Ensuring Basic Technological Processes at a Poultry Farm by Developing an Autonomous Robotic System

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Abstract: This paper discusses the issues of poultry technology in the Russian Federation, development prospects, and a new technology called "Smart Farm". Today, to increase the productivity of poultry farms, it is necessary to rethink existing technologies for the production of poultry meat, eggs and introduce new technological solutions for basic technological processes, namely: watering, feeding, disinfection of litter, collection of eggs, monitoring of poultry health by biological external signs. Our idea is that we want to eliminate the human factor from production technology by robotizing the main technological processes. These robots should reduce the likelihood of infections in poultry, increase the productivity of poultry farms, reduce the number of workers involved in the production process, and the number of bulky and energy-intensive stationary installations.

1 INTRODUCTION

Industrial poultry farming is one of the main components of the food safety of our country. This industry is currently undergoing a stage of transition to full automation of all technological processes, and this industry begins its development in 1962. This year, the first mechanized technological solutions for outdoor poultry keeping were manufactured, and mass production was already started in 1965 Modern technology for poultry farming has more than 100 different machines and automated systems.

Mechanization and automation are an integral part of modern poultry farming, its technical basis, and the merger of these two industries gives the concept of robotization of production. On the basis of robotization, not only the consolidation of poultry farms takes place, but also the creation of eco-logical and, no less importantly, sterile technology, which reduces the cost of human labor and increases productivity significantly.

In this regard, the goal is automation and robotization of farms, transition to autonomous operation of the enterprise (without the participation of human labor).

The main problem is to get away from manual labor, which occupies up to 70% of the total volume of robots on poultry farms, by introducing autonomous robots to implement the main technological processes on poultry farms.

2 RESEARCH METHODOLOGY

Description of existing technologies for breeding poultry for outdoor maintenance and comparison with the developed technology "Smart farm". Development and writing of patents.

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3 RESEARCH PART

Outdoor poultry keeping is a fairly widely used method of breeding poultry. With this method, the places of detention are equipped with special feeders, drinkers, roosts and bathrooms with ash.

For the manufacture of roosts, smooth polished wooden blocks are used, the length of the bars should be such that the livestock can fit on it.

Feeders are of great importance in the arrangement of outdoor poultry keeping. Their correct shape allows you to reduce the loss of feed on the placer. Groove feeders are most often used. A bar is attached above the feeder, fixed in such a way that it turns when the bird tries to sit on it. This feature allows you to avoid contamination of the feed with droppings, as well as to prevent the burying of feed by birds.

Basically, either vacuum or round drinkers are used for floor maintenance.

The bedding for poultry should be deep, mainly hay or wood shavings are used to create it. Peat or crushed corn stalks can also be used for these purposes. The bedding is changed annually. The average cost of bedding material for one bird is: for chickens – 10 kg, turkeys – 25-30 kg, geese – 40 kg.

Due to the fact that the litter self-heats up due to chemical reactions occurring in it, the bird is not cold during the cold period of time.

We propose to carry out the robotization of these technical processes by replacing the described technical solutions with autonomous robots, namely a robot drinker, a robot feeder, a robot for collecting eggs, and a robot for stirring the litter.

Next, 4 robotic systems will be described for performing technological operations for growing poultry using the Smart Farm technology.

A robot drinker is necessary to provide birds with water (up to 1000 heads). It consists of a housing in which a chassis with an electric motor and a control unit is enclosed, also located vertically on the tank body with a volume of 200 liters, drinking systems are attached to the tank, which include nipple, removable drinkers in the amount of 12 pieces. The robot's control unit has a trajectory along the working area of the poultry house, it is also equipped with a water level sensor, a filter for purifying water from microorganisms, and a special funnel for refueling water.

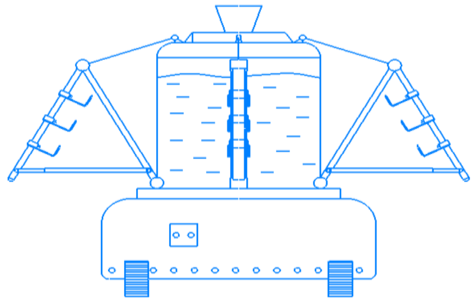

Figure 1: The appearance of the drinker robot (patent No. RU was obtained 2,768,843 C1 IPC A01K 39/024 2021.g).

