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IMPROVING THE TECHNIQUE OF PROTECTING CONCRETE FLOORS IN POULTRY HOUSES

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The object of the study was concrete floors in a poultry house with different types of litter. The paper addressed the problem of reducing microorganism contamination of concrete floors in poultry houses to prevent biological corrosion.

Corrosion of the surface of the concrete floor in the form of the formation of calcium oxalate monohydrate crystals was established by scanning electron microscopy; microscopic fungi: A. pullulans, F. sporotrichioides, and A. niger were detected. The TPD MS method established that concrete samples obtained in a room with straw lose moisture by 51.52 % more, with granules – by 342.42 % ($p\leq0.05$), with shavings by 6.06 %, compared to control. CO from concrete samples is released less with sawdust litter by 86.40 %, with straw – by 83.49 %, with shavings – by 76.69 %, with granules – by 69.90 % ($p\leq0.05$). The CO_2 content in concrete samples from the room with sawdust was lower by 86.88 % ($p\leq0.05$), with straw – by 55.73 %, with shavings – by 38.52 %, with granules – by 23.77 %, compared to control without litter.

Microbiological studies have established that 48 hours after disinfection, the total number of colonies of microorganisms on a concrete floor with a sawdust litter likely decreased by an average of 90.19 %, straw – by 91.62 %, shavings – by 79.76 %, granules – by 82.88 % ($p\leq0.05$), in the control – by 83.73 %. It can be argued that the disinfectant destroys microorganisms on the concrete surface regardless of the type of substrate.

The peculiarity of the experiment was the use of scanning electron microscopy and TPD MS methods to study structural changes in concrete. The research is distinguished by the use of a powdered disinfectant to reduce microbial damage to a concrete floor with different types of litter.

The results of the experiment could be used in the aggressive environment of poultry houses to reduce the impact on concrete structures

Keywords: floor, microorganisms, litter, destruction, concrete

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1. Introduction

Conditions for raising poultry, especially turkeys, must meet animal health and welfare requirements. Turkeys, as large animals, are kept on the floor with deep litter. In those countries where climatic conditions allow, poultry are grown in open areas on pasture. In countries where the temperature can drop to –25 °C and below in winter, it is not possible to provide comfortable conditions in the open space. Turkeys are kept in closed rooms with a controlled microclimate throughout the year, depending on the age of the bird. The most difficult conditions are created when young animals are kept from a week to a month, due to a large crowding of livestock and high temperature and humidity in the room.

Despite the climate control, humidity is increased due to litter that is reused and only occasionally mixed with fresh substrate. The type of litter is chosen depending on which manufacturer the farm has an agreement with. Very often, sawdust from various types of wood is used on farms. However, as practical experience shows, sawdust is always moist and does not dry well. Also, a long period of its use leads to the reproduction of a large number of microorganisms, especially microscopic fungi.

Fungi of the genus *Aspergillus* affect the respiratory organs and serous membranes of other organs in birds and humans, which is called pneumomycosis. It should be noted that well-dried sawdust, especially from conifers, has a lower percentage of moisture and damage by micromycetes. Straw is also often used as litter, but it all depends on the features of its preparation and the period of use indoors. Unfortunately, straw is the stems of cereal plants, which are often affected by fungi of the genus *Fusarium*. If the straw has not undergone heat treatment, it will be a source of damage to the concrete by microscopic fungi. That is why straw pellets have been used as litter in poultry farming. The raw material for granules must undergo heat treatment, which prevents the reproduction of microorganisms in it. In addition, after a short period of use, the granules turn into a fine mass that is quickly soaked with moisture. Therefore, the period of safe use of pellets is also limited. To prevent the reproduction of microorganisms in the litter, which is the main source of bacterial and fungal infections, it is necessary to use disinfectants. The powdered disinfectant is mixed and spread on the floor with litter. To reduce moisture in the litter, the disinfectant includes artificial zeolite, which has hygroscopic properties. In addition, the composition of the product includes substances of different classes, so the widest possible antimicrobial spectrum is covered. Due to the need to use the disinfectant in the presence of animals, the toxicity of the active ingredients on the animal's body was taken into account. In addition, the selected components of the disinfectant based on sodium benzenesulfochloramide, copper and iron sulfates, thymol, artificial zeolites have no corrosive activity.

The relevance of the research is related to the prevention of biological corrosion of concrete floors in poultry houses through the use of a dry disinfectant.

2. Literature review and problem statement

Despite the fact that concrete and metal structures are used for the construction of agricultural structures, there is a problem of their corrosion under the influence of an aggressive environment. The authors of work [1] in their research came to the conclusion that concrete structures collapse in environments with high humidity and the presence of animal manure. Poultry, cow, and pig manure contains a mixture of different chemicals such as chlorides, sulphates, nitrates, hydrogen sulfide, and ammonia which lead to the deterioration of concrete. Researchers demonstrate the influence of the poultry house environment on the structure of concrete, depending on the area of operation, but do not offer a way to protect building structures.

The behavior of new stable concrete in an environment of 3 % sulfuric acid and 1.5 % nitric acid was studied in [2]. The results of the experiment showed that the loss of concrete mass and compressive strength in acidic environments was minimal when replacing cement with 30 % of ash. The study proposed a new composition of concrete to increase stability, but the experiment was limited to tests under laboratory conditions.

Concrete samples based on Portland cement were kept for 28 days in sulfuric acid of natural and artificial origin. In work [3] it was established that gypsum was the main product of corrosion in all samples, regardless of the origin of sulfuric acid. Research shows that exotoxins produced by microorganisms have the same destructive effect on concrete as artificial acids and alkalis. Therefore, the biological impact on concrete in livestock premises cannot be underestimated. However, the study was time-limited and not replicated in real-world settings.

Studies [4] prove that reducing the calcium content in concrete by replacing 10 % of cement with nano silica during the preparation of the concrete mixture reduces the destruction of concrete under the influence of acid attacks in the piggery. In work [5] it was established that it is necessary to determine the influence of microorganisms on the physical and chemical parameters and structure of concrete. It is important to combine the results of materials science and microbiology to design new materials and prevent concrete corrosion. Researchers recommend using bacteriostatic agents to limit the growth of microorganisms. However, the use of bacteriostatic agents over time ceases to act on microorganisms due to the acquisition of resistance to them.

In work [6], the composition of the microflora of the piggery was investigated and the effective concentration of the disinfectant for the destruction of microorganisms in the piggery was determined. The study was conducted under specific farm conditions, so the effectiveness of the proposed disinfectant may vary depending on the object.

Costs for construction, repair, maintenance, and operation of agricultural facilities are not justified by the fixed cost due to profit from the obtained products. Therefore, in work [7], the allocation of additional funds for preventive measures to prevent the destruction of buildings was emphasized.

