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DEPENDENCE OF THE MICROCLIMATE PARAMETERS OF THE PIG HOUSE ON DIFFERENT FREQUENCY OF MANURE PITS EMPTYING AND OUTDOOR TEMPERATURE

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Abstract

In order to study the dependence of the microclimate indicators in the fattening building on the frequency of drainage of manure pits and the external temperature, an experiment was conducted in the production conditions of the pig complex. Four groups of pigs with 2,500 heads in each group were selected for the experiment. In the first control group, the draining of the manure pits took place before the animals were placed for fattening and as the pits were filled. In the experimental groups, the pits were drained before planting and every 14 days in the second group, every 21 days in the third group, and every 28 days in the fourth group. Gas content and air humidity indicators were measured every third day at 07:00, 13:00 and 18:00 in all four buildings at 6 points in different equally spaced pens of the fattening building under the ventilation valves. It was found that the average concentration of hydrogen sulfide and ammonia depended on the frequency of emptying the pits in the building, while the content of carbon dioxide did not depend on it. The content of hydrogen sulfide and ammonia depended on the frequency of emptying manure pits, and the content of carbon dioxide did not depend. At the same time, the content of ammonia and carbon dioxide depended on the external temperature, while the content of hydrogen sulfide did not depend on it. The relative humidity in the fattening building increased with a decrease in the frequency of draining pits, however, it did not depend on the external temperature.

Key words: *ammonia content, hydrogen sulfide, carbon dioxide, humidity, temperature*

INTRODUCTION

The problem of the latest research on the welfare of pigs have needed to provide a microclimate in the pig house for their comfortable keeping, which is currently achieved in most pig farms due to high energy consumption and over expenditure of resources [46]. Modern sow farrowing facilities have unique microclimate control limitations. The ventilation system must simultaneously meet the thermal needs of farrowing sows and newborn piglets [25, 41]. The microclimate of livestock premises is a set of physical, chemical and biological factors of the external environment that constantly affect animals and technological equipment. The combination of these factors, as well as their impact on the animal body, can be different [17].

Inconsistency of the microclimate parameters with the sanitary and hygienic standards causes in animals a violation of metabolism and reproductive function, a decrease in the body's resistance and productivity, a delay in the growth and development of young animals, and in ensuring high resistance of the body, the creation of an optimal temperature and humidity regime in the piggery is of great importance [16]. Extreme conditions of the microclimate have a negative effect on the body during the embryonic period of development. The high temperature (27–35°C) of the surrounding air during the fertilization period and the first two weeks of growth leads to a sharp decrease in the number of embryos and subsequently in fertility. Under the influence of high temperature, the level of natural resistance and the intensity of carbohydrate metabolism decrease in suckling sows. The blood serum of piglets during the weaning period contains less albumin than globulin fractions [6, 14]. Inconsistency in the main parameters of the microclimate causes in animals a violation of metabolism and reproductive functions, a decrease in body weight gain, feed consumption. Unfavorable conditions of temperature, humidity, air movement and other factors for normal heat transfer cause a violation of the thermal state of the animal organism [2, 12, 38].

Global warming has caused an increase in the incidence of heat stress in recent decades in pigs [40]. One of the parameters for characterizing and classifying the animal farm environment is the temperature comfort range, which reflects the behavior of the animal indoor temperature [7]. High temperature together with high air humidity cause heat stress in pigs. As a result, the production performance of growing and fattening animals deteriorates, and the fertility and milk yield of sows decreases [21, 23]. The air humidity in the building is directly related to the temperature: as the temperature increases, the air humidity, as a rule, decreases, and the lower the air temperature, the lower the animal's body temperature, the slower its recovery. Moisture is released by animals with the released air during evaporation from the surface of the skin, and its amount depends on the live weight. It affects the thermoregulation of the animal's body, and in particular, its heat transfer. The optimal relative humidity of the air in pig houses should be within 60–80%, and the temperature in the building depends on the method of keeping sows and animals for growing and fattening [8, 19]. To prevent overheating in the pig house, it is necessary to establish an optimal air movement system. It is also worth avoiding the formation of drafts, which can overcool the pigs [42]. With a decrease in air flow speed, the probability of the appearance of moisture and exhaust air with an increased concentration of carbon dioxide, ammonia and hydrogen sulfide compounds increases [31, 33]. An excessive amount of these gases indoors leads to breathing problems in pigs, and can even cause pulmonary edema. And the abnormal content of carbon dioxide in the air leads to increased breathing, arrhythmia and even poisoning [35, 45].

It has been established that ammonia, hydrogen sulfide, and carbon dioxide are among the most critical harmful gases for pigs [5, 47], namely their welfare and health [36, 48]. Atmospheric pollution by methane (CH_4),nitrous oxide (N_2O) and carbon dioxide (CO_2), known to account for an average of 81%, 17% and 2% of the total emissions from pig farms, which is 3.87, 0.83 and 0.11 kg CO_2 eq. with kg of carcass, respectively [30]. At the same time, the release of harmful gases from vital activities occurs in different ways, which must be taken into account in preventive measures to reduce them. In particular, concentrations of ammonia and carbon dioxide are usually much higher in winter than in summer ($p < 0.05$). Also, in some studies, measurements of gas content showed the highest content in the morning [32], and in others reports [34] at night. When using both "natural" non-mechanized and mechanized closed microclimate systems of negative or uniform pressure, the influence of the seasonality factor of fluctuations in concentrations of harmful gases during changes in the annual dynamics of temperature and wind speeds outside the pigsty is monitored [20, 28, 50]. Many authors report elevated measured concentrations of harmful gases due to factors such as pigs age and body weight, ventilation system features [37], availability of cleaning systems [44], farm location [18], local climate or season of the year [3].

