Reducing the carbon footprint when using non-metallic minerals as litter in poultry farms

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Abstract.- Poultry farming is one of the most efficient and dynamic branches of animal husbandry. The advantages of the poultry industry are lower prices compared to other types of meat and its high quality (white meat with low-fat and high protein content). The article presents the results of industrial and experimental studies on using a cellulose-containing natural component (diatomite) as part of litter material in poultry farms to improve sanitary conditions and reduce the negative impact on the environment. Experiment study was chosen as the main research method. The research was carried out on the territory of a poultry enterprise with a total population of 24.000 heads. The authors conclude that using a cellulose-containing natural component (modified diatomite) as part of the litter material in poultry farms allowed to reduce emissions of pollutants, thereby reducing the greenhouse effect at the level of one poultry farm.

Keywords: diatomite; carbon footprint; organic matter; non-metallic minerals; pollution.

Reducción de la huella de carbono al utilizar minerales no metálicos como cama en granjas avícolas

Resumen.- La avicultura es una de las ramas más eficientes y dinámicas de la ganadería. Las ventajas de la industria avícola son los precios más bajos en comparación con otros tipos de carne y su alta calidad (carne blanca con bajo contenido de grasa y alto contenido de proteína). El artículo presenta los resultados de estudios industriales y experimentales sobre el uso de un componente natural que contiene celulosa (diatomita) como parte del material de cama en granjas avícolas para mejorar las condiciones sanitarias y reducir el impacto negativo sobre el medio ambiente. El estudio experimental fue elegido como el principal método de investigación. La investigación se llevó a cabo en el territorio de una empresa avícola con una población total de 24.000 cabezas. Los autores concluyen que el uso de un componente natural que contiene celulosa (diatomita modificada) como parte del material de cama en las granjas avícolas permitió reducir las emisiones de contaminantes, reduciendo así el efecto invernadero a nivel de una granja avícola.

Palabras clave: diatomita; huella de carbono; materia orgánica; minerales no metálicos; contaminación.

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1. Introduction

According to the Ministry of Agriculture of the Russian Federation, there are 643 medium and large poultry farms in the aggregate of all categories of poultry for 2018, which contain approximately 465,2 million poultry heads [1].

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Egg production in the Russian Federation in 2018 amounted to 44 901,2 million pieces, while egg sales – 1,9 billion tons [2]. In poultry farms in Russia in 2020, approximately 6,7 million tons of poultry meat were produced (for slaughter in live weight). According to the statistics of the Ministry of Agriculture, production growth amounted to 0,3 % (compared to 2019). In 2021, poultry production in Russia will amount to about 6,8 million tons, and eggs production will reach 44,9 billion pieces (http://www.moshol14.ru/press-centr/novostirynka/proizvodstvo-pticy/).

Poultry farming in the Tyumen Region is represented by four poultry farms: two poultry farms of the egg production (the total number of poultry is about six million heads), and two farms – for the meat production (including an enterprise for raising broiler turkeys with a population of 300 thousand heads and broiler chickens with a population of 2,7 million heads). The main raw materials for poultry feeding are barley and wheat [3, 4, 5, 6].

In 2020, the number of poultry in agricultural organizations of the Tyumen Region increased by 93 thousand heads, or 1,1 %, in comparison with 2019; egg production amounted to 1474,1 million pieces (−1,7 %), and poultry meat production in live weight −63,0 thousand tons (−2,7 %).

It should be noted that poultry farms are enterprises that emit a significant amount of dust, harmful gases, and specific odors into the environment, as well as accumulate a large amount of waste [7].

According to expert estimates, the laying hen produces about 170-190 g of waste, while meat chicken: 280-300, broiler: 240-250, turkey: 420-450, goose: 490-600, and duck: 250-420. In the context of current conditions of keeping and growing poultry, up to 40 thousand tons of poultry manure is produced per year at one poultry farm of average capacity (400 thousand laying hens or 6 million broiler chickens) (http://www.xn–80aaaadedzmbq9apqb6adtv1p.xn–p1ai/).