In work [8], it was proved that disinfection of poultry houses with slaked lime to destroy microorganisms on the surface of concrete structures was effective. However, the use of slaked floor lime when keeping birds on deep litter is inconvenient to use.

The authors of work [9] determined that microclimate indicators such as temperature and humidity, air movement speed affect the survival of microorganisms in the environment. The researchers identified possible ways of spreading microorganisms in the room but did not offer ways to reduce their number.

Microbial cells are able to secrete extracellular polymeric substances for adhesion on the surface of materials, such as concrete or metal. After a strong adhesion to the surface, microorganisms lead to the dissolution of the material where they are fixed. In work [10] it is proposed to use specific breeding strains of microorganisms and their properties for the formation of a biofilm that will protect the surface of the material from corrosion. However, this experiment is still in the stage of long-term development and improvement.

Conventional concrete is exposed to corrosion, forming large deposits of algae on the surface and accompanied by grinding [11]. In work [12] it was proved that the combination of basalt fiber and waterproofing made of inorganic aluminum salt increased the resistance of concrete to corrosion.

Works [13, 14] analyzed types of concrete with the addition of various antimicrobial substances. The authors also carried out classification and methods of introducing antimicrobial agents into cement mortar. However, the studies do not provide recommendations for the protection of existing concrete structures with a long service life.

Therefore, to protect the concrete floor from fecal masses in the poultry house, a deep litter of the type: granules, shavings, straw and sawdust is used. Each of the litters has a different diameter, hygroscopic properties, and the accumulation and growth of microorganisms. To increase the effectiveness of concrete floor protection, the litter is mixed with a powdered disinfectant based on sodium benzenesulfochloramide, copper and iron sulfates, thymol, artificial zeolites. All components are selected with safety in mind for concrete pavement and poultry.

3. The aim and objectives of the study

The purpose of this study is to determine the impact of different ways of keeping poultry on concrete floors and to implement protection methods. This will make it possible to determine the degree of destruction of the concrete floor depending on the type of litter using modern methods and to devise methods of protection.

To achieve the goal, the following tasks were solved:

– to determine the degree of corrosion of concrete floors in different ways of keeping poultry;

– to investigate the methods of protection of concrete floors during operation.

4. Materials and research methods

4. 1. Object and conditions of research

The idea of the experiment was that under the conditions of the poultry house, the floor is constantly exposed to moisture, fecal masses, and disinfectants, and as a result, corrosion of concrete occurs, which is reflected in the change in the structure and heat resistance of concrete.

The object of our study is concrete in a poultry house with different types of litter.

The subject of the study is the regularity of the degree of corrosion of concrete, depending on the technology of poultry farming.

The main hypothesis of the study assumed that depending on the type of litter and the period of operation of the room, the degree of destruction of the concrete floor depends.

The research was conducted at the certified laboratory “Veterinary Pharmacy” of the Department of Veterinary Expertise, Microbiology, Zoo hygiene, and Safety and Quality of Livestock Products at the Sumy National Agrarian University during 2022–2023 (Sumy, Ukraine).

Experimental studies were carried out at the poultry farm “Indychka” in the village Krovne, Sumy district, Sumy oblast. Ukraine.

The poultry house for 2,500,000 heads was built in 1995. The water supply and lighting were renovated. The building is made of reinforced concrete (frames) with a concrete floor. Type of poultry housing on the floor with different types of litter: pellets, shavings, straw, and sawdust.

We used sawdust from a mixture of coniferous and deciduous trees with a diameter of up to 30 mm, an average bulk density of up to 200 kg/m^3 with a specific weight of up to 100 kg, and a moisture content of up to 15 %.

In another room, we used chips of the P brand (coniferous, soft deciduous, birch) with a thickness of 0.05–0.1 mm, a width of 6–8 mm, a length of 200–530 mm, a bulk density of up to 25 %, a moisture content of up to 15 %.

Straw for litter used was wheat and rye straw chopped at the rate of 1.5 kg per m^2, the absorption capacity was 3–4 liters.

Straw pellets with a diameter of 6.8 mm and a length of 50 mm with a moisture content of up to 10 % were used.

Poultry houses are equipped with infrared lamps and forced ventilation. There are nipple drinkers and feeders around the entire perimeter of the poultry house. Due to a significant accumulation of birds and contamination of the floor with fecal masses, there is a need to use a disinfectant that is evenly mixed with the litter.

The sampling procedure was as follows. Concrete samples were obtained from four facilities where poultry were housed on pellets, shavings, straw, and sawdust. Five concrete samples were taken from the surface of each object to a depth of up to 1 cm in all four rooms. As a control, a concrete sample was taken from the floor of the poultry house, where no birds resided. A total of 25 samples were obtained. Concrete samples weighing 5–10 mg were used for the TPD MS method. Samples up to 1 cm in diameter were used for scanning electron microscopy.

4. 2. Methodology for examining concrete samples using TPD MS

Thermally programmed mass spectrometry (TPD MS), which consists of a high-temperature furnace and a gas mass spectrometer MX-7304 (VAT SELMI, Sumy, Ukraine), was used to study the thermal stability of concrete samples. Concrete samples weighing 5–10 mg were heated from 40 to 900 °C at a rate of 15 °C/min with the simultaneous registration of the mass spectra of the mixture of gases released every minute. The obtained gases were determined with the help of a mass spectrum, and their identification was carried out by molecular masses (m/z): 18 – water; 24 – carbon dioxide CO, 44 – carbon dioxide CO_2 [15].

4. 3. Scanning electron microscopy technique

The microscopic structure of concrete was studied using scanning electron microscopy on a REM 106 device (VAT SELMI, Sumy, Ukraine) under the secondary electron mode in the range of electron-optical magnification from 200 to 5,000 times [16]. The study of the microscopic structure was carried out from different sides of the chips of the concrete sample.

4. 4. Method for determining microbial contamination in a poultry housing room

Research on microbial contamination of the concrete floor was performed before and after disinfection in the sections where the bird was on pellets, shavings, straw, and sawdust. Sections of the concrete floor, where the bird was not residing, served as a control. Washes from the floor into sterile tubes with a nutrient medium were selected at the beginning of the study (before disinfection) and after applying the disinfectant after 48 hours. A powdered disinfectant based on sodium benzenesulfochloramide, copper and iron sulfates, thymol, and artificial zeolites was sprinkled on the floor and mixed with the litter. In the control room, the disinfectant was simply sprinkled on the floor at the rate of 150 g per m^2. 5 samples (n=5) were taken from each room at the beginning and after the end of disinfection. The total number of samples was 50 samples. Incubation of microorganisms was carried out on selective media according to species [17]. Cultivation of microscopic fungi was carried out in Petri dishes on Capek-Dox medium [18]. Colonies were counted on each Petri dish. Then the total number of colonies of each type of microorganism was counted at the beginning and at the end of disinfection. The obtained reliability between indicators was calculated by the Fisher-Student method.