We want to present the feeding system in the form of a robotic feeder.

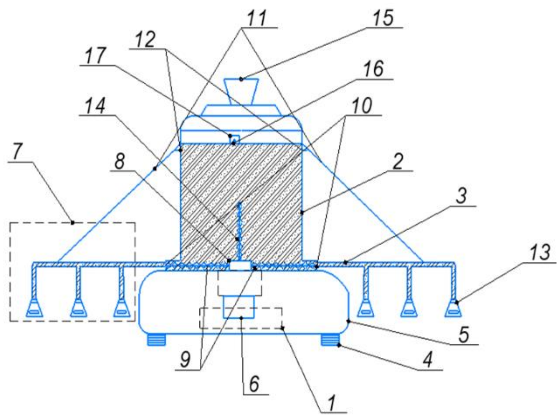

Figure 2: Appearance of the feeder robot: twin electric motor 1, reservoir 2, supply line 3, tracked chassis 4, box-shaped housing 5, control unit 6, sections with feeders 7, gearbox 8, two horizontal augers 9, discharge hatches 10, two winch cables 11, two electric winch units 12, removable cone-shaped feeders 13, vertical auger 14, loading funnel 15, warning light 16, surveillance camera 17.

A robot feeder for feeding agricultural products. birds with outdoor maintenance work as follows: the box-shaped housing 5 begins to move on the tracked chassis 4 along a predetermined route, which is programmed in the control unit 6, the system occupies a predetermined position in the hangar and the control unit sends a signal to two electric winch units 12, which the winch cable 11 begins to lower from the supply line 3 fixed on them, with cone-shaped feeders 13 fixed on them, after that the control unit sends a signal to a dual electric motor 1, which, through a gearbox 8, activates horizontal augers 9, those, in turn, promote the feed into the discharge hatches 10, and from them the feed enters the feed line from where it gets into the feeders, after emptying the tank, the system comes into a transport position and goes to the feed mill to refuel the tank, refueling takes place through the loading funnel 15, the surveillance camera 17 displays the environment around the moving unmanned system, the alarm system lamp 16 reflects its working condition.

There is a problem with the processing of bedding material, as this is one of the sources of poultry diseases. To solve this problem, we present a robot-agitator of bedding material.

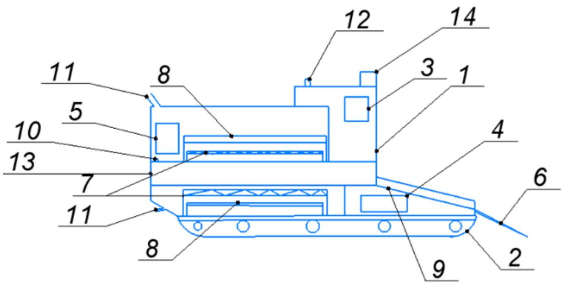

Figure 3: Appearance of the litter trowel robot: housing 1, chassis 2, control unit 3, two electric motors 4, 5, pick-up blades 6, heating elements 7, fans 8, perforated conveyor belt 9, temperature sensor 10, air ducts 11, warning lamp 12, discharge opening 13 video surveillance camera 14.

The robot agitator for processing poultry litter material works as follows: a chassis 2 is attached to the lower part of the housing 1, the control unit 3 sends a signal to two electric motors 4 and 5, a video tracking camera 14 turns on, an unmanned self-propelled system for processing poultry litter material starting movement picks up the litter using a pick-up blade 6, directing it to two heating elements 7 and two fans 8, using a perforated belt conveyor 9, the temperature sensor 10 monitors the temperature in the working area and throughout the unit, giving a signal to the warning lamp 12, air enters the fans 8 through two (upper and lower) air ducts 11, then the bedding material is discharged back through the discharge hole 13, while the heating elements 7 with fans 8 are located above and under the perforated belt conveyor 9, in front of which a pick-up blade 6 is mounted connected to the lower part of the body 1, and the chassis 2 is made tracked.

Our technology also provides for the robotic egg collection of laying hens.