According to Art.1 of Federal Law No. 89-FZ [8] "On production and consumption waste", chicken manure refers to production waste, since it results from the production of poultry products by poultry farms. Fresh chicken manure belongs to hazard class 3, rotted chicken manure belongs to hazard class 4.

According to statistical data, less than half of the manure formed at large poultry facilities is used in the country. One poultry farm raising 10 million broiler chickens annually produces about 100 thousand tons of manure and over 500 thousand m^3 of wastewater.

Accumulated manure has become a very significant source of environmental pollution because large poultry farms often do not have even the simplest equipment for disposal (disposal means beneficial utilization rather than simple destruction) of such volumes of manure [9].

Long-term accumulation of manure causes the spread of infectious diseases, alienation of fertile arable land from circulation, as well as pollution of surface and groundwater [10, 11].

The existing environmental pollution, based on monitoring data, quite naturally causes serious concern among environmental authorities for the sanitary and ecological well-being of territories where large poultry farms operate [12].

According to S.M. Lukin, Director of the Institute of Organic Fertilizers and Peat (http://www.priroda.ru/reviews/detail.php?ID=12542), up to 40 % of chicken manure is stored at the sites of poultry farms, or placed in recycling fields. This leads to the contamination of ground and surface waters with poultry waste. During long-term storage of organic fertilizers at ground sites, up to 6340 kg of mineral nitrogen per one ha was contained in the soil layer of 0-4 m, including up to 4500 kg/ha of nitrate nitrogen, which is 20 times more than that contained in pure soil. The content of nitrate-nitrogen in groundwater at storage sites exceeded that in field drainage waters by 2 times, ammonia nitrogen by 8 times, phosphorus by 1172 times, and potassium by 106 times.

In the work of O.R. Ilyasov [13], it is noted that at a distance of 400 m from the poultry farm, the number of microorganisms in the air decreases only twice as compared with the air at a distance of 100 m. A characteristic feature of poultry farm emissions is specific odors that spread over considerable distances depending on the season and weather: in winter – up to 0,5 km, and in summer up to 3,5-5 km. Fetid gases contain up to 60 compounds, such as hydrogen sulfide, ammonia, amines, volatile fatty acids, alcohols, aldehydes, mercaptans, esters, and carbonyls. Such odors can cause nausea, headache, breathing problems, insomnia, loss of appetite, irritation of the eyes, ears, and larynx in people [13].

Chicken manure, when decomposed into organic substances during natural composting, releases ammonia (NH_3), methane (CH_4), hydrogen sulfide

(H_2S), carbon oxides (CO, CO_2), and other hazardous substances. Since all these components pose a great danger to the environment, and, consequently, adversely affect human health, the disposal and processing of chicken manure require a special approach when solving this problem [14].

Ammonia and other odor-producing sources are formed primarily during the denitrification of poultry manure and can be released directly into the atmosphere at any stage of the processing, including in form of emissions through the ventilation system of buildings and at storage sites. Unpleasant odors from poultry manure are caused by the anaerobic conditions of its storage and the active vital activity of anaerobes.

In 2017, a set of recommendations has been prepared for the popularization of the green economy [15]. Current commitments under the Paris Agreement indicate an increase in global warming by 2,7 °C by the end of the century. Even if the world limits warming to 1,5 or 2 °C, as specified in the Agreement, many climate threats will still persist.

Measures to reduce greenhouse gases in Russia are laid down in the national "Ecology" project, federal projects "Clean Air", "Implementation of the best available technologies", "Clean Country", and "Integrated Solid Municipal Waste Management System". Moreover, a strategy for the long-term development of Russia until 2050 is being developed, assuming the possibility of reducing greenhouse gas emissions (http://government.ru/docs/37917/).

According to the national inventories of anthropogenic emissions from sources and removals by sinks of all greenhouse gases, currently, the total amount of greenhouse gas emissions has decreased by 47,6 % compared to 1990, taking into account the sector "Land use, land-use change and forestry", and by 30,3 % excluding the latter. The distribution of contributions to the total anthropogenic greenhouse gas emissions in Russia in 2018 by industry sectors is as follows: energy – 78,9 %, industrial processes, and product use – 11,0 %, agriculture – 5,7 %, and waste – 4,4 %. Energy sector emissions continue to play a dominant role in total emissions, while the contribution of agriculture has decreased [16].