4. 5. Statistical analysis

The calculation of statistical data was carried out using the Fisher-Student method, taking into account statistical errors and the probability of comparative similar indicators. Indicators were considered probable with a level of more than 95 % (p<0.05).

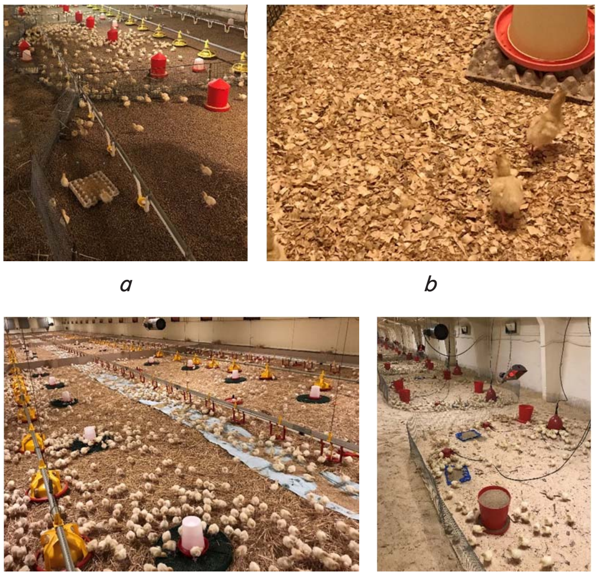
5. The results of the study of concrete floors in the poultry house

5. 1. The degree of corrosion of concrete floors in different ways of keeping poultry

At the farm, turkeys aged 7–14 weeks are kept in closed rooms on the floor with a deep litter with pellets (Fig. 1, *a*), shavings (Fig. 1, *b*), straw (Fig. 1, *c*), and sawdust (Fig. 1, *d*).

To ensure the comfort of the bird, the maintenance is focused on the addition of dry litter and heating with infrared lamps. Poultry keeping is also based on sanitary treatment of the premises to prevent infection in the herd. The problem of the poultry house is a significant crowding of livestock in a limited area. Due to the constant movement and motion of birds, a significant amount of dust and microorganisms constantly enters the air. Due to the flow-exhaust ventilation system, part of the air is constantly replaced by clean air that came in from the street. However, the constant presence of birds on concrete remains a problem. A complete change of litter takes place after the transfer of the bird to another unit by age; however, the bird is placed again in this place after disinfection and replacement of the litter. Thus, concrete does not have time to dry, and its operation lasts for years.

An urgent problem is the reduction of moisture and the destruction of microorganisms in the substrate, respectively, and on the surface of the concrete. It is necessary to use a disinfectant powder that has antimicrobial and hygroscopic effects. In addition, the agent will be used in the presence of birds and will be constantly on the floor.


a *b*

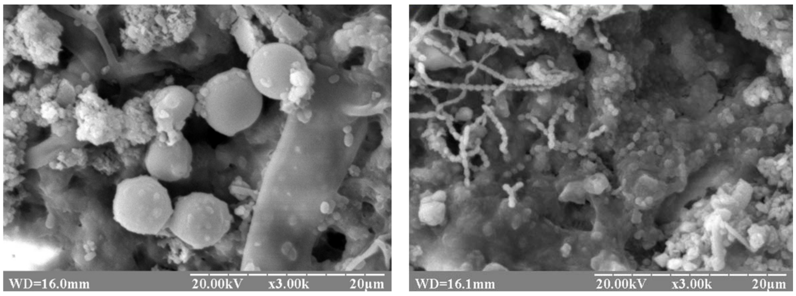
c *d*

Fig. 1. Images of different ways of keeping chickens on the floor with litter: *a* — pellet; *b* — shavings; *c* — straw; *d* — sawdust

The photograph shows the premises where young birds are kept. The constant load on the floor leads to its deterioration, and the lack of a long drying period and the use of acid disinfectants during periods of livestock change further worsen the condition of concrete.

In the course of the study, samples of concrete were obtained from the floor of four premises. The methods of scanning electron microscopy and thermoprogrammed mass spectrometry were used to study concrete corrosion.

Scanning electron microscopy revealed microscopic fungi *Aureobasidium pullulans* (Fig. 2, *a*), *Fusarium sporotrichioides* (Fig. 2, *b*), and *Aspergillus niger* (Fig. 3) on the concrete surface.



a *b*

Fig. 2. Raster electron microscopic image of microscopic fungi on concrete: *a* — Aureobasidium pullulans; *b* — Fusarium sporotrichioides

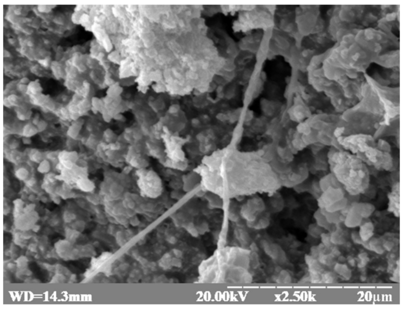


Fig. 3. Raster electron microscopic image of Aspergillus niger on concrete

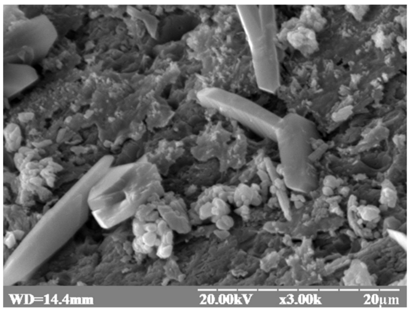


Fig. 4. Raster electron microscopic image of calcium oxalate monohydrate crystals on the surface of the concrete floor of the poultry house

Black yeast-like microscopic fungus *Aureobasidium pullulans* (Fig. 2, *a*) uses different environments for life: soil, water, limestone and, as it turned out, concrete. The fungus is usually a parasite on grain crops, so its appearance in the concrete of the poultry house is quite justified.

Fusarium sporotrichioides (Fig. 2, *b*) parasitizes plants, causing their damage known as fusarium wilt. Very common in countries with a tropical and temperate climate. *Aspergillus niger* (Fig. 3) has the appearance of black mold, which often occurs in damp rooms where people and animals live.

In addition to being able to infect grain, litter, and concrete, micromycetes also cause disease in poultry. Fig. 4 shows calcium oxalate crystals on the surface of the concrete floor of the poultry house, which were formed under the action of organic acids produced by microscopic fungi.

Tests of concrete samples from different premises for keeping poultry by the TPD MS method show the presence of corrosion under the influence of the created operating conditions (Fig. 5).