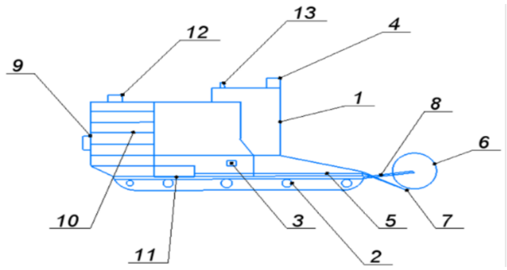

Figure 4: Appearance of the egg collector robot: housing 1, chassis 2, control unit 3, motion controller 4, egg picker made in the form of a belt conveyor 5, feed roller 6, spring–loaded grip fingers 7, two brackets 8, storage hopper 9, cassettes for storing eggs 10 pressure sensor 11, chamber video surveillance 12 and warning light 13.

The egg collector robot works as follows when kept on the floor: the feed roller 6 sends the eggs to the spring–loaded gripping fingers 7, through them they move to the perforated conveyor belt 5 and further into the egg storage cassette 10 located in the storage hopper 9, it contains a pressure sensor 11, necessary to determine the weight of eggs in the cassette storage by this weight, the degree of filling of the hopper is determined. As soon as the cassette is filled with eggs, a signal is sent to the control unit 3 about the need to replace the cassette, it sends a signal to the storage bin 9, to move the cassette to the lower part of the storage bin and an empty cassette is installed in its place, as soon as all cassettes are filled, the control unit 3 starts the crawler chassis 2, it is directed in the unloading shop, the egg cassettes are removed and replaced with empty ones, and so the repeated egg collection cycle begins. Thanks to the video surveillance camera 11, manual control is possible, the warning lamp 13 serves to indicate the status of the robot.

Also, the designed technology includes three automated units shown in Figure 5 for cleaning robots from poultry droppings and other contaminants, a water refueling unit for a drinker robot, and finally a unit for refueling a feeder robot, this unit is connected to the feed shop using a feed line. These blocks make it possible to completely eliminate the factor affecting the spread of infections, namely, to disinfect working installations.

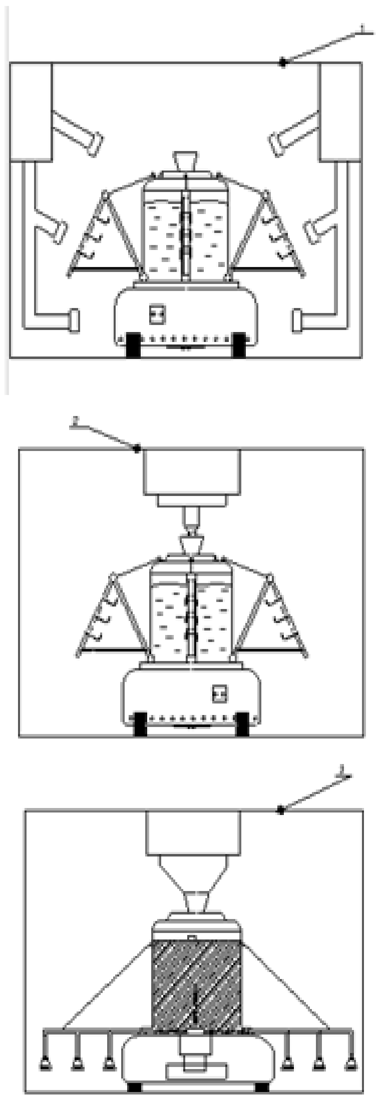

Figure 5: 1 cleaning unit, 2 feed filling unit, 3 water filling unit.

These units together form a machine system called a smart farm. To test and compare with existing technologies, we took a robot sawyer and compared economic indicators in the following section.

4 ECONOMIC EFFICIENCY OF THE RESEARCH RESULTS

To determine the economic efficiency of the developed robotization of a poultry farm, we will calculate the technical and economic data based on the work of the applied and developed means of robotization and compare these technical solutions.

The main productivity of laying hens depends on the conditions of their maintenance, since, for example, with a lack of feed or an incorrectly selected temperature, laying hens stop laying at any time.

Total output:

$$Q_{\text{г}} = n \cdot B \qquad (1)$$

where $Q_{\text{г}}$ – annual volume of poultry products, c/year;
n – number of birds, head;
B – productivity of one bird c/pt.