The spread of polluting gases outside the pigsty is an undesirable component of their activity, but it is beyond the bounds of possibility to completely get rid of this phenomenon [11, 26]. Emissions of NH_3 and deposition play a critical role in ecosystem acidification and eutrophication and contribute to indirect emissions of N_2O [39]. Methane emissions increase the greenhouse effect [1]. The use of air purifiers to reduce ammonia emissions from production premises in pig industrial complexes is a promising method of the Gothenburg Protocol [13] and other European norms, including the Industrial Emissions Directive [22]. Different types of air purifiers are used to remove ammonia from the exhaust air from piggery premises. Most of them fall into three types: wet scrubbers (also called water-only scrubbers or bio-droplet filter scrubbers), chemical scrubbers and air scrubbers [24]. The use of scrubbers reduced ammonia emissions from pigsty by at least 70%. Similar filters with an efficiency of at least 80% are also used for the decomposition of hydrogen sulfide [15]. Measures to minimize methane emissions also had a positive result, in particular, pig farms using biogasification and acidification had 91% and 93% lower emissions, respectively, than farms without exhaust air treatment [43]. There are also complex solutions that, due to the addition of active chemical compounds to the manure in the manure removal system of the pig house, decompose pollutants into neutral ones and lead to a decrease in their concentrations inside the building and, accordingly, to a decrease in their emissions [49]. There have also been reports that the content of harmful gases decreases with an increase in the frequency of cleaning of manure pits and manure gutters [4]. However, there are directly opposite results, which say that the more often the manure is drained from the pit, the higher the air exchange in it and, as a result, the higher the ammonia content in the pig house [27]. The height of the space above the manure surface in the pit depends on the cleanliness of the drainage of the manure pits. The height of the space above the surface of the manure affects the evaporation and content of ammonia and other gases due to higher diffusion rates and increased air exchange rates in the pit space [10], which increases the content and emissions of these gases.

Thus, taking into account that microclimate systems that do not have special equipment for reducing the concentration of harmful gases, although they satisfy the normal life activity of pigs, but require additional actual scientific research and technical solutions for complete degassing of ammonia, hydrogen sulfide, and carbon dioxide in order to completely purify the air.

The purpose of our research is to study the influence of the frequency of emptying manure pits as a method of reducing the concentrations of harmful gases in the premises of the piggery complex for fattening and determining its influence on microclimate indicators.

MATERIALS AND METHODS

The study included the determination of microclimate parameters (aeration, humidity, and air temperature) depending on the frequency of emptying of manure pits, the level of their filling with manure, and the ambient temperature. It was carried in the feedlot of LLC "Globinsky Pig Complex", Globinsky district, Poltava region. The experiment was conducted during the autumn-winter period. Four groups of hybrid pigs of Irish origin obtained from crossbred sows of the Large White breed and boars of the MaxGro synthetic line were formed in the amount of 2,500 heads in each group.

Control group I was put on fattening in building No. 3, where draining of the manure pits was carried out before placing the animals and then partially by ¼ of the volume every 7 days as it was filled with manure.
Experimental group II was fed for fattening in building No. 2, where pits were drained before placing the animals and then every 14 days.
Experimental group III was placed for fattening in building No. 1, where pits were drained before placing the animals and then every 21 days.
Experimental group IV was fed for fattening in building No. 16, where pits were drained before placing the animals and then after 28 days.
Gas content and humidity were measured every third day at 7 a.m., at 1 p.m., and at 6 p.m. in accordance with existing methods in all four buildings at 6 points in different equidistant pens in the building under ventilation valves. A Testo 425m thermal anemometer (Testo AG, Lenzkirch, Germany) was used to determine the air temperature. The content of ammonia (NH_3), carbon dioxide (CO_2), and hydrogen sulfide (H_2S) was determined using the DOZOR-S-M gas analyzer (Testo AG, Lenzkirch, Germany). Air humidity was determined using a Testo 605 thermo-hydrometer (Testo AG, Lenzkirch, Germany) at the level of standing pigs (60 cm).
In addition, on the days of measuring the microclimate, the parameters of the temperature outside the building and the level of filling of the pits were measured.
Animals in all enclosures were kept in buildings measuring 102 by 20 m, in group pens of 50 heads, which were located in four rows, on a completely slotted floor at the rate of 0.75 m^2 per pig. The feeding of pigs of all experimental groups was identical, complete and balanced in a multiphase mode, with compound feed of own production. The type of pig feeding was liquid using the WEDA liquid feeding system. Mixing of feed with water in the ratio of 1 part of dry feed to 3 parts of water was carried out in hopper mixers, after which the feed was transported to the feeders in liquid form, in equal portions 10 times per day. Feed accounting in all pens was carried out automatically, on the computer of the feeding system, and additionally, daily, it was recorded in the act of accounting for feed.
The ventilation in all buildings was the same, with the help of the Big Dutchman company's negative pressure system, where the exhaust air was removed with the help of exhaust roof and mine fans, which created negative pressure in the building, and the inflow of fresh air into it was carried out through supply valves. Coordination of the opening of the supply valves with the power of the fans was carried out by a special processor.
Manure removal was vacuum-gravity from the pits under the pens, by opening the plugs in each. Manure was moved to an intermediate storage tank located below the level of the pit bottom. Next, the manure was transported with the help of fecal pumps to the point of its separation into fractions. The solid fraction of manure with a moisture content of 55–65% was stored on the territory of the pig complex, and its liquid fraction was pumped to lagoons outside the pig complex.
The results of the experiment were analyzed in Excel 2010. The results of the measurement of indicators were presented in table of mean values, standard deviations and errors of the mean value. The significance of the discrepancy ($P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$) between the measured microclimate parameters was analyzed using the Kruskal-Wallis test.
Changing the frequency of draining manure pits did not worsen the humane treatment of experimental animals and their usual housing conditions.

