 % decrease for each degree. When keeping egg-laying chickens, a decrease in temperature reduces laying eggs by 2 % for each degree, and by 1.5 % for each degree when the temperature increases. In both cases, there is a need for additional power consumption. It is preferable to switch to intensive technologies to realize the potential of efficiency in poultry farming [6]. However, the intensification of the area increases the anthropogenic load on the environment. The main source of environmental risk is the utilization systems of poultry droppings. Studies have shown that 85 % of negative effects on the environment is caused by poultry and livestock wastes. Lighting plays a significant role in poultry farming. Therefore, lighting is the basis for electricity consumption. Industrial lighting is important for bird physiology and is quite energy-consuming. In addition, the lighting for birds requires slow switch on and off in a way that imitates the sunrise and sunset.

The abundance of technologies and methods offered for improvement and the variety of possibilities of existing installations make it necessary to search for more rational, more efficient and adaptable design methods for these technological conditions to improve the production process on poultry farms.

In [7], scientists analyze the industrial production of eggs, where artificial lighting is necessary to stimulate the reproduction of birds. The lighting systems currently in use have limitations when used in aviaries and need to be improved to ensure energy savings and production optimization. This study presents three original contributions:

1) a proposal for a low-power linear lighting system developed for commercial egg production, and a methodology for determining the dimensions of linear lighting;

2) comparative analysis of the same with conventional LED lamps in terms of energy efficiency, light distribution, attenuation and temperature radiation;

3) using the geostatistical method to analyze the vertical distribution of light in the fence. The authors basically built their methodology on the results of a linear lighting system in the form of flexible LED strips, the use of which reduced energy consumption by 32 % compared to LED lamps and improved light distribution in cells, but, unfortunately, the results of studies that helped solve the problem of lighting conditions in poultry farms are not given. The paper [7] is entirely devoted to poultry farming. The authors have done a lot of work to identify the need for the development of this branch of animal husbandry. An analysis of the effectiveness of a small poultry farm was also carried out. Despite the critical analysis, the authors did not address issues such as litter disposal, as well as lighting. The work [8] analyzes LED lamps (LED) in the production of broilers, since they

have adjustable brightness and are more energy efficient than compact fluorescent lamps. While there is some research on how the spectrum of light can affect production, little has been done about how it can affect stress and behavior. To determine how different spectra of light produced by LED lamps can affect productivity, stress and behavior, they conducted a study on growing broilers under LED lamps with a color temperature of 2,700 K (WARM) or 5,000 K (COLD). To determine the bilateral asymmetry of sensitivity to stress (ASYM, $n=128$), the concentration of corticosterone in plasma (CORT, $n=40$) and the ratio of heterophiles/lymphocytes (HL, $n=80$) were measured. The results showed that raising broilers under 5,000 K LED lighting can reduce their stress, fear and increase weight gain compared to 2,700 K. These results show that the spectrum of light used to raise broilers is important not only for production, but also for the well-being of birds. The authors have done a lot of work to identify light-like lighting and its effect on birds. Despite the work done, LED lamps are economical, but also partially negatively affect the mental state of birds. Therefore, the authors did not address these aspects in their work, which negatively affects productivity. The work [9] analyzes LED lamps in the production of broilers, since they have adjustable brightness and are more energy efficient than compact fluorescent lamps. While there is some research on how the spectrum of light can affect production, little has been done about how it can affect stress and behavior. These results show that the spectrum of light used to raise broilers is important not only for production, but also for the well-being of birds. The authors have done a lot of work to identify light-like lighting and its effect on birds. Unlike the previous work, the process of negative influence on birds has been analyzed, but the research methodology does not fully reveal the advantage of this process over the existing one. The authors [10] indicated and analyzed the problem of food safety. About the quality of animal products and emphasized poultry farming as one of the most frequently used. About the battles that can get into the human body through the animal organism.

Work has been done on the process of identifying diseases. Therefore, the condition of poultry farms is one of the most important tasks. But the authors did not indicate the problems of the occurrence of diseases and ways to solve them. The achievements of science help to improve [11] the condition of livestock facilities by introducing modern systems that guarantee adequate climatic conditions in the premises necessary to maximize the use of the genetic potential of animals and increase their productivity. The paper analyzes one of the problems of poultry factories climate control. Consequently, climate control is closely related to productivity, as well as to other areas of animal husbandry, delineating a network of relationships between them. The results show that climate control plays a key role in intensive livestock complexes, as it is closely related to animal welfare, emissions, productivity, health and energy consumption. This is especially relevant given such aspects as the expected growth in livestock production in developing countries and global warming. But the authors did not show the methodology used specifically in comparison with the existing one, so that the effectiveness of the proposed one could be compared. The study [12] influences the intensity, wavelength and duration of light, and the behavioral patterns of these animals are important indicators of stress for laying hens. As has been pointed out by previous scientists, light is one of the important factors affecting health and productivity. The studies were mainly conducted to assess the group and behavior of laying hens exposed to three environments with different modes of monochromatic lighting (blue, green and red). The relationship between lighting and the thermal environment has been observed, indicating the need for additional research in this area to better understand these behavioral changes. As can be seen from the results of the study, light affects birds in different ways, and the authors have not fully determined the type of lighting, as well as the types of lamps. The authors of [13] analyze the introduction of energy-saving technologies, especially technologies for the use of renewable energy sources, which is closely related to the problems of energy independence of domestic enterprises. This task is the main worldwide transition to renewable sources. As it was precisely indicated during the introduction of the latest energy-saving technologies, including advanced technologies for the conversion and use of renewable energy sources, it is necessary to form a kind of system of indicators of the energy security of the enterprise. The authors mainly analyzed the economic part, but did not fully address the areas and methods of using this energy both positively and negatively.