Technogenic pollution of the environment, in particular greenhouse gas emissions, which make up about half of the human biological footprint, is most likely the cause of climate change occurring on the planet (when considering this process on a time scale of decades) with rather unpredictable consequences and, possibly, global catastrophes [17].

Regulating greenhouse gas emissions, in particular, their main component – carbon dioxide, faces the problem that its lifetime in the Earth's atmosphere is quite long amounting to about 100 years. As a result, measures aimed at reducing anthropogenic CO_2 emissions, even if they are highly successful, will be manifested only in a few decades or later. In this situation, the idea of reducing emissions of short-lived climate pollutants (or short-lived climate impact factors), including methane, whose impact on the radiation regime and climate is also significant, but the residence time in the atmosphere is significantly less, is being actively proposed [18].

An indicator of anthropogenic impact on the climate system can be an indicator such as the carbon footprint. This indicator is a set of greenhouse gas emissions (water vapor, carbon dioxide, methane, nitrous oxide, etc.) obtained as a result of human activity, organization, or any other object, which is mainly associated with the extraction of raw materials, product manufacturing, rendering services, as well as further consumption of products, recycling or its secondary use [19].

The calculation of the carbon footprint based on the Cool Farm Tool method is quite interesting since it allows inputting and analyzing data that go beyond standard inventory methods. It is widely used in the world. For example, it was used to assess greenhouse gas emissions from crop and livestock production in India [20].

2. Methods

Production and experimental studies were carried out in the territory of the poultry enterprise within the framework of the cooperation agreement in July-August of 2021. The agreement was concluded to effectively interact between the parties and create conditions for implementing a scientific project on integrated research, developing technologies, and producing organometal mixtures, to improve the environmental safety of agricultural products, as well as increase the productivity of crop production, animal husbandry, and poultry farming.

The experiment was carried out in four sections of the building, with total livestock of 24 000 heads (6000 heads in each section). Diatomite in the amount of 6,6 m^3 (or 3762 kg at a density of 0,570 kg/m^3), and sawdust – 18,15 m^3 (3630 kg) were used as poultry litter material when testing in the poultry house for chicken fattening. The height of the litter was regulated according to the accepted technology for this period of the year. (Table 1, Figure 1).

Table 1: Scheme of the experiment

Group/Section	Poultry litter description
1	Sawdust is used as a poultry litter (layer of 3 cm)
2	Diatomite, a layer of 1 cm, the amount of 3,3 m^3 (1880 kg)
3	Diatomite, a layer of 0,5 cm, the amount of 1,65 m^3 (940 kg)
4 (control) Sawdust	Diatomite, a layer of 0,5 cm, the amount of 1,65 m^3 (940 kg) + sawdust (layer of 2,5 cm)

Methods of processing and analysis of experimental data:

1. Daily accounting of poultry livestock.
2. Weekly measuring ammonia concentration.
3. Conducting a visual assessment of the condition of the poultry litter material, photographic evidence, weighing the same amount of litter from each section (beginning and end of the experiment).
4. Carrying out once at the end of the experiment laboratory examination of the litter for moisture, and microbiological indicators, namely, the presence of mold spores, the presence of pathogenic microorganisms (including *salmonella*), the presence of *Eimeria oocysts*; chemical indicators (nitrogen, phosphorus, potassium, copper, zinc, heavy metals).

Figure 1: Chickens-holding (control section No. 4)

3. Results

The microclimate in poultry premises is an important parameter that influences the veterinary well-being of poultry, and hence all production and economic indicators of poultry raising.

Broiler poultry houses are the most difficult among all areas of poultry farming in terms of maintaining an optimal microclimate. This is due to the high poultry-holding density, as well as the most intense nature of growth of this bird. With high air humidity, the condition of the bird deteriorates sharply, which results in productivity decrease. High humidity causes damage to the poultry litter during floor management, and destroys equipment, leading to rapid wear and even destruction of metal and wooden structures of the poultry house. As established by many studies, the optimal relative air humidity in poultry houses for chickens is 60-70 %.

