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ANNUAL DYNAMICS OF MICROCLIMATE PARAMETERS OF FARROWING ROOM IN PIGSTY USING TWO DIFFERENT VENTILATION SYSTEMS

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ABSTRACT. The study aimed to investigate the valve and geothermal microclimate systems' impact on microclimate indicators in farrowing rooms. In farrowing rooms, where the valve type of ventilation was installed, the temperature in the farrowing room in summer and autumn exceeded the norm by 3.90 and 1.60 °C, respectively. The amplitude of the average values of the annual temperature dynamics at all these measurement points was higher at using valve-type ventilation relative to geothermal, which provided a constant temperature during the year. Humidity during all seasons of the year was optimal with the use of both microclimate systems, but in summer and autumn, it was probably higher during using geothermal ventilation. The content of carbon dioxide reached its highest values in the autumn months with the use of both systems to create a microclimate, but without exceeding the norm. At the same time, its content was probably higher in the summer months in the room for keeping pregnant sows with the geothermal type of ventilation by 400 ppm or 50% ($P < 0.01$). The ammonia content tended to increase in the autumn months in both farrowing rooms, but reached its highest values in the fall, remaining, however, within normal limits. The hydrogen sulfide content did not exceed the optimal values for both farrowing rooms during all seasons without a statistically significant difference between different types of ventilation. In the farrowing rooms where the geothermal ventilation system was used, the highest H_2S content was in the winter months, amounting to 3.59 ppm, which is 0.96 ppm or 26.81% ($P < 0.001$) higher than in spring, 0.83 ppm or 23.29% ($P < 0.001$) higher than in summer and 0.26 ppm or 7.44% ($P < 0.05$) higher than in spring.

Introduction

The increase in average annual temperatures and abnormally hot periods during the year, which has been observed in recent decades, determines a new approach to improving the microclimate of livestock facilities. The effects of heat stress, high humidity or gassiness of pig housing are manifested in the disruption of their physiological processes, reduced immunity, behavioural changes and reduced productivity, so the introduction of cooling and air conditioning is a key factor in mitigating these negative effects (Maskal *et al.*, 2018; Watanabe *et al.*, 2019). Various cooling methods have been implemented in pig farms. The air temperature can be reduced with the help of adiabatic cooling technology, as a system of fogging under high pressure (Parois *et al.*, 2018). In modern pig farms, large evaporating plates can support the tunnel ventilation system. Currently, much attention is also paid to the development of energy and water-saving methods of cooling using, for example, heat exchanger "ground-air" or "ground-water" (Wiegert *et al.,* 2018; Godyn *et al.,* 2020).

A review of pig heat and moisture production described in publications (Linden, 2021) reports that new genetic lines of pigs produce almost 20.0% more heat than their counterparts in the early 1980s. Pigs usually develop heat stress at much lower temperatures when humidity is high. The degree of humidity directly affects the metabolic processes in animals. When the indoor air temperature decreases excessively, the moisture concentration automatically increases, as a result of which condensate settles on the surfaces, which leads to moisture and supercooling, development of fungi and pathogenic microflora (Min *et al.*, 2015). At elevated temperatures, the humidity drops critically and the air becomes dry, causing the pigs to overheat, which also negatively affects their overall condition (Tkachuk, 2010).

Heat stress causes behavioural and physiological responses and therefore negatively affects livestock productivity (Vitali *et al.*, 2021). Among agricultural species, pigs are particularly susceptible to high temperatures. The increase in the frequency of hot periods observed in the last decade determines a new approach to the improvement of livestock facilities (Shi *et al.,* 2006). The effects of heat stress are manifested in disorders of physiological processes, immune disorders, and changes in animal behaviour, so the introduction of cooling technologies is a key factor in eliminating these negative effects (Seibert *et al.*, 2018; Godyn *et al.*, 2020). Pigs feel warm depending on temperature and humidity (Ross *et al.*, 2017). Sows and boars suffer from acute and constant exposure to high temperatures and humidity. As a result, infertility can be a relatively short-term or prolonged illness from which the animal does not recover for a long time (Lucy, Safranski, 2002).

The gas composition of the air of industrial premises affects the metabolism, productivity of animals and their disease resistance.

Technologies such as exhaust fans, curtains and heaters are now being introduced in piggeries to increase the efficiency of creating optimal conditions for pigs. Ventilation has undergone some changes as more and more pig farms have begun to rely on electronic modes and mechanics (Sapkota *et al.*, 2016). Due to the development of ventilation control technologies in piggeries, it has become more difficult, given the fan steps and more accurate air inlets, which may lead to a lack of scientific understanding of how to ventilate the premises for optimal health and comfort of pigs (Olczak *et al.*, 2015; Zangaro, 2021).

Given the important issues of pig welfare, it should be noted that the optimal microclimatic conditions for suckling sows with piglets are a major factor in ensuring not only the comfort and health of the animal but also further productivity and growth rate. Thus, the study of improving the microclimate systems in pig farming facilities is a topical issue in modern pig farming.