After we have conducted literary research, the problem of improving the process in poultry farms by substantiating the basic design and operational parameters is open, and therefore we have analyzed the shortcomings made in the research of scientists and try to solve this problem.

3. The aim and objectives of the study

The study aimed to substantiate the energy-saving, environmentally friendly technology for the production of poultry products and its technical solution.

To achieve this aim, the following objectives are accomplished:

– to investigate the humidification systems in the poultry house;

– to investigate computer and experimental LED lighting systems.

4. Materials and methods

The object of the study was to evaluate the annual efficiency of improving production processes at poultry farms. Depending on the nature of the study of technological processes, we have investigated various mathematical methods.

The solution to the problem was implemented using theoretical and empirical research methods. Objects of the research included energy and resource-saving, environmentally friendly technology and technical tools, plastic recuperators, utilization systems of poultry droppings, lighting and radiation processes in the poultry industry.

During conducting laboratory and industrial tests, classical and special methods, including the decomposition method for functional analysis of the utilization technology of bird droppings, the logic-linguistic method for nitrogen preservation assessment during utilization, physical modeling for application of microclimate, nutrition and storage technology, lighting and radiation processes, experiment planning methods and special computer program were used. The data obtained were processed using mathematical statistics and with the application of STATGRAPHICS centurion XV, Microsoft Office Excel 2013 (USA: Redmond, Washington) and AutoCad 2015 (USA: San Rafael (California).

The interrelation of temperature and humidity parameters of ambient air with energy characteristics of cooling and heating complexes was determined in poultry buildings, arguments confirming the superiority of the devices used for normalizing the microclimate, research phases that formulate specific recommendations for the design of these facilities, the conditions affecting the efficiency of their work were substantiated.

Formulas were developed to determine the temperature and humidity parameters of the poultry building when using evaporative coolers and recuperative heat exchangers, a mathematical model and algorithms for its implementation were developed to select parameters and operating modes of cooling tools and plate heat exchangers. Practical recommendations and a software module system were developed to select the system of normalization of temperature and humidity parameters based on the modeling of the thermophysical processes in poultry buildings.

A combined method of utilization technology of poultry droppings for agricultural conditions was proposed, evaluation criterion of its economic efficiency and environmental safety was substantiated. Methods and algorithms were developed to determine the constructive and working modes of the technical systems required for environmentally safe utilization of poultry droppings with minimal nitrogen loss.

Estimation methods of resonance power blocks of light sources, ways to increase the efficiency of the resonant feeding system, also the constructive parameters of the irradiation facilities, which have a therapeutic effect on birds based on ultraviolet (UV) light source, were substantiated. The effectiveness of feeding and keeping egg-laying, meat chicks and hens at energy-saving light, using natural adaptogen and minerals was determined.

The economic efficiency depends not only on the purchase and operation of the cooling system but also on the increase in productivity as a result of decreasing energy costs and improving the bird keeping conditions [11]. To specify the last one is very complex. According to the recommendations of the experts [6, 8, 12], the purchase of equipment and the assessment of the economic benefit of its operation should be carried out in comparison with the base object.

We used the «Klimat-2000» microclimate unit, designed for keeping 30,000 egg-laying chickens as a base option in the Suliddinoghlu village farm of Samukh district for summer. It has a nominal air consumption of 180,000 m^3/h with Mulligan-130-V4D15-5 axial fans to remove harmful impurities from the building during hot periods. For air cooling, a nest humidifier for a 50 m^2 area was used.

The bases and power units for the proposed variants – the ventilators that provide fresh air are the same. The main difference in economic costs is in the acquisition and operation of humidifiers and evaporative blocks. Given that most poultry houses have mechanical ventilation systems without additional refrigerators, the economic evaluation of the use of evaporative blocks may be of practical importance. The farm was found to lose 7 to 10 % of its productive birds in the hot season of the year when the building has a high temperature and the air is not sufficiently fresh in the area.

The optimal temperature inside the building for egg-laying birds is 15...18 °C, for broilers 16...18 °C at the end of breeding. For every degree of the temperature increase, there is a 1.5...2 % reduction in laying. The most favorable range of relative humidity is considered to be 60...70 %. In the absence of the required ventilation within 2...3 hours, the building is filled with 10...20 % carbon dioxide, resulting in oxygen deficiency and paralysis occurs in the respiratory organs of birds.

Thus, the optimum mode of keeping birds in the summer: temperature – 12 °C, relative humidity – 65 %, airspeed in the zone of birds – 1.5 m/sec, air change repetition – 4.0 m^3/h for 1 kg of a bird.

In determining the annual income, the costs of purchasing equipment and operating costs are taken into account. The base variant is compared with a plate-type evaporative cooler block. This block, along with the base ventilation system, provides a cooling depth of 8...12 °C. This increases the cooling capacity of the proposed cooling system to 400–900 kW. The technical characteristics of the compared objects are given in Table 1.

Expected results with the use of evaporative cooler: using plate-type evaporative cassettes and reducing energy consumption by optimizing geometric parameters, increasing poultry productivity by improving temperature-humidity parameters indoors.

Refrigerators are used in the summer. Working hours are 122 days a year, 6 hours a day. Balance price of the new refrigerator is B_y=129,000 AZN=75 $. Balance price of the base cooling system is B_b=111,000 AZN=65.29 $.

The annual amortization rate is calculated according to the nested layout in the base variant or the restoration of the newer variant of the cassette materials. This is determined by the following formula as a percentage of the balance price:

$$H = \frac{1}{T} \cdot 100, \tag{1}$$

where T – the service period of a nested layout or a plated cassette. For the base variant T_b=4 years, for the new variant T_y=8 years.