RESULTS AND DISCUSSIONS

Data analysis showed that frequency of emptying manure pits affected the level of their filling (Table 1). Thus, in the control building, where the pits were emptied as manure accumulated in them, its level was probably higher compared to other experimental buildings. In the premises of the II experimental group, where the pits were drained every two weeks, the average level of manure was significantly ($p<0.001$) almost twice (by 21.5 cm or 48.1%) lower compared to the control group I. In the building, where the animals of the III experimental group were kept and the pit was drained every three weeks, such a decrease in the manure level was 16.4 cm, or 36.7% lower ($p<0.01$) than in group I. In the building where animals of the IV experimental group were kept and the pits were drained every four weeks, the level of manure was 28.2% lower than in group I, which was 12.6 cm ($p<0.01$).

Table 1. The level of filling of manure baths and the parameters of the microclimate in the premises at different frequencies of manure discharge, n = 69

Indicator		Group I	Group II	Group III	GroupIV
The average level of manure in the pit, cm		44.7±4.58^{**cd***b}	23.2±2.96	28.3±3.34	32.1±3.93
Air temperature at the level of the pig's respiratory tract (60 cm), ºC		19.2±0.43	19.2±0.37	18.5±0.52	19.9±0.38^{*c}
Relative humidity, %vol		72.5±0.79	72.1±0.98	73.3±0.96	75.1±0.95^{*ab}
Gascontent	ammonia(NH_3). mg/m^3	15.5±0.96^{*d}	15.2±1.70	13.8±1.04	12.5±0.85
	carbondioxide(CO_2). % vol	0.2±0.02	0.2±0.01	0.2±0.01	0.2±0.01
	hydrogensulfide(H_2S). mg/m^3	2.9±0.23^{***bd**c}	2.1±0.15	1.9±0.13	2.2±0.15

* – P < 0.05; ** – P < 0.01; *** – P < 0.001.
Source: own calculations.

In the building where animals of the II experimental group were kept and the pits were drained after 14 days, the level of manure was 22.0 and 38.4% higher compared to the buildings, where the pigs of the III and IV experimental groups were kept, respectively. At the same time, the level of manure in the pits in the IV experimental building turned out to be 13.4% higher compared to the similar indicator of the III group.

As follows from Table. 1, the air temperature in the premises for fattening pigs corresponded to their physiological needs and was almost independent of the frequency of drainage of manure pits. It turned out to be the lowest in the III experimental group, 18.5ºC, which was probably ($p<0.05$) 1.4ºC (7.6%) lower compared to the IV experimental group and improbably lower by 0.7ºC (3.6%) in comparison with the building, where the animals of the I control and II experimental groups were kept. At the same time, in these buildings, there was a tendency to decrease by 0.7ºC or (3.6%) the average value of the temperature in comparison with the building, where the animals of the IV research group were kept.

The relative humidity of the air in all experimental buildings was at the upper limit of physiologically justified norms and also depended on the frequency of pit emptying. As the frequency of pit emptying decreased, the relative humidity of the air in the buildings increased. Thus, in the premises where the animals of the IV experimental group were kept and the pits were drained once every four weeks, the relative humidity of the air was 75.1%, which is 1.8% lower compared to the building where the animals of the III group were kept and the pits were drained every two weeks and lower 3.0% ($p<0.05$) in comparison with the II experimental building, where the pits were drained every week. Also, the humidity level in the building, where the pigs of the control group were kept was lower by 0.8% compared to building with group III and by 2.6 compared to building with group IV, and where pits drained as they filled.

The content of unhealthy gases in the air of the experimental premises also depended to some extent on the frequency of emptying of manure pits. A higher concentration of ammonia was found in the building, where the pits drained as they filled (I control group) – 15.5 mg/m^3, which is 0.3 mg/m^3 higher compared to the building, where the animals of the II experimental group were kept and by 1.7 and 3.0 ($p<0.05$) mg/m^3, respectively, in comparison with building, where animals of III and IV groups were kept. At the same time, the level of ammonia in the indoor air decreased in parallel with the decrease in the

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frequency of emptying the pits. It should also be noted that the average indicators of the ammonia level for the entire period of the experiment were within the limit of permissible concentrations in all the experimental buildings.

The carbon dioxide content in the air of the buildings did not depend on the frequency of pit emptying and was at the upper limit of the maximum permissible concentrations for fattening pigs.

Meanwhile, the level of hydrogen sulfide had rather low values and depended on the frequency of pit emptying. Its highest content was in the air of the building, where the animals of the control group were kept and the pits were filled and drained according to their maximum filling. In the air of this building, the average concentration of hydrogen sulfide was found at the level of 2.9 mg/m^3, which was probably 27.6%, 34.5% ($p<0.001$) and 24.1($p<0.01$) higher compared to the buildings, where animals of II, III, and IV groups were kept, respectively. The level of this indicator in buildings with periodic draining of manure pits had no probable difference, although it had the lowest value in the building, where the pits were drained once every three weeks.