The combination of high temperature and high relative humidity is especially dangerous for poultry since in this case, the air moisture content in the poultry house, as well as the heat content of the air approaches the maximum values (saturated state). Consequently, the heat exchange of the birds with the environment is minimized which causes heatstroke in the bird. Low relative humidity (below 40-50 %) causes respiratory diseases of poultry, as well as contributes to the increased dustiness of the air. The low relative humidity of the air is especially dangerous for young birds up to the age of one month, since during this period, according to the standards, the air temperature has to be maintained at a relatively high level (22-34°C), and the combination of high temperatures and low relative air humidity leads to drying of the mucous membranes, increased thirst, respiratory diseases, so dangerous for the young bird organism.

When using 1 and 0,5 cm thick modified diatomite as a poultry litter, the moisture content of the litter decreases by 13,9-36,5 %, respectively, in comparison with the control (sawdust). Using 0,5 and 1 cm thick diatomite as a litter reduces waste formation by 2-3 times, respectively (Table 2).

But at the same time, to prevent increased dustiness, additional moistening of the litter is necessary when loading the housing with poultry, otherwise, the used modified diatomite should be in the form of a larger fraction or granules (Figure 2).

Figure 2: Dustiness (Section 3 – diatomite (1 cm))

Most of the time, the bird's immune system can cope with its task. But the concentration of any pathogenic microflora in the poultry house increases as the ventilation level decreases. At night, the situation can become critical, since outside temperature drops and the air exchange decreases, increasing the concentration of pathogenic microorganisms and ammonia. The combination of the growth of pathogens and a high concentration of ammonia, as a rule, suppresses the immune system of poultry. Measurements of the actual ammonia concentration are presented in Table 3.

Based on the presented measurements, it can be concluded that the best indicator was noted in the 2^{arg}nd section, where diatomite thickness amounted to 1 cm. At that, the difference with the control group was noticeable already on the 21^{arg}st day of poultry raising and amounted to 1,5 mg/m^3 (68,2 %). At the end of raising ammonia concentration decreased to 1,4 mg/m^3 (43,75 %).

Ammonia results from the decomposition of nitrogenous bases of poultry manure by bacteria. Certain conditions are necessary for the vital activity and reproduction of microorganisms, namely, optimal humidity and temperature. Accordingly, by controlling the living conditions of bacteria, it is possible to control the process of ammonia formation. Temperature control is not suitable for these purposes, since the temperature regime of the poultry house is strictly regulated.

Thus, the ammonia formation process can be regulated only by controlling the moisture of the litter. At low moisture, the activity of microorganisms is also low. The results of laboratory tests of the litter are presented in Table 4.

Laboratory studies of the litter showed that in the experimental groups with diatomite, compared with the control group, no Eimeria oocysts were found in the litter, the growth of the total microbial number was reduced by 42,7-49,7 %, while molding spores – by 41,7-83,3 %. This fact confirms that diatomite has adsorbing and antimicrobial properties and contributes to the disinfection of the litter against microbial contamination by bacteria, fungi, and protozoa.

According to the results of the studies, the amount of poultry manure formed after the

Table 2: Humidity indicators, %

Group/Section	Humidity, %				
	Indoors		Litter		
	Start of the experiment, July 20, 2021*	End of the experiment, August 01, 2021	Start of the experiment, July 22, 2021	End of the experiment, August 9, 2021	Litter after removal from the building
Diatomite (0,5 cm) + sawdust (2,5 cm) –Section 1	63,12	67,45	21,0	33,6	40,6
Diatomite (1 cm) – Section 2	51,03	68,1	13,4	33,4	23,6
Diatomite (0,5 cm) – Section 3	52,73	65,3	18,2	34,6	17,4
Sawdust (3 cm) (control) – Section 4	69	68,2	34,4	36,0	27,4

Table 3: Actual ammonia content, (mg/m^3)