From these enterprises, the total annual weight of eggs laid by one laying hen is 18 kg per year, B = 0,18 kg/head.

$$Q_{\text{г}}^{\text{с}} = 1000 \cdot 0{,}18 = 180 \text{ c/year};$$

Due to the introduction of the sawyer's work at the outdoor poultry keeping, the incidence due to infectious diseases will decrease by 7%.

$$Q_{\text{г}}^{\text{п}} = 180 + 7\% = 193 \text{ c/year};$$

Labor costs for production are determined by the formula:

$$H_{\text{г}} = l_{\text{р}} \cdot \Phi_{\text{г}}^{\text{р}} \qquad (2)$$

where $H_{\text{г}}$ – labor costs, person.hour./year;
$l_{\text{р}}$ – number of employees, people;
$\Phi_{\text{г}}^{\text{р}}$ – the useful fund of the working time of one employee, h, which is equal to 2190 hours / year.

Let's determine the labor costs:

$$H_{\text{г}}^{\text{с}} = H_{\text{г}}^{\text{п}} = 2 \cdot 2190 =$$

$$= 4380 \text{ person. hour./year};$$

Labor costs per unit of production:

$$H_{y} = \frac{H_{\text{г}}}{Q_{\text{г}}} \qquad (3)$$

where H_{y} – labor costs, pers.h/c.

$$H_{y}^{\text{с}} = \frac{4380}{180} = 24{,}3 \text{ pers. h/c};$$

$$H_{y}^{\text{п}} = \frac{4380}{193} = 22{,}7 \text{ pers. h/c};$$

The specific labor cost savings will be:

$$H_{эу} = H_y^с - H_y^п \qquad (4)$$

where $H_{эу}$ – saving labor costs,

$$H_{эу} = 24{,}3 - 22{,}7 = 1{,}6 \text{ чел. ч/ц}$$

Labor productivity:

$$Р_{тр} = \frac{1}{H_y} \qquad (5)$$

where $Р_{тр}$ – labor productivity, kg/person.h.

$$Р_{тр}^с = \frac{1}{24{,}3} = 0{,}041 \text{ kg/person. h.}$$

$$Р_{тр}^п = \frac{1}{22{,}7} = 0{,}044 \text{ kg/person. h.}$$

Рост производительности труда:

$$Р_{тр}^р = \frac{(Р_{тр}^п - Р_{тр}^с)}{Р_{тр}^с} \cdot 100 \qquad (6)$$

Then:

$$Р_{тр}^р = \frac{(0{,}044 - 0{,}041)}{0{,}041} \cdot 100 = 7\%$$

where К – investments in means of mechanization, rub.;
a – the rate of depreciation on mechanization funds, %;
r – the rate of deductions for repairs and maintenance of mechanization facilities, %.

$$К_п = 116800 + 7941{,}3 = 124741{,}3 \text{ rub.}$$

Thus, the book value of the developed unmanned self-propelled watering system for outdoor poultry maintenance will amount to 124 741,3 rubles.

Calculation of depreciation costs, as well as calculation of repair and maintenance costs for the existing and proposed technology, respectively:

$$С_а^с = \frac{55800 \cdot 20}{100} = 11160 \; rub/year$$

$$С_а^п = \frac{124741{,}3 \cdot 20}{100} = 24947 \; rub/year$$

$$С_{р.то}^с = \frac{55800 \cdot 10}{100} = 5580 \; rub/year$$

$$С_{р.то}^п = \frac{124741{,}3 \cdot 10}{100} = 12474{,}13 \; rub/year$$

The annual electricity consumption is determined by the formula:

$$С_{эл} = А_г \cdot Z_{эл} \qquad (7)$$

where $А_г$ – annual electricity consumption kWh/year;
$Z_{эл}$ – the cost of 1 kWh of electricity, rub.;

$$А_г = N \cdot T_{заг} \cdot К_з \cdot \frac{К_о}{К_с} \cdot \eta \qquad (8)$$

where N – power consumption of the installed equipment;
$T_{заг}$ – annual load, h;
$К_з$ – numerical multiplier of equipment loading, $К_з$ =0,85;
$К_о$ – the numerical multiplier of the simultaneous operation of the equipment, $К_о$= 0,6-0,7;
$К_с$ – a numerical multiplier that takes into account losses on the network, $К_с$= 0,96;
η – numerical multiplier of the efficiency of the electric motor (0,85-0,9).