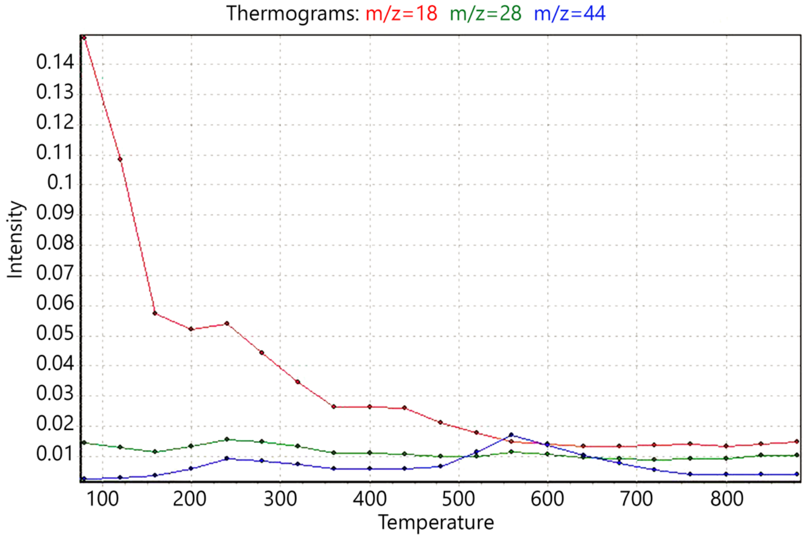


Fig. 5. Thermograms of discharge from concrete samples in the poultry house with sawdust litter: H_2O (m/z 18), CO (m/z 28), CO_2 (m/z 44)

The three samples obtained in the room were heated to a temperature of 1000 °C and the average value was obtained in the form of a plot. It was established that concrete lost moisture at a rate of 0.01–0.14 in the temperature range from 250 °C to 600 °C. Carbon dioxide was released with an intensity of 0.01 to 0.018 in the temperature range from 100 °C to 550 °C. Carbon monoxide was released when heated to 250–550 °C with an intensity of 0.01–0.014.

A concrete sample obtained in a room with straw litter (Fig. 6) when heated to 100–550 °C with an intensity of 0.08–0.25 loses moisture, which indicates its significant content.

Carbon dioxide is released from concrete samples with an intensity of 0.03–0.1 at a temperature of 450–600 °C. The level of CO is somewhat lower, but it is present in concrete and is released with an intensity of 0.01–0.03 at a temperature of 230–560 °C. The results (Fig. 6) show that a small amount of calcite is present in the concrete sample, regardless of corrosion.

When heating a sample of concrete obtained from a room where birds were kept on a floor with a litter of shavings (Fig. 7), water evaporates when heated to a temperature of 120–550 °C with an intensity of 0.015–0.065.

Research has established that on the plot, carbon dioxide has a clear peak with an intensity of 0.025–0.13 and is released when heated to t 450–550 °C. At the same time, carbon monoxide is emitted only with an intensity of 0.013–0.04 at a temperature of 480–560 °C.

Despite the increase in calcite in the samples, the concrete undergoes significant destructive changes that will only increase over time (Fig. 8).

The presence of structural changes in the sample is indicated by the gradual evaporation of moisture from concrete when heated in the range from 100 to 560 °C with an intensity of 0.06–0.22. Carbon dioxide is released when heated to a temperature of 520–600 °C with an intensity of 0.035–0.165. Concrete has a lot of organic content, such as fungi, which burn out unevenly when heated to 520–600 °C, as well as a low content of carbon monoxide with an intensity of 0.02–0.05.

Samples were obtained for comparative analysis as a control in the room of the poultry house, where the birds were not residing (Fig. 9).

As a result of thermogram analysis, it was established that H_2O evaporated in the temperature range of 97–450 °C with an intensity of 0.035–0.15. The intensity of CO_2 release was 0.04–0.180 at a temperature of 550–600 °C, carbon monoxide was released at a temperature of 550–600 °C with an intensity of 0.045–0.057.

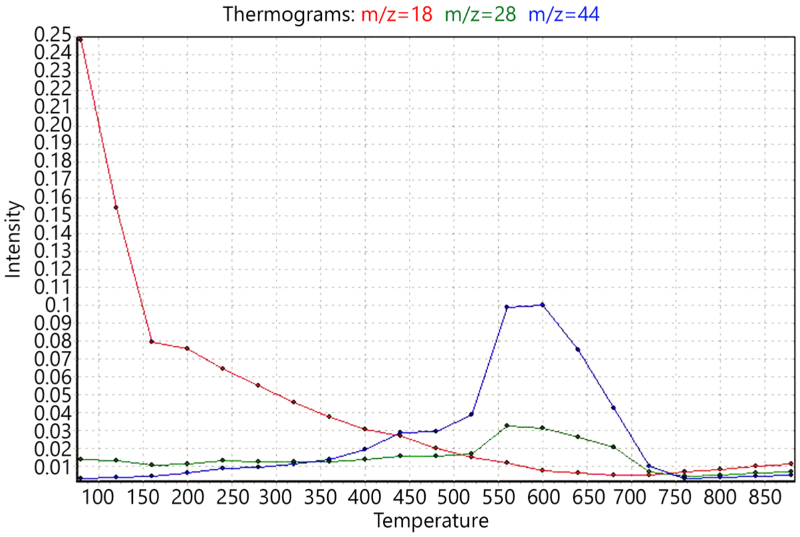


Fig. 6. Thermograms of discharge from concrete samples in the poultry house with litter on straw: H_2O (m/z 18), CO (m/z 28), CO_2 (m/z 44)

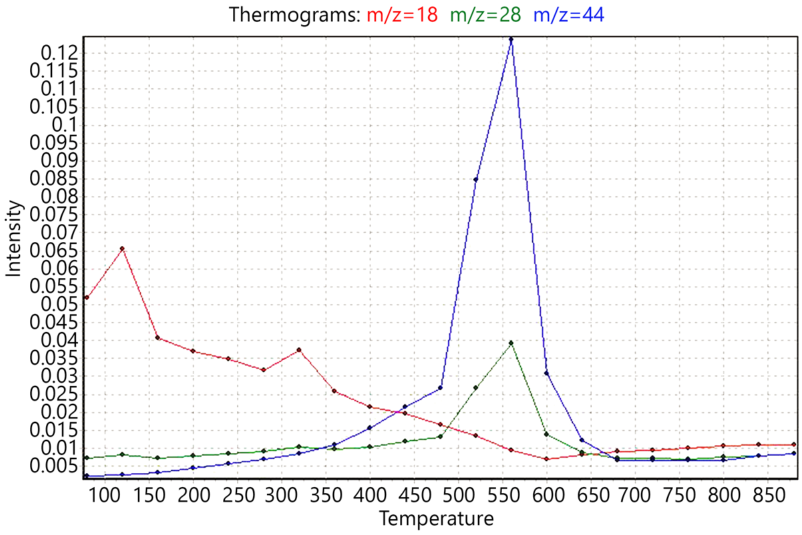


Fig. 7. Thermograms of discharge from concrete samples in the poultry house with sawdust litter: H_2O (m/z 18), CO (m/z 28), CO_2 (m/z 44)