Thus, the average concentration of hydrogen sulfide and ammonia depended on the frequency of emptying pits in the premises, while the carbon dioxide content in the air did not depend on it. The average values of air humidity in the building increased with a decrease in the frequency of draining pits. At the same time, the air temperature did not have a clear dependence on the frequency of draining pits.

When studying the dynamics of changes in air parameters in the middle of the building depending on the dynamics of the filling of the pits, a certain regularity of the dependence of the content of its individual components on the level of manure in the pits was established. Thus, the concentration of ammonia in all test buildings increased with an increase in the content of manure in their pits and decreased with their decrease, although this process was not synchronous (Fig. 1).

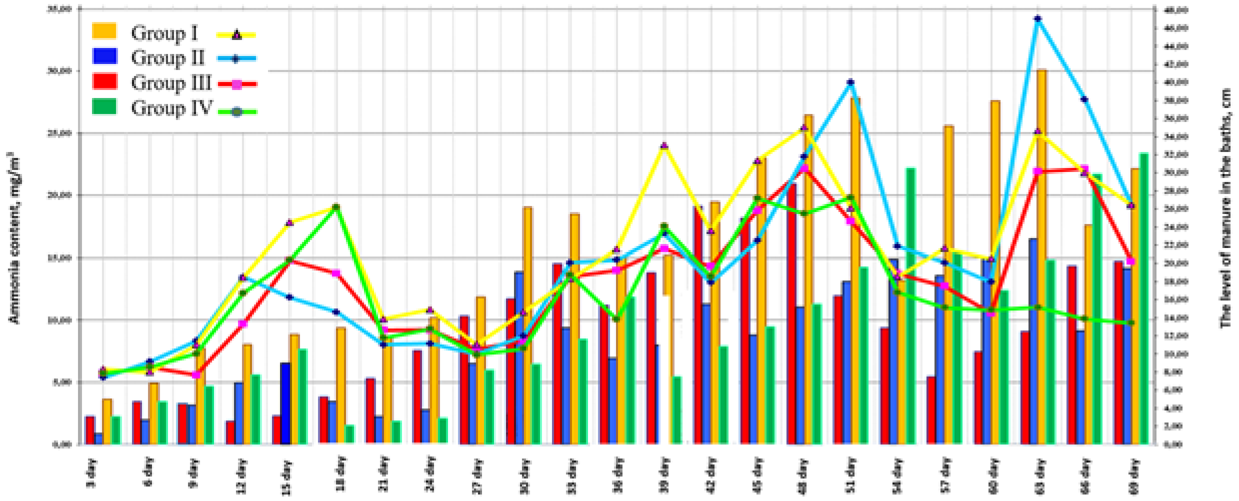

Fig. 1. Dependence of ammonia content on the level of manure in pits
Source: Own calculations.

Thus, an elevated ammonia content was established in all periods of research in the building, where the animals of the I control group were located and the pits traditionally partially drained as they filled. As can be seen from the graph, the highest level of manure in the pits was observed in this building, which in certain periods of research reached the level of 41 cm or 82% of the full capacity of the pit. As can be seen from the same graph, the level of ammonia in the premises of this building was quite high in all periods and almost always exceeded the similar indicator of the experimental groups.

In the II experimental building, where pits were drained according to the methodology every 14 days, after the first draining of the pits, the level of manure in them decreased to 4.7 cm or 9.4% of their full capacity, after which a decrease in the level of ammonia in the air of this building was recorded up to 10.65 mg/m^3. In the same period, the ammonia content in the air of the I control group was 19.08 mg/m^3 with a level of manure in the pits of 12.9 cm or 25.8%. At the same time, in the building, where pigs of the III experimental group were kept, and the draining of pits took place every 21 days, with 10.6% filling of the pit (5.3 cm), the ammonia content was 13.76 mg/m^3, while in the building, where pigs were kept animals of the IV experimental group with a 4.2% level of manure in the pits (2.13 cm), the ammonia level was 9.08 mg/m^3.

After the second draining of the pits in the II control group, which took place 29 days after the start of the experiment, as can be seen from this graph, the level of manure in them remained at a fairly high level of 25.8% of their full capacity (12.9 cm), which caused high level of 16.94 mg/m^3 ammonia content in the air. At the same time, in the control building, the level of manure in the pits was 51.0% (25.46 cm) and the level of ammonia content was 13.67 mg/m^3. After draining the pits 48 days after the start of the experiment, the manure level in them reached 12.12 cm, (25.1% of the maximum filling of the pits), while the ammonia content in the air was 13.02 mg/m^3, after which an increase in its level in the premises was observed to fairly high indicators of 29.09 mg/m^3 after 51 days and up to 34.22 mg/m^3 after 54 days after the start of the experiment, which significantly exceeds the maximum permissible concentrations. At the same time, in the control building, the level of manure in their pits was naturally higher compared to others, while the ammonia content in the air of this building was at a level close to the experimental ones. Thus, the ammonia content in the building changed depending on the level of manure in the pits, but its changes were not synchronous with changes in the level of manure in the pits.

Analyzing the dynamics of the hydrogen sulfide concentration in the test buildings depending on the filling of the pits (Fig. 2), no clear trend was established. However, the graph shows a higher content of hydrogen sulfide in the control building, where the pits were always filled with manure, compared to the experimental buildings, where the pits were periodically emptied.