Тогда:

$$А_г = 0{,}35 \cdot 766{,}5 \cdot 0{,}85 \cdot \frac{0{,}7}{0{,}96} \cdot 0{,}85 = 141{,}33$$

$$С_{эл} = 141{,}33 \cdot 2{,}7 = 381{,}6 \; rub$$

Additional operating costs will amount to 21064 rubles/year.

We know that when using the proposed equipment, the productivity of the poultry farm will increase by 13c eggs per year, which can be sold at a price of 16,670 rubles/c. This will allow you to receive an additional 216,700 rubles annually.

The payback period for additional investments will be:

$$t_о = \frac{124741{,}3}{216700 - 21064} = 0{,}64 \; year;$$

Next, we will determine the amount of specific investments.

$$К_у^с = \frac{55800}{180} = 310\ rub/c;$$

$$К_у^п = \frac{124741{,}3}{193} = 646{,}33\ rub/c;$$

Let's calculate the given costs:

$$П_у^с = 3929{,}32 + 0{,}15 \cdot 310 = \\ = 3975{,}82\ rub/c;$$

$$П_у^п = 3773{,}8 + 0{,}15 \cdot 646{,}33 = \\ = 3870{,}75\ rub/c;$$

The energy intensity of the technological process is determined from the expression:

$$А_у = \frac{\sum А_г}{Q_г} \quad (9)$$

$$А_у = \frac{141{,}33}{193} = 0{,}73\ kW/c$$

The metal consumption of the technological process is determined from the ratio:

$$М_у = \frac{\sum М}{Q_г} \quad (10)$$

Then:

$$М_у^с = \frac{110}{180} = 0{,}61\ kg/c$$

$$М_у^п = \frac{70}{193} = 0{,}36\ kg/c$$

The calculated economic indicators indicate the appropriateness of using the developed self-propelled system for watering poultry.

5 CONCLUSIONS

1. As a result of comparing the two technologies being developed and the existing one, a number of advantages of the technology being developed for the robotization of poultry farms were revealed, namely: low equipment costs, investment is much lower than that of existing technologies, and most importantly, it is to obtain an environmentally friendly product of poultry meat and eggs.

2. We also found out after comparisons and analyses that existing technologies for poultry cultivation in outdoor conditions have a number of disadvantages: cumbersome, time-consuming, insufficiently automated, and also sources of infections for poultry due to contamination accumulated on them.

3. After conducting a patent search for structures for robotization of poultry farms, we proposed a constructive and technological diagrams of robots for drinkers, feeders, agitators, litter and egg pickers. We have sent applications for the invention of the Russian Federation.

4. When commissioning the proposed means of robotization, it is possible to reduce the labor costs of 1 kg of products by 6.6%, but operating costs increase by 3%, while the productivity of the poultry farm will increase by 13 kg of products per year, these products by 16,670 rubles /ts, this will increase the annual profit by 216,700 rubles, the payback period of investments will be 8 months. all these data indicate the full feasibility of using these robotic systems in poultry farms.

REFERENCES

Kotelevskaya, E. A., Klasner, G. G., Tolstov, K. S., 2020. Determination of safe conditions for moving ears to the working surface of the plant for sorting ears of seed corn. IOP Conference Series: Earth and Environmental Science : conference proceedings, Krasnoyarsk, Russia, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 421. – Krasnoyarsk, Russia: Institute of Physics and IOP Publishing Limited, 2020. P. 22014.

Klasner, G. G., Tarasov, V. S., Baranov, V. P., 2020. The study of the moment of resistance of the grinder of legumes. Conference Series: Earth and Environmental Science : conference proceedings, Krasnoyarsk, Russia, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 421. – Krasnoyarsk, Russia: Institute of Physics and IOP Publishing Limited, 2020. P. 22013.

Kremyansky, V. F., Klasner, G. G., Yaroslavtsev, D. I., 2020. Factor analysis in the lame problem (the problem of composite cylinders).IOP Conference Series: Materials Science and Engineering, Krasnoyarsk, Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. Vol. 862. – Krasnoyarsk: Institute of Physics and IOP Publishing Limited, 2020. P. 32043.