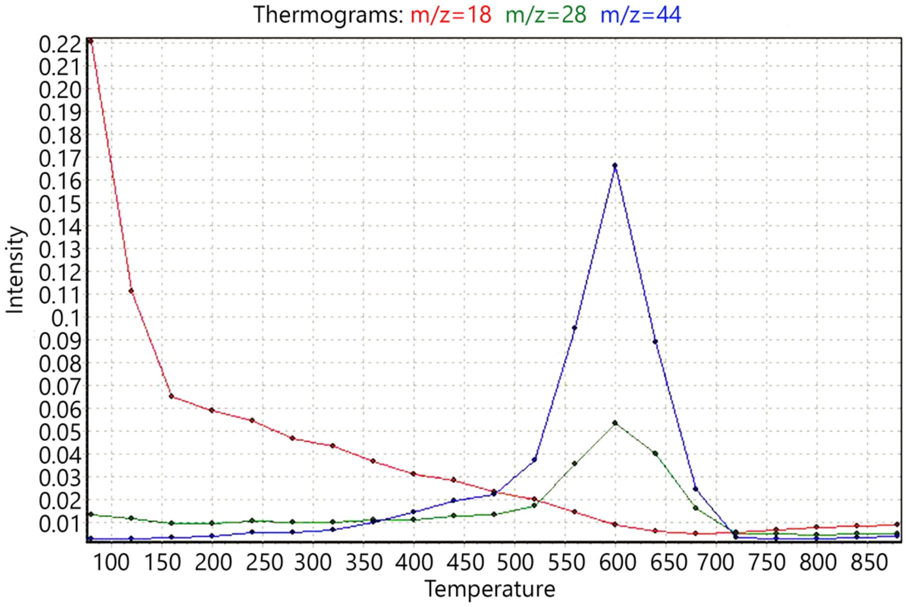


Fig. 8. Thermograms of discharge from concrete samples in a poultry house with litter on pellets: H_2O (m/z 18), CO (m/z 28), CO_2 (m/z 44)

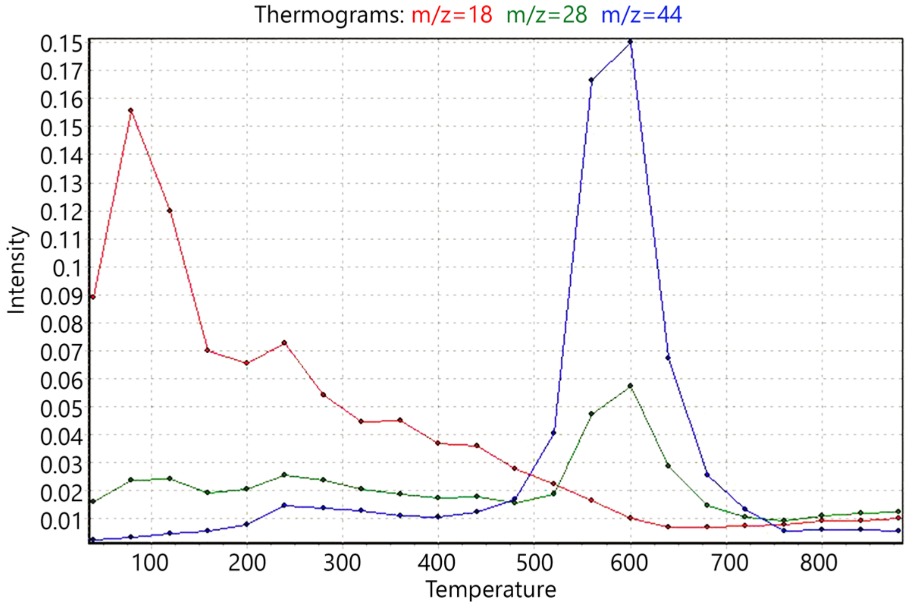


Fig. 9. Thermograms of discharge from concrete samples in the poultry house without litter (control): H_2O (m/z 18), CO (m/z 28), CO_2 (m/z 44)

The obtained mass spectrometry data were entered to a reliability table for statistical processing. The results are given in Table 1.

Table 1

Comparative analysis of TPD MS results, M±m, n=5

Intensity of discharge	Room with litter				
	sawdust	straw	chips	granule	control (without litter)
H_2O	0.025±0.01	0.016±0.03*	0.035±0.01	0.146±0.03	0.033±0.01
CO	0.014±0.002*	0.017±0.004*	0.024±0.007*	0.031±0.008*	0.103±0.02
CO_2	0.016±0.002*	0.054±0.015	0.075±0.019	0.093±0.023	0.122±0.03

*Note: * – p≤0.05, compared to control*

When heated, moisture evaporated from concrete samples obtained in a room with sawdust by 24.24 % less, compared to the control sample. The samples obtained in the room with straw lose moisture by 51.52 % more, with pellets – by 342.42 %, the difference is significant ($p \leq 0.05$), with shavings by 6.06 %, compared to the control.

Carbon oxide from concrete samples with sawdust litter is released reliably ($p \leq 0.05$) by 86.40 % less, with straw – by 83.49 %, with shavings – by 76.69 %, with granules – by 69.90 % compared to control.

The carbon dioxide content in concrete samples from the room with sawdust was lower by 86.88 % ($p\leq 0.05$), with straw – by 55.73 %, with shavings – by 38.52 %, with granules – by 23.77 %.

Based on our results of thermoprogrammed mass spectrometry, it can be concluded that the samples obtained in the room with the pellet litter are maximally close to the control in terms of indicators.

5. 2. The method of protecting the concrete floor during operation

In the poultry house, as a result of long-term operation, the concrete floor is soaked with moisture, disinfectants, and feces. Also, a large number of microorganisms that affect poultry and concrete are concentrated in the room. As it was established in previous studies, the concrete floor was affected by microscopic fungi *Aureobasidium pullulans*, *Fusarium sporotrichioides*, *Aspergillus niger*.

Microbial contamination of the concrete floor was determined at the beginning and after disinfection after 48 hours in the sections where the turkeys were kept with litter made of pellets, shavings, straw and sawdust. A powdered disinfectant based on sodium benzenesulfochloramide, copper and iron sulfates, thymol, artificial zeolites was sprinkled on the floor and mixed with the litter. As a control, sections of the concrete floor in the passages between the sections without birds were used. In the control areas, the disinfectant was simply sprinkled on the floor (Table 2).