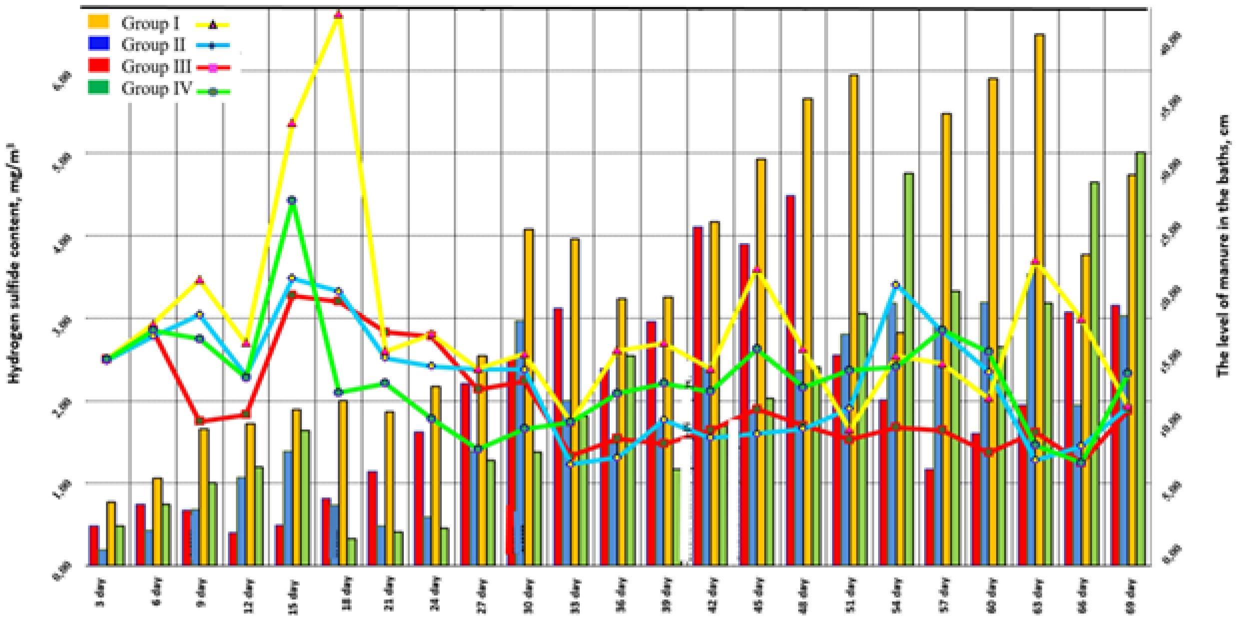

Fig. 2. Dependence of the content of hydrogen sulfide on the level of manure in pits
Source: Own calculations.

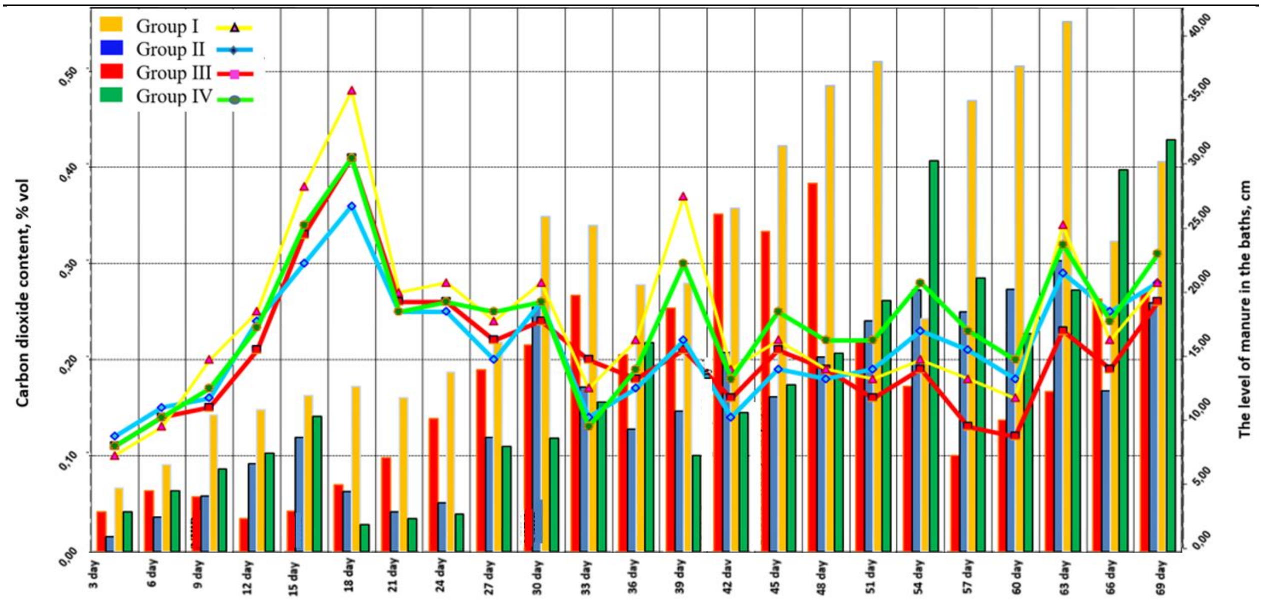

Fig. 3. Dependence of carbon dioxide content on the level of manure in pits
Source: Own calculations.