Table 1

Technical characteristics of cooling systems

No.	Indicators	Base «Klimat-2000»	Plate-type cooling system
1	Nominal air consumption, m^3/hour	180,000	180,000
2	Cold efficiency, W	198,000	400,000
3	Cooling depth, °C	3	8
4	Air temperature in the poultry building (when the outdoor air temperature is 30 °C), °C	29	25
5	Number of Multifan-130-V4D15-5 fans	6	6
6	Fan performance, m^3/hour	31,500	31,500
7	Electric motor power, kW	0.6	0.6
8	Area of irrigation unit/plate, m^2	50	20

So,

$$H_b = \frac{1}{4} \cdot 100 = 25\,\%, \tag{2}$$

$$H_y = \frac{1}{8} \cdot 100 = 12.5\,\%. \tag{3}$$

Considering these, the total depreciation for 1 hour of annual loading is calculated by the following formula:

$$a = \frac{BH}{W_{il} \cdot 100}, \tag{4}$$

where W_{il} – annual load of layout, hour, B – balance price.

Given that the layout works 122 days in the summer and 6 hours a day, we can write:

$$W_{il} = 122 \cdot 6 = 732 \text{ saat}, \tag{5}$$

$$a_b = \frac{B_b H_b}{W_{il} \cdot 100} = \frac{111{,}000 \cdot 25}{732 \cdot 100} = 37.9 \text{ man}, \tag{6}$$

$$a_y = \frac{B_y H_y}{W_{il} \cdot 100} = \frac{129{,}000 \cdot 12.5}{732 \cdot 100} = 22.03 \text{ man}. \tag{7}$$

Due to the difference in the number of products produced in the base and new variants, we determine the energy capacity per unit of production by the following formula:

$$N_{xus} = \frac{E}{Q}, \tag{8}$$

E – required nominal power, kW; Q – the number of purchased products, the number of eggs.

Only the power of the ventilators is taken into account in the calculation. The power of each is 0.6 kW. The power used by the ventilation system for the summer is as follows:

$$E = 0.6 \times 6 \times 732 = 263.52 \text{ kW}. \tag{9}$$

Eggs are taken as a produced product. The number of eggs for the given period for the base variant Q_b=3,267,857; for the new variant Q_n=3,660,000.

Thus,

$$N_{xus}^{y} = \frac{E}{Q_y} = \frac{2{,}635.2}{3{,}267{,}857} = 0.0008, \tag{10}$$

$$N_{xus}^{y} = \frac{E}{Q_y} = \frac{2{,}635.2}{3{,}660{,}000} = 0.0007. \tag{11}$$

Annual maintenance costs are calculated as follows:

$$I_{il} = G + Y + A_m + R_m, \tag{12}$$

G – salary of the employee in the base and new variants, for both variants, G=1,800 AZN=1,058 \$; Y – the price of energy carrier for both variants, AZN; A_m – total amortization deductions, AZN; R_m – normative deductions for current repairs, technical service, and maintenance, AZN.

The cost of energy carriers is as follows:

Y=26,352·0.07=184.46 AZN=108.51 \$.

Amortization deductions:

$$A_m = a \times T_{day} t_{day}, \tag{13}$$

T_{day} – working days of the device per year, T_{year}=122 days; t_{day} – working period of the device within a day, t_{day}=6 hours.

Considering the values:

$$A_m^b = 37.9 \cdot 122 \cdot 6 = 27{,}742.8 \text{ man}, \tag{14}$$

$$A_m^y = 22.03 \cdot 122 \cdot 6 = 16{,}125.9 \text{ man}. \tag{15}$$

Current repair, technical service and maintenance are defined as follows:

$$R_m = \frac{Bn_r}{100}, \tag{16}$$

n_r – % normative deduction rate based on the balance price for current repair, technical service and maintenance:

$$n_r = \frac{1}{T} \cdot 100. \tag{17}$$

Considering the repair and technical service of the ventilators, their service life is T=15 and the balance price B_V=3,750 AZN=2,205 \$.

$$n_r = \frac{1}{15} \cdot 100 = 6.7\%, \tag{18}$$

$$R_m^b = R_m^y = \frac{B_v n_r}{100} = \frac{3{,}750 \cdot 6.7}{100} = 251.25 \text{ man} = 147.8\,\$. \tag{19}$$

Now we calculate annual operating costs for the base and the new variants:

$$l_{year}^{c} = 1.800 + 184.46 + 27.7428 + \\ +251.25 = 29.97851 \text{ man} = 1{,}763\,\$, \tag{20}$$

$$l_{year}^{n} = 1.800 + 184.46 + 16.1259 + \\ +251.25 = 16.37775 \text{ man} = 963\,\$. \tag{21}$$

Annual operating cost savings are defined as follows:

$$F = \left(\frac{I_{il}^{b}}{Q_b} - \frac{I_{il}^{y}}{Q_y} \right) Q_y. \tag{22}$$

If we write the values of indicators, we get:

$$F = \left(\frac{29{,}978.51}{3{,}267{,}857} - \frac{16{,}377.15}{3{,}660{,}000} \right) \cdot 3{,}660{,}000 = \\ = 1{,}720.2 \text{ man} = 1{,}011.2\,\$. \tag{23}$$

The economic efficiency of the new cooling system is calculated with the following formula:

$$E = \left(P_y - I_{il}^{y} \right) - \left(P_b - I_{il}^{b} \right). \tag{24}$$

P_n, P_c – prices of the product (egg) produced in the new and base variants. The price of an egg is accepted as 0.18 AZN.

So,

$$P_b = 3,267,857 \times 0.18 = \\ = 588,214.26 \text{ AZN} = 346,011.16 \text{ \$}, \quad (25)$$

$$P_y = 360,000 \times 0.18 = 658,800 \text{ AZN} = 387,532.51 \text{ \$}. \quad (26)$$

Taking these prices into account, we can define the economic efficiency of the applied cooling system:

$$E = (658,800 - 16,377.15) - (588,214.26 - 29,978.51) = \\ = 84,187.1 \text{ AZN} = 48,438.73 \text{ \$}. \quad (27)$$

The technical and economic indicators of the evaporative cooler are presented in Table 2. On the one hand, improving micro-climatic parameters – activation of birds productivity under favorable conditions, on the other hand, decreasing losses help to increase productivity.