48 hours after disinfection, it was established that the number of *E. coli* colonies on the concrete floor with sawdust litter decreased by 94.33 % ($p\leq 0.05$), compared to before the start of the study. In addition, *E. coli* was more at the beginning of the study by 74.29 %, and after disinfection by 59.13 %, compared to the control floor. The level of *S. typhimurium* significantly ($p\leq 0.05$) decreased by 84.98 % after disinfection. At the beginning of the study, it was 99.6 % and at the end of the study it was higher by 75.53 %, compared to the control. The number of *S. Enterica* colonies decreased after disinfection by 79.10 % ($p\leq 0.05$) but was higher by 64.46 % at the beginning of the study and by 79.72 % at the end compared to the control. *C. Perfringens* decreased by 87.29 % after disinfection. Despite this, the level of *C. perfringens* was 54.19 % higher at the start of the study and 59.86 % higher at the end compared to the no-litter control. The level of *C. citratus* decreased by 94.55 % ($p\leq 0.05$) after disinfection. At the beginning of the study, *C. citratus* was isolated more by 82.6 % and after disinfection by 46.56 %, compared to the control. The number of *S. aureus* colonies decreased by 95.4 % compared to the beginning of the study. However, the level of *S. aureus* was higher at the beginning of the study by 73.61 %. After disinfection, the results were similar on the sawdust floor and in the control.

The number of microscopic fungi *A. pullulans* decreased by 84.74 % on the floor with sawdust after disinfection ($p\leq 0.05$). Compared to the control, *A. pullulans* was 74.52 % more at the beginning of the study and 55.35 % more after disinfection. The number of colonies of the fungus *F. sporotrichioides* decreased by 89.91 % ($p\leq 0.05$) after disinfection. In addition, compared to the control, *F. sporotrichioides* was 51.23 % more at the beginning of the study, but after disinfection in the study, the level decreased by 59.75 %. The number of *A. niger* colonies decreased by 92.3 % after disinfection. At the beginning of the study, *A. niger* was isolated more in the experimental room with sawdust litter by 36.09 %. However, after disinfection, the amount of *A. niger* fungus was less in the experiment by 23.52 %, compared to the control.

On average, the total number of colonies of microorganisms on a concrete floor with a sawdust litter after disinfection probably decreased by 90.19 % ($p\leq 0.05$), compared to the beginning of the study.

In the experimental section with straw litter, the amount of *E. coli* decreased by 84.35 % ($p\leq 0.05$). However, the level of *E. coli* at the beginning of the study was 51.1 % and at the end 28.14 % higher, compared to the control. The number of *S. typhimurium* colonies decreased by 89.44 **%** after disinfection. Compared to the control at the beginning of the study, 58.33 % and at the end of the study, the level of *S. typhimurium* was higher by 38.01 %. The number of *S. Enterica* colonies decreased by 93.6 % after disinfection ($p\leq 0.05$). However, there was a 71.62 % higher level of *S. enterica* at the start of the study and a 61.7 % higher level at the end compared to the no-litter control.

Table 2

Results of the effect of disinfectant on floor contamination by microorganisms, $M\pm m$, $n=5$

Types of microorganisms	Number of colonies of microorganisms on the concrete floor in sections with litter:									
	sawdust		straw		chips		granule		control (without litter)	
	Start of the study	After disinfection	Start of the study	After disinfection	Start of the study	After disinfection	Start of the study	After disinfection	Start of the study	After disinfection
Escherichia coli	328.4±74.68	18.60±5.06*	172.6±4.79	27.00±4.55*	143.60 31.19±	59.00±12.80*	119.4±19.69	20.4±2.38*	84.4±6.75	7.6±1.96*
Salmonella typhimurium	250.4±38.89	37.60±7.08*	229.20±49.68	24.20±6.13*	153.80±24.90	61.20±10.9*	109.40±12.58	17.20±2.78*	95.2±3.96	9.2±1.59*
Salmonella enterica	273.80±46.96	57.2±10.4*	294.60±74.35	18.8±3.53*	234.6±33.36	38.4±5.87*	114.80±10.29	17.8±1.66*	83.6±5.68	11.6±1.29*
Clostridium perfringens	231.40±54.88	29.40±6.90*	279.40±56.97	12.80±2.60*	163.4±25.13	21.4±2.54*	126.80±11.00	20.8±2.13*	106.0±5.54	11.8±1.36*
Cymbopogon citratus	481.00±87.53	26.20±5.89*	220.6±36.06	24.4±1.91*	124.60±25.36	16.40±4.41*	103.60±4.56	19.60±1.44*	83.6±8.89	14.0±2.3
Staphylococcus aureus	413.80±52.90	19.00±6.71*	305.00±65.24	15.00±2.83*	176.8±21.71	24.8±2.75*	136.80±11.1	20.6±2.96*	109.2±5.49	18.6±1.5*
Aureobasidium pullulans	146.816.45±	22.4±3.08*	109.60±18.38	12.83±1.94*	90.2±3.98	10.4±1.44*	53.00±14.04	16.6±2.44*	37.4±8.74	10.0±1.1*
Fusarium sporotrichioides	97.2±9.65	9.80±0.66*	85.8±8.99	5.8±1.24*	84.6±10.06	7.6±1.21*	66.8±8.52	9.2±1.77*	47.4±8.5	16.4±1.44*
Aspergillus niger	101.4±7.48	7.8±1.59*	72.6±4.79	7.4±1.50*	61.8±4.31	10.4±1.63*	61.00±10.29	10.4±1.96*	64.8±11.83	10.2±1.46*
On average	258.24±44.52	25.33±5.04*	196.6±30.2	16.47±2.54	137.04±17.83	27.73±6.87	99.06±10.27	16.95±1.45*	79.06±8.25	12.86±1.25*

*Note: * – $p\leq 0.05$, compared to the beginning of the study*

After disinfection, *C. Perfringens* decreased by 95.4 % ($p \leq 0.05$). *C. perfringens* levels were 37.93 % higher on the straw littered floor at the start of the study and 7.81 % higher at the end compared to the control.

After disinfection, the level of *C. citratus* decreased by 94.55 %. At the beginning of the study, *C. citratus* was isolated more by 62.10 % and after disinfection by 42.62 %, compared to the control.

On concrete with straw litter, the number of *S.* aureus colonies decreased by 95.08 %, compared to the beginning of the study. However, the level of S. aureus was higher at the beginning of the study by 35.8 %. After disinfection, the level of S. aureus was lower by 19.35 % compared to the control floor.