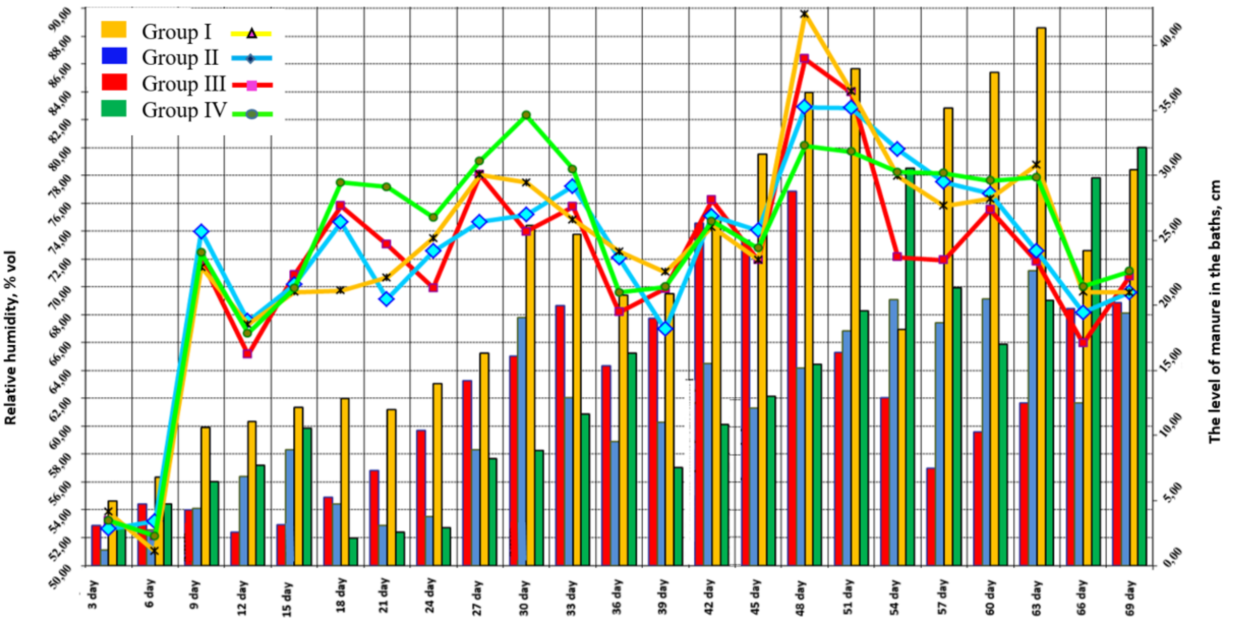

Fig. 4. Dependence of relative air humidity on the level of manure in pits
Source: Own calculations.

The dynamics of the carbon dioxide content in the experimental buildings also did not depend on the level of filling of the pits (Fig. 3), but rather depended on other factors and changed almost synchronously in all four experimental buildings.

At the same time, the values of relative humidity had a significant dependence on the level of fullness of the pits, and with the increase in the level of manure in the pits, the level of relative humidity of the air (Fig. 4) in all experimental buildings also increased.

As can be seen from the graph (Fig. 5), the ammonia content to some extent depended on the temperature outside the building. In our opinion, this is related to the level of intensity of air exchange, which depended on the temperature outside the building. There was not established significant difference between the groups II, III and IV. The concentration of this gas changed almost synchronously in all experimental groups.

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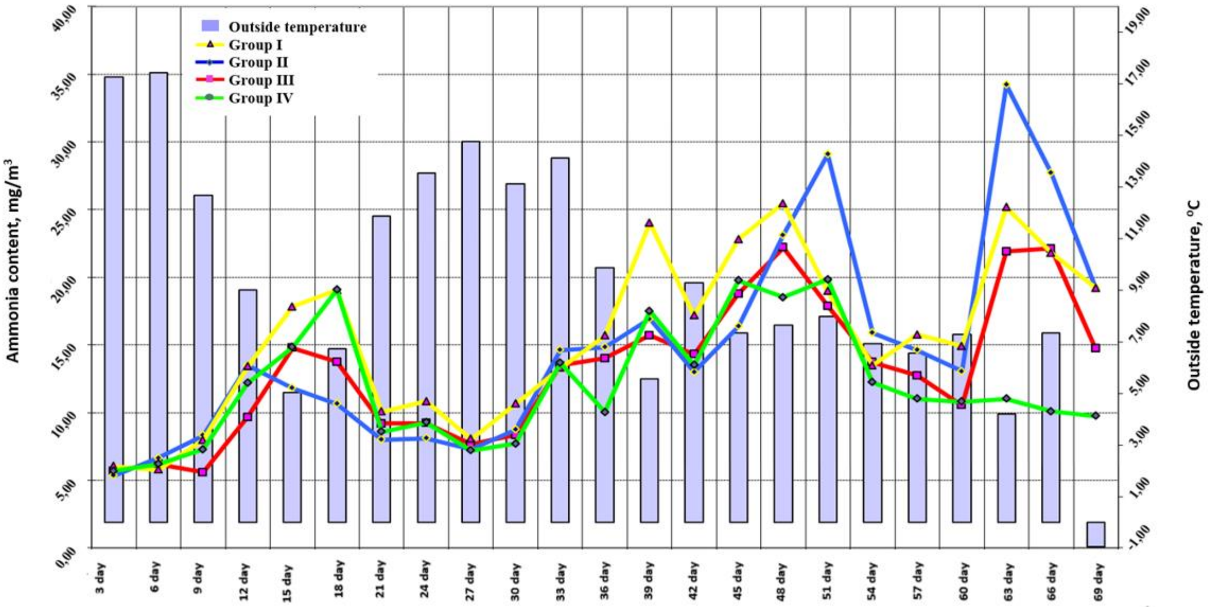

Fig. 5. Dependence of the ammonia content in the air of the experimental premises on the air temperature outside the premises
Source: Own calculations.