Thus, the economic effect of using a pre-evaporative plate cooler in the hot season is 84,187.1 AZN=49.52 $. This price is achieved by reducing the special costs of purchasing a unit of production and increasing the productivity of poultry by 10 % in the new version.

5. Results of research on improved production processes at poultry farms

5. 1. Humidification systems in the poultry building

According to our expert assessment, K-P-6 was a complex of microclimate equipment. This complex includes 10 disk humidifiers and auxiliary equipment. To study the effectiveness of the humidification equipment complex, two identical poultry houses were selected. One of them has 10 disk humidifiers along the entire length of the building. The experiment was conducted in the summer of 2016.

Table 3 characterizes the parameters of the ventilation system in a poultry house with a humidifier and in control poultry houses without similar humidifiers having similar technological equipment.

Based on the data in Table 3, it can be noted that the technological parameters of both poultry farms are the same. Only 10 humidifiers are installed in the experimental poultry room.

The study showed that the use of artificial humidification mechanisms inside the building, as expected, led to an increase in the average relative humidity in the experimental building and a slight decrease in the average air temperature.

Table 4 describes the indoor microclimate during the first study using a disk humidifier. During the experiment, the average air temperature in the experimental building was 26.0 °C, and in the control 27.5 °C. At the same time, the humidity in the experimental building was 6 % higher than in the control one.

Table 2

Technical and economic indicators of the evaporative cooler

No.	Indicator	Unit of measurement	Base «Klimat-2000»	Plate-type cooler
1	Balance price	AZN/$	111,000/6,529	129,000/75,882
2	Special energy capacity	W_{en}/W_{soy}	0.0008	0.0007
3	Operating costs for the summer	AZN/$	29,978.51/17,634.56	16,377.15/9,633.69
4	Saving costs for the summer	AZN/$	1.620.5/953.24	1,720.2/1,011.89
5	Economic efficiency	AZN/$	77,024.1/45.31	84,187.1/49.52

Table 3

Ventilation systems and humidifiers for the hot season

No.	Indicator	Unit of measurement	Experimental case	Control case
1	Number of fans	pieces	4...8	4...8
2	Hood performance	1,000 m^3/h m^3/saat	6.0...76.2	7.0...76.2
3	The amount of air conditioner cold	pieces	10	10
4	Efficiency of frost-resistant ventilation	1,000 m^3/h	6.0...40.2	7.0...40.2
5	Fan performance	1,000 m^3/h	6.0...36.0	6.0...36.0
6	Amount of humidifiers	pieces	10	10
7	Water consumption by humidifiers	l/h	20	20
8	Total water consumption by humidifiers	l/h	200	200
9	Productivity of climate change	1,000 m^3/h	6.0...76.2	7.0...76.2

Table 4

Microclimate indicators

No.	Indicator	Unit of measurement	Experimental case	Control case
1	Number of chickens	week	1...9	1...9
2	Outdoor air temperature	°C	28.6	28.7
3	Relative humidity of the outdoor air	%	71.3	70.9
4	Productivity of climate change	1,000 m^3/h	46.2	46.2
5	Indoor air temperature	°C	26.0	27.5
6	Relative humidity inside the building	%	63.9	57.9
7	The amount of ammonia in the air	mg/m^3	9.7	9.7
8	Microbial air pollution	1,000 mik/m^3	40....60	60...100
9	Air velocity	m/sec	0.38	0.39

An additional effect of artificial humidification is to reduce bacterial contamination in humid conditions. This is due to the fact that microorganisms move more dust in the indoor air, they constantly hang in the air together with light dust particles. Humidification of the air leads to dust deposition and a 50–60 % reduction in the mass of microorganisms in the air. Microorganisms that settle on the floor material with water particles have little contact with the respiratory tract of chickens. To some extent, this creates good sanitary and hygienic conditions for their growth and development. The peculiarity of the broiler growing process is that as the chickens grow and their live weight increases, the load on the air supply system increases, and therefore the load on the humidification mechanisms. Therefore, it would be more correct to make a more accurate judgment about the productivity and efficiency of the system based on indicators corresponding to the final stage of broiler breeding, rather than the average microclimate in the poultry house.

In this regard, when 9-week-old chickens are in experimental and control rooms, the microclimate temperature, relative humidity, and ammonia content in the air are at the level of eighteen points indoors, in the area where the chickens are located (0.2 m above sea level and at the human level (1.7 m above the floor). The results of measuring the microclimate indicators at eighteen points of the housing during the final maturation of broilers in the experimental and control buildings are shown in Table 5.

The results of the analysis of the microclimate parameters showed that the use of a humidification system led to a significant improvement in the microclimate in the experimental building. The air temperature in the experimental building decreased by 1.2 °C, and humidity increased by 6.5 %.

The results of the study showed that the air exchange system of the poultry house has the necessary performance and is able to provide the regulatory parameters of the microclimate in the final crisis phase of broiler breeding.

The system lowered the air temperature in the poultry house, which provided a standard air exchange, and brought it closer to the norm required by the age of birds in the room. At the same time, the relative humidity was normalized.

Creation of favorable conditions for broiler breeding: normalization of temperature and humidity conditions in the experimental room of the poultry farm, reduction of microbial air pollution have created favorable conditions for the growth and protection of broilers, as well as rational use of feed.

The results of the experiment showed that when using the humidification system, protection in the experimental group increased by 4.9 % compared to the control group. The average live weight was slightly higher in wet conditions, due to 1 kg of live weight gain, 0.2 kg of feed consumption was saved. The total feed savings during the cultivation of one experimental batch amounted to 1.5 tons.