The number of microscopic fungi *A. pullulans* decreased by 88.29 % after disinfection on the straw floor. At the beginning of the study compared to the control *A. pullulans* was 65.87 % more and after disinfection by 22.05 %. After disinfection, the number of *F. sporotrichioides* colonies decreased by 93.24 %. At the beginning of the study *F. sporotrichioides* was 44.75 % more, but after disinfection on the straw floor there were 35.36 % fewer colonies, compared to control. The number of *A. niger* decreased by 89.80 % after disinfection. At the beginning of the study, 10.74 % more *A. niger* was isolated on the floor with straw. However, after disinfection, the number of *A. niger* colonies was 27.45 % lower on the test floor than in the control.

The total number of colonies of microorganisms on average on a concrete floor with straw litter after disinfection decreased by 91.62 %, compared to the beginning of the study.

On the experimental floor with sawdust litter after disinfection, the number of probable *E. coli* colonies decreased by 59.91 % ($p \leq 0.05$). However, *E. coli* levels were 41.22 % higher at baseline and 87.11 % higher at baseline compared to controls. After disinfection, the number of *S. typhimurium* colonies decreased by 60.20 %. Compared to the control at the beginning of the study, 38.10 % and at the end of the study, the level of *S. typhimurium* was higher by 84.96 %. The number of *S. Enterica* colonies decreased by 83.63 % after disinfection ($p \leq 0.05$). There was 64.36 **%** and 30.20 % higher levels of *S. Enterica* at the start of the study compared to the no litter control.

After disinfection, the number of *C. Perfringens* decreased by 86.90 %. *C. Perfringens* levels were 35.12 % greater on the wood chip litter floor at baseline and 44.85 % greater at the end of the study compared to controls.

The level of *C. citratus* colonies decreased significantly by 86.83 % ($p \leq 0.05$) after disinfection. At the beginning of the study, *C. citratus* was isolated more by 32.90 % and after disinfection by 14.63 %, compared to the control.

On the floor with sawdust litter, the number of *S. aureus* colonies decreased by 85.97 % ($p \leq 0.05$), compared to the beginning of the study. However, the level of *S. aureus* was higher at the beginning of the study by 38.23 % and after disinfection by 25 %, compared to the control floor.

The number of microscopic fungi *A. pullulans* decreased by 88.47 % ($p \leq 0.05$) after disinfection on the wood shavings floor. At the beginning of the study, compared to the control, *A. pullulans* was 41.46 % more and after disinfection the indicators coincided. After disinfection, the number of colonies of the fungus *F. sporotrichioides* probably decreased by 91.01 %. At the beginning of the study, *F. sporotrichioides* was 43.97 % more, but after disinfection, the colonies on the sawdust floor were 46.34 % less, compared to control. The number of *A. niger* decreased by 83.17 % ($p \leq 0.05$) after disinfection. At the beginning of the study, more *A. niger* was isolated on the straw floor by %. However, after disinfection, the number of *A. niger* colonies was the same in the control and experiment.

On average, the total number of colonies of microorganisms on a concrete floor with a litter of shavings after disinfection reliably decreased by 79.76 %, compared to the beginning of the study.

48 hours after disinfection, it was established that the number of *E. coli* colonies on the concrete floor with granule litter decreased by 82.91 % ($p \leq 0.05$), compared to before the start of the study. It was also established that *E. coli* was more at the beginning of the study by 29.31 %, and after disinfection by 37.25 %, compared to the control. The level of *S. typhimurium* significantly ($p \leq 0.05$) decreased by 84.27 % after disinfection. At the beginning of the study, it was higher by 12.97 % and at the end of the study by 53.48 %, compared to the control. The number of *S. enterica* colonies decreased after disinfection by 84.49 % ($p \leq 0.05$) but was higher by 27.17 % at the beginning of the study and by 34.83 % at the end compared to the control. The number of *C. Perfringens* colonies decreased by 83.59 % after disinfection. Despite this, the level of *C. Perfringens* was 16.4 % higher at the start of the study and 56.73 % higher at the end compared to the no-litter control. The level of *C. citratus* decreased by 81.08 % ($p \leq 0.05$) after disinfection. At the beginning of the study, *C. citratus* was isolated more by 19.30 % and after disinfection by 28.57 %, compared to the control.

The number of *S. aureus* colonies decreased by 84.91 % compared to the beginning of the study. However, the level of *S. aureus* was higher at the beginning of the study by 20.17 %. After disinfection, the results were similar on the granule floor and in the control.

The number of microscopic fungi *A. pullulans* decreased by 68.67 % on the floor with granules after disinfection ($p \leq 0.05$). Compared to the control, *A. pullulans* was 29.43 **%** more at the beginning of the study and 39.75 **%** more after disinfection. The number of colonies of the fungus *F. sporotrichioides* decreased by 86.22 % ($p \leq 0.05$) after disinfection. Also, compared to the control, at the beginning of the study, *F. sporotrichioides* was 29.04 % more, but after disinfection in the experiment, the level decreased by 43.9 %. The number of *A. niger* colonies decreased by 82.95 % after disinfection. At the beginning of the study, almost the same amount of *A. niger* was isolated from the floor with pellet litter and in the control. After disinfection, the amount of *A. niger* fungus decreased in the control and experiment to the same values.

On average, the total number of microorganism colonies on the concrete floor with granule litter after disinfection reliably decreased by 82.88 % ($p \leq 0.05$), compared to the beginning of the study.

From the surface of the floor without litter after disinfection, the number of *E. coli* colonies also decreased by 90.99 %, *S. typhimurium* – by 90.33 %, *S. enterica* – by 86.13 %, *C. perfringens* – by 88.86 %, *C. citratus* – by 83.25 %, *S. aureus* – by 82.96 %, *A. pullulans* – by 73.26 %, *F. sporotrichioides* – by 65.40 %, *A. niger* – by 84.25 % ($p \leq 0.05$).

In the control without litter after disinfection, the number of colonies of microorganisms on average reliably decreased by 83.73 %.

Average floor contamination at the start of the study was 69.38 % higher on sawdust, 59.78 % straw, 42.30 % sawdust, and 79.81 % higher pellet compared to the control. After

48 hours of disinfection, the rate of microbial contamination of the floor was greater with sawdust by 49.23 %, with straw by 21.91 %, with chips by 53.62 % and with pellets by 24.12 % compared to the control.

According to the results of the experiment, it was established that the experimental powdered disinfectant showed bactericidal properties against microorganisms. In addition, it was established that on the surface of the floor without litter, a significantly smaller amount of microorganisms was released, compared to litter. The application of a powdered disinfectant for decontamination of concrete has a perspective for further testing under industrial conditions.