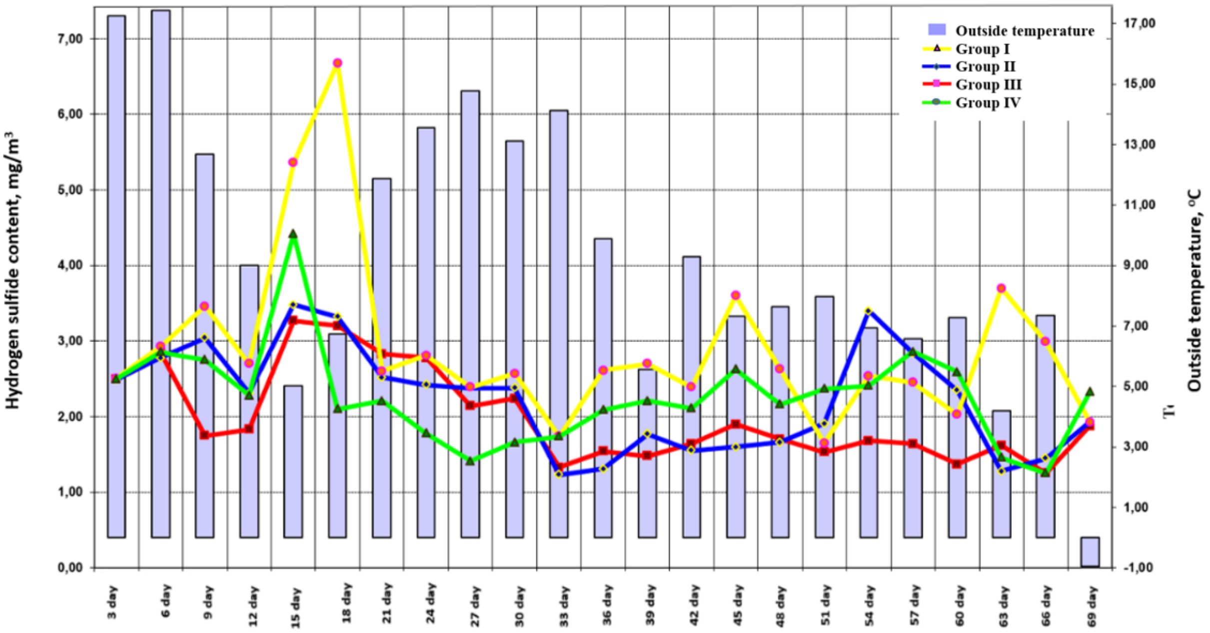

Fig. 6. Dependence of the content of hydrogen sulfide in the air of experimental premises on the temperature of the air outside the premises
Source: Own calculations.

At the same time, the content of hydrogen sulfide, in our opinion, did not depend on the temperature of the external environment (Fig. 6) and had slightly higher values in different buildings, which depended on the frequency of pit emptying.

The dynamics of the carbon dioxide content in the test buildings depended on the temperature outside the building (Fig. 7). As the ambient temperature decreased, the carbon dioxide content in the air increased. In our opinion, this is related to the intensity of air exchange in the building, which is related to the temperature of the outside air.

In the comparison of the experimental groups according to the change of this indicator, there was no any difference between the groups.

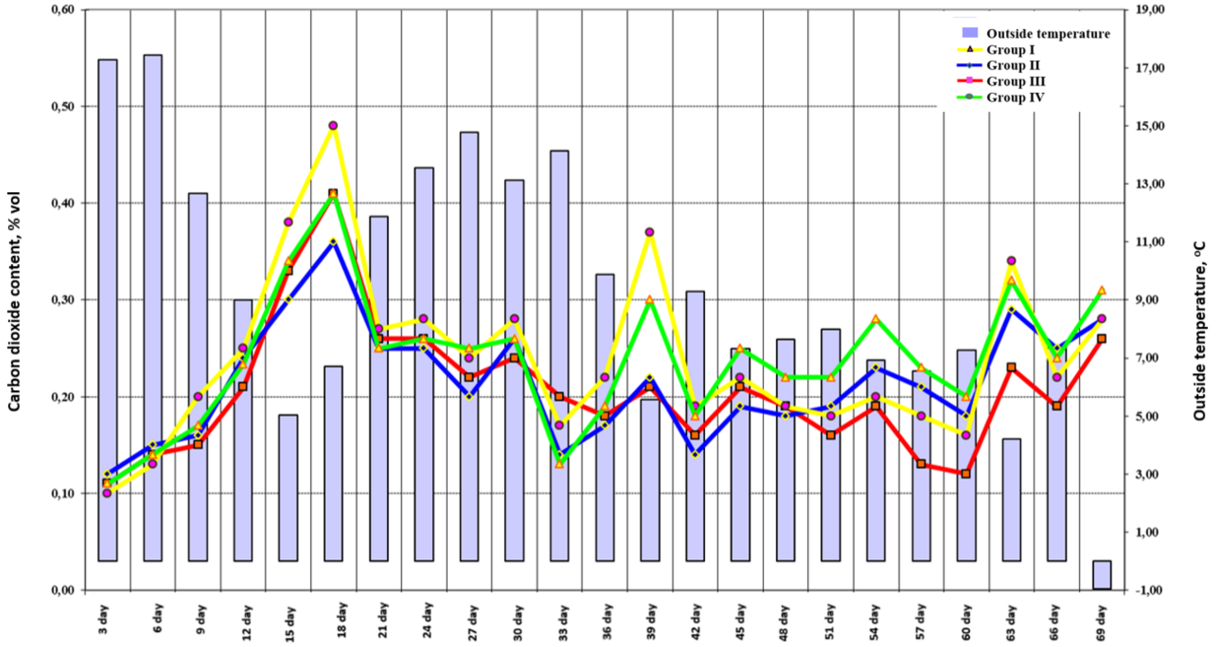

Fig. 7. Dependence of the carbon dioxide content in the air of the experimental premises on the temperature of the air outside the premises
Source: Own calculations.