Our research allows us to conclude that it is possible to improve the temperature and humidity regime in the poultry building in Azerbaijani conditions with artificial humidification of the air with disk humidifiers.

However, it should be noted that the set of humidifying equipment used cannot be considered perfect from the point of view of design. During the experiment, frequent breakdowns of this equipment were observed. In case of a malfunction, a leak occurs, which makes it impossible to operate the equipment in automatic mode. The most serious drawback in the operation of such humidifiers is the formation of a layer of salt on the rotating disk and, as a result, its failure. The results obtained allowed us to determine the directions of improvement of humidifiers.

5. 2. Computer and experimental LED lighting systems

Computer studies are of particular importance in the study of agricultural processes. A computer study of the illumination and an assessment of the optimal pricing parameters using this method were carried out for the technological LED lighting system of two poultry farms.

In the selection of input parameters on both objects, a line γ=15° was taken, placed with an interval j=7. The selected angle (γ) does not violate the conditions of the blinding effect of 40...50°, and therefore the initial angle is assumed to be β_0=45°.

Circular symmetrical LEDs with a diameter of no more than 5 mm were chosen to use a large number of low-power light guides (p_1). The studies were carried out to estimate the opening angles of the light guides from α 15° to α 30°. The selected LEDs do not require cooling at a voltage U=3 V and current I=0.02 A, while the light axis strength I_0=20 kd, the power of one LED P_1=0.06 W. The computer experiment consists in the following for the case when the opening angle of the light stream from each building for birds is α=20°:

1. For technological lighting in a poultry house with dimensions a=66 m, b=12 m, 72 LEDs-19.2 are used (LED p_1=0.08 W, η=62.5 lm/W). They are located at a height of N_L=3. The height of the canopy of lamps H=3.5 m.

The total energy use is P_0=1382.4 watts, while the power of each lighting device is 19.2 watts. Illumination measurements determined the interval of the coefficient of uneven illumination Z in the transverse plane from 1.146 to 1.430.

The distance between the luminous lines in accordance with the physical modeling is assumed to be L_0=8 m with the number of lines N_L=2. If the length of the illuminator is 1 m, the placement distances are also 1 m. The number of illuminators in one place is $a/2$=33, then

$$S_0=(a/2)\cdot N=66.$$

Table 5

Microclimate indicators in poultry houses in the hot season

No.	Indicator	Unit of measurement	Experimental case	Control case
1	Age of chickens	week	9	9
2	Outdoor air temperature	°C	33.2±0.5	33.2±0.5
3	Relative humidity of the outdoor air	%	54.3±1.0	54.3±1.0
4	Productivity of climate change	1,000 m^3/h	76.2	76.0
5	Indoor air temperature	°C	26.4±0.2	27.6±0.2
6	Relative humidity inside the building	%	64.9±1.2	58.4±1.2
7	The amount of ammonia in the air	mg/m^3	11.6±0.4	11.3±0.4

Then we apply the algorithm for the opening angle of the luminous flux $\alpha=20°$. As a result of the report, an intermediate value of $N_0=18{,}018$ for the number of LEDs and the values of the coefficient of unequal illumination $Z_0=1{,}086$ at $L_0=8$ m were obtained. After evaluating the optimal values of the distance between the lines, we obtain $L_{opt}=8.11$ m. At this distance, the best number of LEDs and the best uneven illumination coefficient $N_{opt}=18{,}018$ and $Z_{opt}=1.081$ are obtained (Fig. 1).

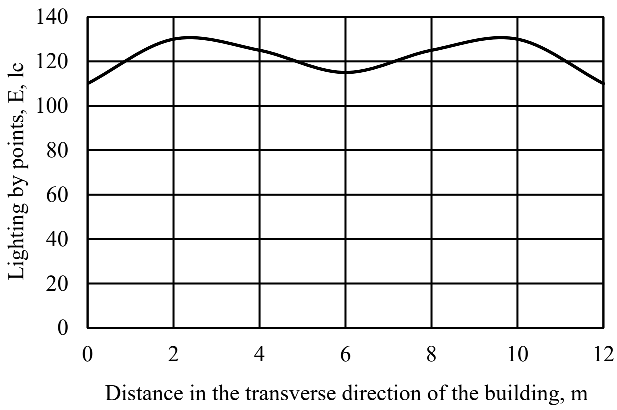

Fig. 1. Lighting in the direction of the poultry house with a width of 66×12 m: $E_{min}=112.2$ lk; $E_{max}=130.35$ lk; $Z_{opt}=1.081$; $L_{opt}=8.11$ m

The power of the lighting system for the selected LEDs $W_{opt}=W_1{\cdot}N_{opt}=0.06W{\cdot}18{,}018=1081.1$ W. This is 27.9 % less than the lamps produced by LLC «Reserve».

The results of the study of the luminous flux (α) in the range from 15° to 30° in the poultry building under study (dimensions 66×12 m) are shown in Table 6.

As can be seen from Table 2, the use of LEDs with an opening angle of 30° degrees increases the effect of energy consumption in the poultry house by 2.6 times. In this case, $Z=1.1$ increases only slightly (3 %). It should be noted that the difference between the optimal value of the distance between the lamps and the value obtained by physical modeling of L_{opt} compared to $L_0=8.0$ m was very small (2.5 %).

Thus, in a poultry house with dimensions $a=66$ m and $b=12$ m, it is possible to recommend placing 66 LED lamps in a longitudinal line $N_L=2$ (the distance between the lines is 7.84 m). The number of LEDs (opening angle of 30°) in the lamp is 133, power is 7.98 watts. This option is 2.4 times more efficient than LED-19.2. Lighting quality $Z=1.1$ (Table 7).

2. In the second case of a poultry building (dimensions $a=78$ m, $b=18$ m), 160 LEDs GL036-D016.ON were used (LED $W_1=1W$; $\eta=112.5$ lm/W). They are arranged in longitudinal lines with $N_L=4$. The total power consumption of each lamp is 16 watts $W_0=2{,}560$ W.