6. Discussion of results of investigating concrete floors in the poultry house

The destruction of the concrete floor was determined by scanning electron microscopy; the microscopic fungi *Aureobasidium pullulans* (Fig. 2, *a*), *Fusarium sporotrichioides* (Fig. 2, *b*), and *Aspergillus niger* (Fig. 3) were detected. In work [19], it was established that microscopic fungi were one of the causes of concrete corrosion in a room for keeping animals. Also, during the study of concrete samples from the floor of the poultry house, the formation of calcium oxalate monohydrate crystals was found as a result of the metabolism of fungi. It should be noted that colonies of microscopic fungi and crystals were found in all concrete samples obtained in rooms where birds sat on four types of litter (Table 2). Scientists [20] studied the growth and metabolic activity of microscopic fungi in concrete.

Using the method of thermoprogrammed mass spectrometry, it was established that concrete samples obtained in a room with straw litter lose moisture by 51.52 % more, with granules – by 342.42 %, the difference is reliable ($p \leq 0.05$), with shavings at 6.06 **%**, compared to the control (Table 1).

It was established that CO is released from concrete samples obtained in the room with sawdust litter reliably ($p \leq 0.05$) less by 86.40 %, with straw – by 83.49 %, with shavings – by 76.69 %, with granules – by 69.90 % compared to the control (Fig. 5–9). The intensity of CO_2 release from concrete samples from the room with sawdust was lower by 86.88 % ($p \leq 0.05$), with straw – by 55.73 %, with shavings – by 38.52 %, with granules – by 23.77 %. As a result of the research, it was established that the samples obtained in the room with the granule litter are maximally close to the control in terms of indicators, that is, they have the least destruction of the structure. Research [21] established that microscopic fungi in the process of their metabolism are able to form organic acids that react with the components of concrete (limestone). Lactic, acetic, and malonic acids have the greatest corrosive activity. As a result, soluble calcium salts are formed.

Also, researchers [22, 23] found that a community of microscopic fungi is able to dissolve calcium by releasing organic acid. As a result of these processes, the constituent component of concrete, calcium carbonate ($CaCO_3$), turns into calcium oxalate monohydrate ($CaC_2O_4.H_2O$) with the formation of crystals (Fig. 4).

On turkey farms, 82 % of farmers added fresh litter for each batch, but only 27 % removed old litter. This leads to the accumulation of moisture, manure, and used disinfectants in the concrete. Due to the lack of a drying period of the concrete floor, favorable conditions for the development of microorganisms are created. Researchers [24] indicate that dry shavings are not a favorable environment for the development of microscopic fungi and bacteria, unlike straw.

A dry disinfectant was used to reduce the accumulation of microorganisms on the concrete floor. Microbiological studies have established that 48 hours after disinfection, the total number of colonies of microorganisms on the concrete floor with sawdust litter reliably decreased by an average of 90.19 % ($p \leq 0.05$), compared to the beginning of the study (Table 2). At the same time, the number of microscopic fungi decreased, *A. pullulans*, by 84.74 % ($p \leq 0.05$), *F. sporotrichioides* by 89.91 **%**, and *A. niger* by 92.3 %.

It was established that the total number of microorganism colonies on average on a concrete floor with straw litter after disinfection decreased by 91.62 **%**, compared to the beginning of the study. The number of microscopic fungi decreased after disinfection on the floor with straw, *A. pullulans* – by 88.29 %, *F. sporotrichioides* – by 93.24 %, *A. niger* – by 89.80 %.

The total number of colonies of microorganisms on a concrete floor with a litter of shavings on average after disinfection reliably decreased by 79.76 %. The number of microscopic fungi decreased after disinfection on the floor with shavings, *A. pullulans*, by 88.47 % ($p \leq 0.05$), *F. sporotrichioides* – by 91.01 %, *A. niger* – by 83.17 % ($p \leq 0,05$).

On average, the total number of microorganism colonies on the concrete floor with granule litter after disinfection reliably decreased by 82.88 % ($p \leq 0.05$), compared to the beginning of the study. The number of microscopic fungi decreased on the floor with granules after disinfection, *A. pullulans*, by 68.67 % ($p \leq 0.05$), *F. sporotrichioides* – by 86.22 % ($p \leq 0.05$), *A. niger* – by 82.95 %.

Average floor contamination at the start of the study was 69.38 % higher on sawdust, 59.78 % straw, 42.30 % sawdust, and 79.81 % higher on pellet compared to the control. After 48 hours of disinfection, the rate of microbial contamination of the floor was greater, with sawdust, by 49.23 %, with straw by 21.91 %, with chips by 53.62 %, and with pellets by 24.12 % compared to the control. Similar results were obtained by researchers [25] when using a dry disinfectant for the pigsty.

Our research shows the disadvantages of using concrete floors in poultry houses. An important aspect of this research is the determination of the safest litter for concrete and poultry – pellets. On the floor with a litter of sawdust and straw, a lot of moisture accumulates, and microscopic fungi and bacteria develop well [26]. The use of a powdered disinfectant makes it possible to reduce the number of microorganisms on the surface of the concrete floor.

The limitation of the study is that the entire experiment was conducted at one farm where specific conditions were created. However, this experiment is an example for improving the conditions of keeping birds and operating concrete floors.

The disadvantage of the study is that there are no studies of symbiotic relationships between species of microscopic fungi that were isolated during the experiment.

The direction of further research is to find communities of microscopic fungi that can contribute to the microbial self-healing of concrete.

7. Conclusions

1. Corrosion of the surface of the concrete floor was established by scanning electron microscopy; the microscopic

fungi were identified: *Aureobasidium pullulans*, *Fusarium sporotrichioides* and *Aspergillus niger*. Using TPD MS, it was established that concrete samples obtained in a room with straw lose moisture by 51.52 % more, with granules – by 342.42 %, the difference is reliable ($p \leq 0.05$), with shavings by 6.06 %, compared with control. Carbon oxide from concrete samples with sawdust litter is released reliably ($p \leq 0.05$) by 86.40 % less, with straw – by 83.49 %, with shavings – by 76.69 %, with granules – by 69.90 %. The carbon dioxide content in concrete samples from the room with sawdust was lower by 86.88 % ($p \leq 0.05$), with straw – by 55.73 %, with shavings – by 38.52 %, with granules – by 23.77 %, compared to the control. Based on the results of TPD MS, it can be concluded that the samples obtained in the room with the pellet litter are as close to the control as possible.

2. Microbiological studies have established that 48 hours after disinfection, the total number of colonies of microorganisms on a concrete floor with sawdust litter reliably decreased by an average of 90.19 % % ($p \leq 0.05$), with straw litter – by 91.62 %, with sawdust litter – by 79.76 %, with granule litter – by 82.88 % ($p \leq 0.05$), in the control – by 83.73 %. It can be argued that the disinfectant destroys microorganisms regardless of the type of litter.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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