The article aims to investigate the influence of different microclimate systems on the microclimate parameters in the farrowing room during the year and to identify their dependence on changes in seasonal factors.

Materials and Methods

The experiment was conducted in the conditions of the industrial pig complex of Globinsky Pig Complex LLC, Globino, Poltava region, Ukraine (49.394005, 33.311125). The influence of the type of microclimate system in the sections of the premises for keeping suckling sows on its parameters was established by the object of research. The data obtained from measurements of microclimate parameters were the material of the study. Measurements of microclimate parameters were carried out in the same rooms for farrowing, which differed in the system of microclimate. The operation of microclimate systems in both farrowing rooms was adjusted so that the microclimate parameters were at the level of values approved in the departmental standards of technological design of pig farms (VNTP-APK-20.05, 2005). But the microclimate systems did not equally cope with the values of the microclimate at the level of approved standards (Table 1).

Table 1. Departmental norms of technological design of pig enterprises

Indicator	Norms
Indoor air temperature, °C	19–24
Air temperature in the area of piglets activity, °C	22–30
The temperature of the piglet's lair, °C	28–35
The temperature of the sow's lair, °C	24–36
Air velocity, m s^{-1}	0.15
Relative air humidity, %	40–70
Indoor air characteristics:	
CO_2, ppm	2 000
NH_3, ppm	28.18
H_2S, ppm	7.04

The farrowing room No. 1 of Globinsky Pig Complex LLC, where the microclimate system was created and maintained by the ventilation equipment of the German company Big Dutchman: with microclimate control module 307pro L15CE6, was taken as a control room. Microclimate control module connected to temperature sensor DOL 12 (measuring range –10…+40 °C), relative humidity sensor DOL 114 (measuring range 17–100% RH), vacuum sensor DOL 18 (measuring range 6.89–68.9 kPa), CO_2 sensor DOL 19 (measuring range 0–10 000 ppm), NH_3 sensor DOL 53 (measuring range 0–100 ppm) and meteorological station. Sows with piglets of the control group were kept in farrowing rooms with an air supply in the farrowing section utilising supply valves CL 1911 F located on both sides of the farrowing section there (Fig. 1). Exhaust air was extracted from the farrowing room through the roof shafts CL 600 equipped with two exhaust fans FF 063-6ET.

The design features of the experimental room for farrowing No. 2 of Globinsky Pig Complex LLC (Fig. 2) were identical to the planning and ventilation equipment of the German company Big Dutchman: with microclimate control module 307pro L15CE6, connected to temperature sensor DOL 12 (measuring range –10…+40 °C), relative humidity sensor DOL 114 (measuring range 17–100% RH), vacuum sensor DOL 18 (measuring range 6.89–68.9 kPa), CO_2 sensor DOL 19 (measuring range 0–10 000 ppm), NH_3 sensor DOL 53 (measuring range 0–100 ppm) and meteorological station. But experimental microclimate system there was fundamentally different in type and technological implementation from the air supply system in the farrowing section. In this farrowing room, external unprepared air enters the farrowing section via two underground air ducts and four perforated under-ceiling air distribution ducts located above the farrowing pens.

In general, both the control and research rooms for farrowing were identical to the configuration of the interior layout and were built of the same building material. The sections of the premises where the piglets were farrowed and kept during the suckling period until weaning were of equal area, had the same number of individual pens, the same watering systems, transport and distribution systems and identical designs of vacuum-self-flowing manure removal systems, but they differed microclimate systems.

The study and the methods used to obtain the result were approved by the committee on ethics and humane treatment of animals of the Sumy National Agrarian University.

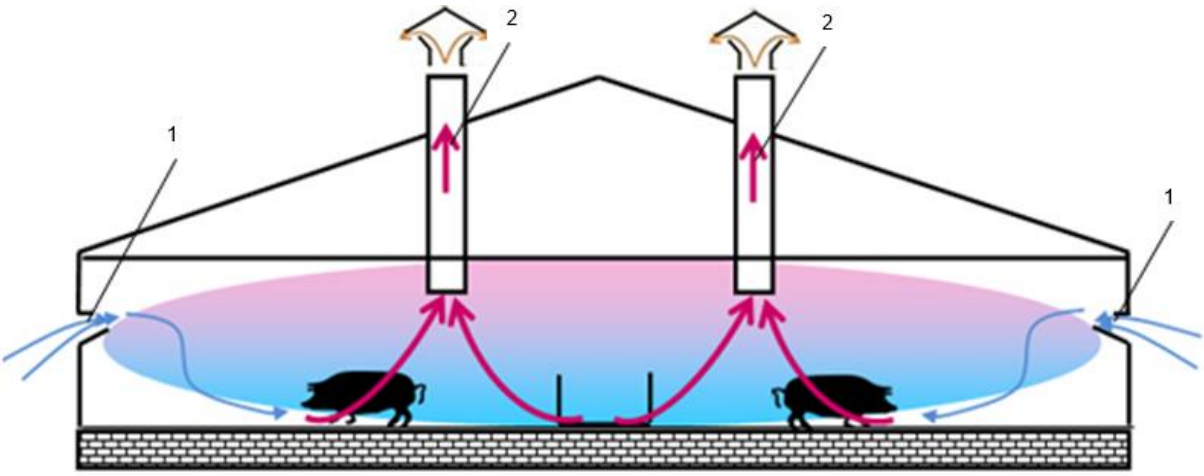

Figure 1. Scheme of air movement in the farrowing room with valve ventilation (I control group) (1 – supply valve; 2 – exhaust shafts)