According to the physical modeling, the distance between the lines of lamps is $L_0=8$ m, and the number of lines is $N_L=3$. Given that the length of the lamp is $l=1$ m, and they hang at a distance of 1 m from each other, the number of lamps in the line is $a/2=39$, then $S_0=(a/2)\,N_L=117$. According to the results of computer reports (also at $\alpha=20°$), the intermediate value of the number of LEDs was $N_0=31{,}122$, and the value of $Z=1.071$ with an unequal illumination coefficient $L_0=8.0$ m. When estimating the optimal value of the distance between the lines, as a result, $Z=1{,}046$ was obtained with $N_{opt}=30{,}303$ and $L_{opt}=7.83$ m (Fig. 2).

The results of the report for the variation of x from 9 m to 69 m do not differ from the values obtained at $x=39$ m. The illumination of the system for the selected LEDs is $W=W_1{\cdot}N_{opt}=0.06{\cdot}30{,}303=1{,}818.2$ watts. The production of this Gelan LLC is 40.8 % less than the use of lamps (Table 8).

Table 5 shows that the use of LEDs with an opening angle from 15° to 25° increases the energy efficiency of the poultry house from 13.3 % to 117.1 %. At the same time, the lighting quality is high (the coefficient of uneven illumination $Z<1.1$).

The slightly reduced (less than 0.8 %) energy efficiency of lighting in such a birdhouse is more than 3 times higher. The difference between the optimal value of the distance between the rows of lamps (L_{opt}) and the value of the physical simulation $L_0=8.00$ m is less than 7.2 %.

Thus, in a bird building with dimensions $a=78$ m, $b=18$ m, 117 LED lamps distributed along the longitudinal line $N_L=3$ can be recommended. The distance between the lines is assumed to be 7.46 m (Table 9).

Table 6

Energy consumption in a poultry building measuring 66×12 m at various values of α, N, Z and L_0 at $W=1382.4$ watts, results of evaluation of optimal prices

α, degrees	η, lm/W	E_{or}, lk	L_{opt}, m	Z	N_{opt}	W_{opt}, W	W_o/W_{opt}
15	18	120.2	8.04	1.080	30,594	1,835.6	0.753
20	31.83	121.3	8.11	1.081	18,018	1,081.1	1.279
25	49.67	125.5	7.94	1.105	12,012	720.7	1.918
30	71.33	130.4	7.84	1.130	8,778	526.7	2.625

Table 7

Comparison of lighting systems of a poultry building with a size of 66×12 m

Object	Type of lighting (l=2 m)	Number of LEDs in the illuminator	Lamp power, W	Number of illuminators	Number of lighting lines	Luminous flux of the illuminator, lm
Poultry building 66×12 m	Existing lighting system					
	LED-19.2	240	19.2	72	3	1,200
	Upgraded lighting system					
	Recommended lighting (l=1 m)	133	7.98	66	2	569.24

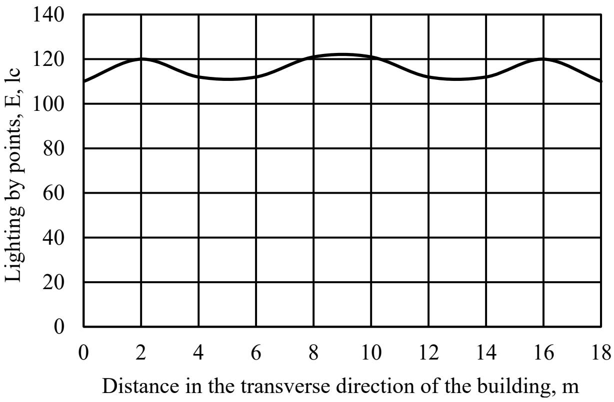

Fig. 2. Lighting in the transverse direction of the poultry building (78×18 m): $E_{\min}$=125.44 lk, Z=1.046, L_{op}=7.83 m

LEDs in one lamp: opening angle – 30°, number – 112, lamp power – 6.72 W, which is 2.4 times more efficient than the GL036-D016.ON lamp. At the same time, the lighting quality is close to Z=1.1.

An economic evaluation of the utilization technology of bird droppings was implemented based on the tests performed in the «Suliddinoghlu» village farm of Samukh district. The main activities of the farm are poultry breeding, producing eggs, bird meat, and dairy products.

There are great opportunities for the utilization of collected bird droppings for the purpose of organic fertilizer and using them in the around farms. Conducted investigations and design of the utilization technology of bird droppings based on the expert system have shown the feasibility of the application of bio-fermentation in the fermentation chambers.

The concrete platform for the utilization of bird droppings was maintained in stencil for 3 months. Organic fertilizer was realized to the sown areas of the farm and other farms when ordered. The selection of bio-fermentation technology is related to getting high-quality organic fertilizer.

A staged application plan has been developed because of the high cost of application of this technology. The completion of such a facility under the poultry factory is planned for 2020. At present, the first stage has been realized and this can utilize 20 % of bird droppings. Although private investment is a little more compared to base technologies, Z=0.078 AZN/tonnes=0.05 $ against Z=75 AZN/tonnes =44.12 $. Economic efficiency compared to the base technology is E_y=7,945.58 AZN=4,571.65 $ against E_b=1.642.5 AZN=966.18 $.

The efficiency indicators of the proposed technology are presented in Table 10.