Age, days	Group/Section			
	Diatomite (0,5 cm) + sawdust (2,5 cm)	Diatomite (1 cm)	Diatomite (0,5 cm)	Sawdust (3 cm) (control)
0	0	0	0	0
7	0	0	0	0
14	0	0	0	0
21	1,8	0,7	0,9	2,2
28	3,0	1,8	2,1	3,2

Table 4: Results of laboratory tests of litter

Indicators	Group			
	Diatomite (0,5 cm) + sawdust (2,5 cm)	Diatomite (1 cm)	Diatomite (0,5 cm)	Sawdust (3 cm) (control)
The presence of Eimeria oocysts	not detected	not detected	not detected	isolated cases have been detected
Presence of mold spores	2 000 000	6 000 000	7 000 000	12 000 000
Presence of pathogenic microorganisms (including salmonella)	not detected	not detected	not detected	not detected
Total microbial number	17 200 000	15 100 000	15 300 000	over 30 000 000

completion of the experiment was determined (Figure 3). The greatest decrease in poultry manure formation by 13 % was observed in section 1 compared to the control.

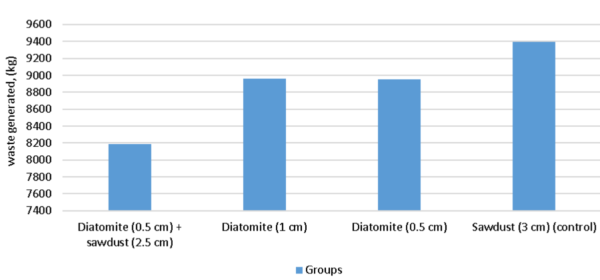

Figure 3: The amount of waste generated, (kg)

Analyzing the amount of chicken manure formation, it should be noted that a large amount of pollutants, including greenhouse gases, will be polluted to atmospheric air. Calculating the pollutant emission capacity into the atmosphere from agricultural livestock facilities experimentally confirms R. Lindeman's energy law, according to which only about ten percent of the energy comes from each previous trophic level to the next. According to this law, animals absorb from 7 to 13 % of energy (or feed in the energy terms).

The remaining 87-93 % of organic matter (animal waste products) are processed by microorganisms or disposed of. As a result of their

Table 5: Characteristics of pollutant emissions into the atmosphere

Contaminating substance		The maximum one-time release, g/s	Annual release, ton/year
Code	Substance		
303	Ammonia	0,163995	5,17175
333	Dihydrosulfide (Hydrogen Sulfide)	0,009048	0,285338
380	Carbon Dioxide	38,91771	1227,3089
410	Methane	0,649194	20,47298
1052	Methanol (Methyl alcohol)	0,0065598	0,20687
1071	Hydroxybenzene (Phenol)	0,000855	0,0269644
1246	Ethyl Formate	0,0190008	0,599209
1314	Propanal (Propionaldehyde)	0,0075777	0,2389703
1531	Hexanoic acid	0,0084825	0,267504
1707	Dimethyl Sulfide	0,0428649	1,351787
1715	Methanethiol	0,0000016	0,0000514
1849	Methylamine	0,0029406	0,0927348
2603	Microorganisms	0,0000042	0,0001325
2920	Fur dust	0,0003782	0,0119266

enzymatic decomposition, a tenth of pollutants will be released directly into the atmosphere from 10 % of the feed assimilated by animals.

With the number of 6000 heads and the formation of fresh chicken manure in the amount of 9392 tons (control) at the poultry farm during the period of the experiment, the maximum one-time release of pollutants amounted to 39,8286121 g/s, the annual release will be 1250,03516 tons/year (Table 5). The annual release of major greenhouse gases, such as carbon dioxide and methane will amount to 1227,3089 and 20,47298 tons/year, respectively. Ammonia emissions will amount to 5,17175 tons/year [21].

4. Conclusion

Currently, at the level of the Tyumen Region, one of the most serious problems is the disposal of chicken manure, classified as a waste of hazard class III.

The proposed technology for studying the use of litter made of the cellulose-containing natural component as part of the litter material in poultry farms to improve the sanitary condition and reduce dust, harmful gases, and specific odors into the environment, has confirmed its effectiveness.

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