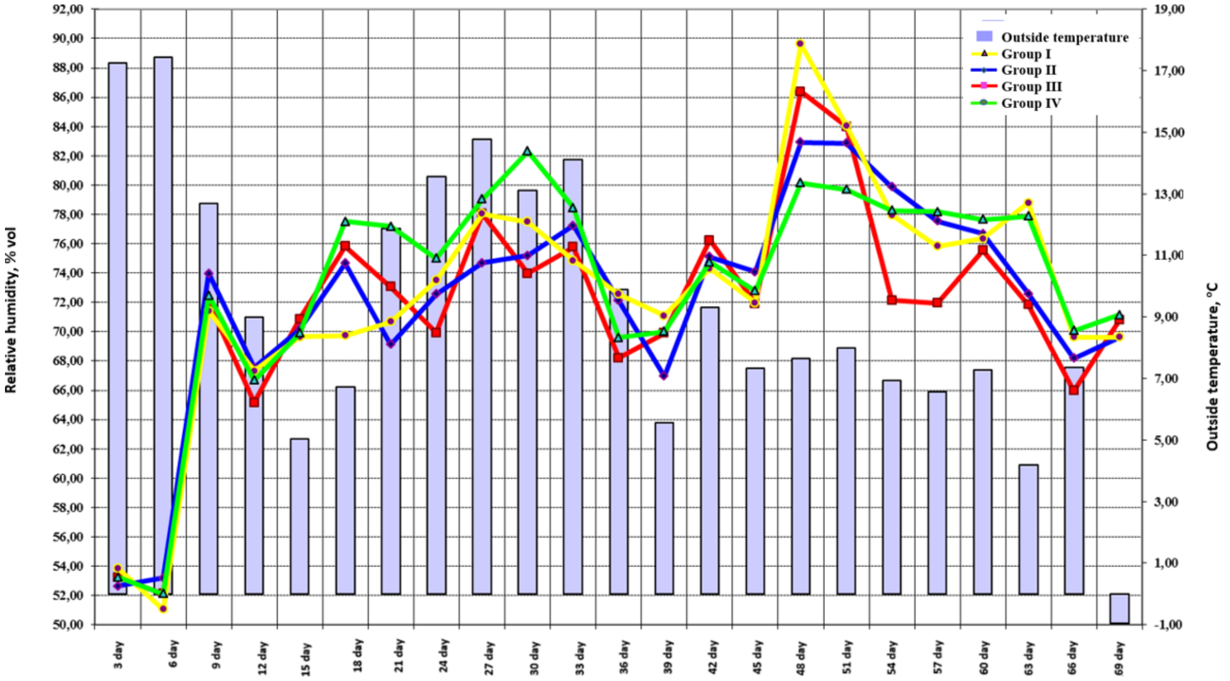

Fig. 8. Dependence of the relative humidity in the air of the experimental premises on the temperature of the air outside the premises
Source: Own calculations.

The relative humidity of the air, as can be seen from the graph (Fig. 8) did not depend on the external temperature as well as on the frequency of pit emptying.

Thus, the content of ammonia and hydrogen sulfide depended on changes in the ambient temperature, while the hydrogen sulfide content in the air and its relative humidity did not depend on the temperature outside the building.

Therefore, our research on the dependence of gas content on the frequency of drainage of manure pits coincided with similar conclusions of other scientists [4, 10, 27].

At the same time, the data we obtained contradicted the arguments presented in the publication [4], which spoke of a decrease in ammonia content with an increase in the frequency of draining manure pits. We obtained the opposite results, which show an increase in the ammonia content with an increase in the frequency of draining the pits. Such conclusions coincided with the results of the experiment [10, 27], which associated the increased concentration of ammonia in the building with their increased evaporation due to the high turbulence of the air flow in the manure-free space of the pit.

We established the lack of influence of the frequency of drainage of manure pits on the concentration of hydrogen sulfide, as did other scientists [9], who had a similar result. However, the absence of such a relationship between the content of hydrogensulfide and the frequency of draining manure pits did not coincide with the data of the authors [29], who confirm an increase in the content of hydrogensulfide in buildings, where pits were cleaned frequently.

CONCLUSIONS

It was established that the average concentration of hydrogen sulfide and ammonia depended on the frequency of emptying of manure pits in the premises, while the content of carbon dioxide in the air did not depend on it. The average values of air humidity in the building increased with a decrease in the frequency of draining pits.

The dependence of the concentration of ammonia in the air and its relative humidity on the level of manure in the pits and the absence of such dependence in the concentration of hydrogen sulfide and carbon dioxide were determined.

It was proven that the content of ammonia and carbon dioxide depended on changes in the ambient temperature, while the concentration of hydrogen sulfide in the air and its relative humidity did not depend on the temperature outside the building.

Frequent draining of manure pits leads to an increase in the content of ammonia and hydrogen sulfide, which negatively affects the indicators of the microclimate in the pig fattening building.

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