Table 8

Energy consumption in a poultry building measuring 78×18 m at various values at W=2560 watts, results of evaluation of optimal prices

α, degrees	η, lm/W	E_{or}, lc	L_{opt}, m	Z_{opt}	N_{opt}	W_{opt}, W	W_o/W_{opt}
15	18	120.2	7.94	1.078	54,054	3,243.2	0.789
20	31.83	120.2	7.83	1.046	30,303	1,818.2	1.408
25	49.67	124.7	7.60	1.078	19,656	1,179.4	2.171
30	71.33	120.4	7.46	1.108	13,104	786.2	3.256

Table 9

Comparison of lighting systems of a poultry building with a size of 78×18 m

Object	Type of lighting (l=2 m)	Number of LEDs in the illuminator	Lamp power, W	Number of illuminators	Number of lighting lines	Luminous flux of the illuminator, lm
poultry building 78×18 m	Existing lighting system					
	GL036-D016.ON	16	16	160	4	1,800
	Upgraded lighting system					
	Recommended lighting (l=1m)	112	6.72	117	3	479.36

Table 10

Evaluation of the application efficiency of the utilization technology of bird droppings

No.	Indicator	Unit of measurement	Technology	
			Base technology	Designed technology
1	Collected bird droppings	tonne/year	4,562.5	4,562.5
2	Amount of annual organic fertilizer	tonne/year	4,562.5	8,212.5
3	Investment	1,000 AZN/$	2,322/1,365.01	4,603.5/2,648.72
4	Amortization, current repair, and technical service	1,000 AZN/year/$	184.6/108.59	261.78/153.99
5	Energy costs	kW hour/year	354,781/204,130	436,540/256,790
		1,000 AZN/$	28,604.2/16,826	30,557.8/17,582
6	Fuel costs	tonne/year	198.16/116.82	577.9/339.94
		1,000 AZN/$	178.35/104.91	404.53/237.96
7	Labor input	person/hour	12140	26,810
		1,000 AZN/$	12.1/7.14	26.81/15.77
8	Supplementary material	1,000 AZN/$	2,730/1,605.4	3,650/2,147.08
9	Operating costs	1,000 AZN/$	404.52/237.95	1,418.1/834.18
10	The amount of starting nitrogen	tonne	82.13	82.13
11	The ratio of nitrogen preservation	tonne	0.37	0.77
12	Specifically reduced costs	1,000 AZN/ tonne/$	0.075/0.04	0.0786/0.05
13	Environmental and economic effects	1,000 AZN/$	1,642.5/966.18	7,945.58/4,673.91
14	Loss of nitrogen	tonne	51.74	18.89/11.11
15	Effect indicator of affordable technology	1,000 AZN/tonne/$	127.7/75.12	143.9/84.65

Evaluation of LED lighting was performed in «Ismayilli Zarat broiler» poultry farming with the size of 66×12 (the hanging height of the lighting – 3.5 m, number of birds – 50,000 hens, method of keeping – on the floor). The lighting mode was the same in both bird buildings with control and experimental facilities, switching on and off were implemented with a «Rassvet-200» lighting controller. Indicators for determining annual energy savings are given in Table 11.

We evaluate the economic efficiency of the application of LEDs for bird buildings based on lamps with a capacity of 16.4 W. Lighting with LSP 2×36 type luminescent lamps was selected for comparison. Considering the unevenness of economic costs, we accept the following prerequisites:

1) losses and feed costs are the same in both cases;
2) the number of hens is the same in an older brood.

Considering the recommendations [14–26], when evaluating investment projects, the use of cash flow at various times can be implemented by discounting to the initial period $t_0=0$. Discounting means finding a sum corresponding to a certain moment (t), which can increase with further calculating percentage. The value found by discounting the increased value is a reduced value. Inflation processes, bank investments for loans, time factors associated with securities are considered in financial calculations.

Discount norm equal to income return on investment is used to reduce various expenses, outcomes and effects. This is measured by the share unit or percentage for a year.

Technically, bringing cash flow to the base is determined by multiplying it by the discount rate. When using private investment in the market economy, discount rates are determined based on deposit interests on investment. In practice, the value is higher due to inflation and risk. If all investments are debt, then the discount rate reflects the appropriate interest rate. It is recommended to use the following indicators to evaluate the effectiveness of an investment project:

1) net discounted income (NDI);
2) profitability index (PI);
3) term of payment of investments;
4) other indicators that reflect the project specificity or the interest of the participants. Net discounted income is the most important efficiency criterion. NDI values calculated for different years are given in Table 12.

Costs reduced to the base moment (for the first year of the project) are determined by multiplying with their discounting coefficient.

Discounting coefficient is determined by the following formula:

$$a_1 = \frac{1}{(1+E)^t}, \qquad (28)$$

where t – years (0, 1, 2,..., T); E – discount rate, E=15 %.

The results of the evaluation of efficiency when replacing luminescence lamps with LED lamps are given in Table 13.

If t=10 years, the discounting coefficient is as follows:

$$a_1 = \frac{1}{(1+0.15)^{10}} = 0.247. \qquad (29)$$

Net discount income (NDI) characterizes increasing total incomes compared with total costs, given the inequality of the effect for the project at different times.

Table 11

Determination of annual energy savings

No.	Parameter	Poultry building with a luminescence lamp	Poultry building with LED-19.2	GL036-D016ON LED lamps	Poultry building with designed lamps
1	The number of lamps	72	72	160	66
2	Lamp power, W	36·2=72	19.2	16	16.4
3	Total power of the lighting system, W	5.18	1.38	2.56	1.08
4	Specific total power of the lighting system, W/m^2	6.54	1.74	1.82	1.36
5	Working time of the lamp in a year, hour	5,100	5,100	5,100	5,100
6	The cost of 1 kW·hour, AZN	0.07/0.04			
7	Special price for electricity in a year, AZN/m^2	4.0/2.35	1.06/0.62	1.57/0.92	0.83/0.49

Table 12

Final estimation results of NDI

Service period T, year	Discount coefficient	Income	Net discounted income
0	1.000	0	2,688.6
1	0.870	1,349.25	1,515.33
2	0.756	1,349.25	495.11
3	0.658	1,349.25	392.04
4	0.572	1,349.25	1,163.47
5	0.497	1,349.25	1,834.29
6	0.432	1,349.25	2,417.61
7	0.376	1,349.25	2,924.84
8	0.327	1,349.25	3,365.92
9	0.284	1,349.25	3,749.46
10	0.247	1,349.25	4,082.97

Table 13

Evaluation of the efficiency of replacing luminescence lamps with LED lamps

Symbol	Indicator	Unit of measurement	Price	Calculation method
T_e	Price of electricity	AZN/$	0.07/0.04	$a_1=\frac{1}{(1+E)^t}$
P_b	System power before modernization	kW	5.18/3.05	
P_m	System power after modernization	kW	1.08/0.64	$a_2=\frac{1}{(1+E)}$
T_{il}	Working period of the lighting system throughout the year	hour	5,100/3,000	Average value (14 hours a day)
W_n	Use of electricity before modernization	kW·hour	26,418/15.54	$P_n \cdot T_{year}$
W_m	Use of electricity after modernization	kW·hour	5,508/3.24	$P_m \cdot T_{year}$
Modernization costs of the system				
price of lamps		AZN	1,188/698	66 lamps
Costs of pre-project work and preparation of technical task		AZN	60/35.29	66 lamps
installation costs		AZN	1,443.45/353.792	66 lamps
Total indicators				
ΔW	Saving electricity	kW·hour	20,910/12.29	W_n-W_m
	Self-paid term	year	2	W_n-W_m

NDI for the reporting period is defined as total current E_m effects (efficiency):

$$XDG=E_m=\sum_{i=0}^{T}\frac{P_t-z_t}{(1+E)}-K=\sum_{i=0}^{T}(P_t-Z_t)a_1-K, \qquad (30)$$

P_t – the result obtained in step (stage) t; Z_t – costs without considering the investment in the same step; K – expenses.

Table 13 shows that NDI achieved a positive value in the third operating year.

6. Discussion of the results of studying processes at poultry farms

The result of the research process proved that when analyzing the microclimate, the temperature inside the poultry house was 1 °C when using the experimental setup, as well as air pollution by microbes was 40 mic/m^3 less compared with the control sample. As can be seen from Table 4, during the experiment, the average air temperature in the experimental building was 26.0 °C, and in the control – 27.5 °C. The result of the research process (Fig. 1) showed that when applying the algorithm for the opening angle of the luminous flux α=20°, as a result of the report, we obtained an intermediate value of N_0=18,018 for the number of LEDs and the values of the coefficient of unequal illumination Z_0=1.086 at L_0=8 m were obtained. After evaluating the optimal values of the distance between the lines, we obtain L_{opt}=8.11 m. At this distance, the best number of LEDs and the best uneven illumination coefficient N_{opt}=18,018 and Z_{opt}=1.081 are obtained. According to the results of the studies carried out in Fig. 2 of computer reports, the average number of LEDs was N_0=31,122, and the value of Z=1.071 with an unequal illumination coefficient L_0=8.0 m. When estimating the optimal value of the distance between the lines, the result was Z=1,046 with N_{opt}=30,303 and L_{opt}=7.83 m.

It has been experimentally proved that the combined effect of ultraviolet radiation and ozone can increase the effect of air neutralization by 25...40 %.

Theoretical and experimental studies conducted on the disinfection of air with ultraviolet bactericidal irradiators in poultry houses allow us to determine the level of disinfection, the required degree of irradiation and the time of irradiation. Based on this, the development of highly effective bactericidal devices is considered one of the important tasks. From this point of view, the scientific justification of energy-saving lighting and irradiation equipment for poultry farming is also very relevant, which can be solved in the course of further research.

During our research, there were certain difficulties in obtaining more accurate data. As for example, during a detailed study of the cooling system in the poultry house, Table 1. The balance price of the new refrigerator was B_y=129,000 AZN or 75,882 $; and the price of the basic cooling system was only B_b=111,000 AZN or 65,866 $. As well as the service life of a nested layout or a coated cassette. For the basic version, it was T_b=4 years, for the new experimental T_y=8 years.

The main way to solve these problems is to develop a new less energy-intensive refrigeration unit, as well as a lighting system, which is one of the important factors. Also, our research was carried out on the analysis of the effect of illumination on birds. At the same time, the obtained research results have shown that properly selected lighting for the poultry house provides the most rational productivity of the fattened poultry and brings income to the enterprise. The UV germicidal lamps we offer are more effective than conventional ones.

7. Conclusions

1. The results of determining the climate in the poultry room showed that the farm loses 7–10 % of its productive poultry if the temperature inside the building is high during the hot season and there is not enough fresh air flow to the area where birds are located. The optimal indoor temperature for laying hens is 15–18 °C, and for broilers at the end of cultivation – 16–18 °C. Each degree of temperature increase is accompanied by a decrease in ovulation by 1.5–2 %. The most favorable range of relative humidity is considered to be 60–70 %. In the absence of the necessary ventilation, after 2–3 hours, the room is filled

with carbon dioxide by 10–20 %, which leads to oxygen deficiency and paralysis of the respiratory organs of birds. Thus, the optimal mode of keeping birds in the summer is considered to be: temperature 12 °C, relative humidity 65 %, air velocity in the area where birds are located 1.5 m/s, the frequency of air exchange in the room 4.0 m^3/h per 1 kg of bird weight.

2. The conducted studies have proved that UV bactericidal lamps with a protective glass coating are the most effective means of both lighting and dehumidification of air in poultry houses. They exclude radiation at a wavelength of 184.9 nm. The ozone capacity of these lamps is 4.5 mg/kWh. There are also special lamps with quartz glass, the ozone capacity of which is 900 mg/kWh. It has been experimentally proved that the combined effect of UV radiation and ozone can increase the effect of air neutralization by 25...40 %.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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