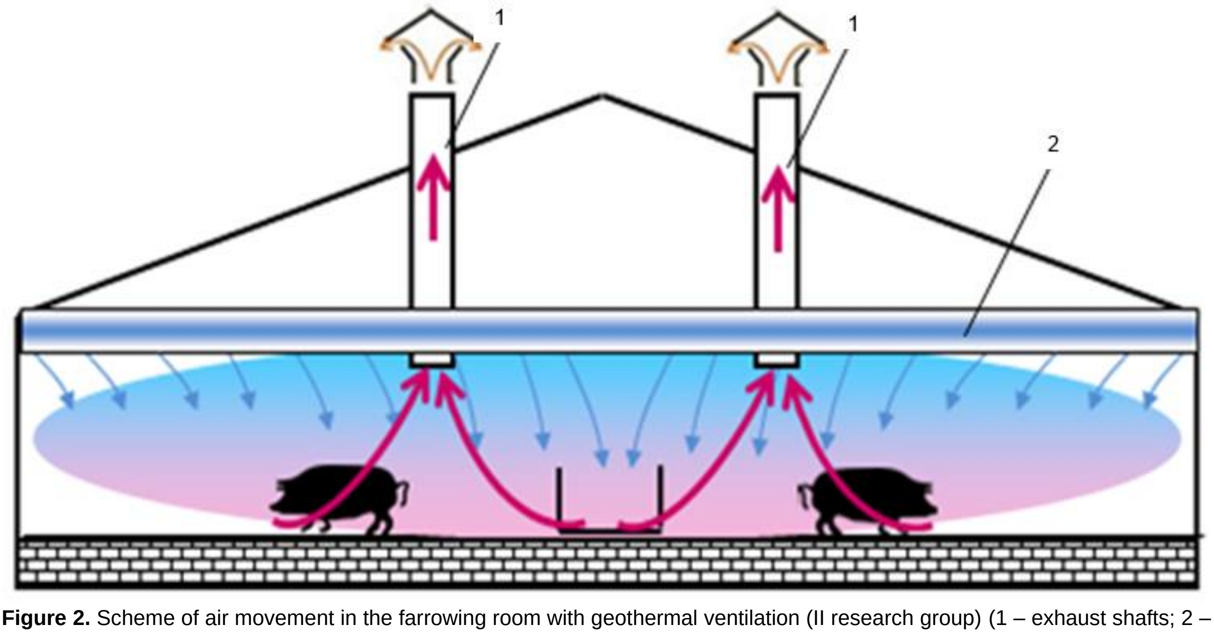

Figure 2. Scheme of air movement in the farrowing room with geothermal ventilation (II research group) (1 – exhaust shafts; 2 – sub-ceiling supply air duct)

Measuring the microclimate parameters

Microclimate parameters were measured three times for each season of the year, once a month. On the day of measurement, microclimate parameters were measured once in the morning and once in the evening at the same time. During the winter season, three measurements were performed: one in December, one in January, and one in February. In the spring season, three measurements were made: one in March, one in April and one in May. During the summer season, three extinctions were carried out: one in June, one in July and one in August. In the autumn season, three measurements were made: one in September, one in October and one in November.

Indoor air temperature and air temperature in the area of piglet activity were measured using pyrometer Testo 805 (Testo AG, Lenzkirch, Germany) with a measuring range –25…+250 °C (±1.0 °C). Measurement areas were chosen in the middle and two opposite corners of the room, departing from the walls up to one meter. Vertically, temperature measurements were carried out in three zones: 0.3 and 0.7 m from the floor and 0.6 m from the ceiling.

The temperature of the piglet's lair, the temperature of the sow's lair and air velocity were measured using a thermo-anemometer Testo 425M (Testo AG, Lenzkirch, Germany) with a measuring range of 0 to 20 m s^{-1} (±0.03 m s^{-1}) and –20…+70 °C (±0.5 °C). The temperature of the piglets' and sows' lairs was measured in each pen. The average values of piglet lair measurements and sow lair temperature were taken into account.

Relative air humidity was measured using thermo-hygrometer Testo 605 (Testo AG, Lenzkirch, Germany) with a measuring range of 5–95% RH (±3.0% RH). Measurements of indicators were made at the level of lying piglets (7.0 cm), their standing (25.0 cm) and the level of the respiratory tract of an adult (160.0 cm).

Content in the air of ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) were measured using the gas analyzer DOZOR-CM4 (NPP ORION, Ukraine) with a measuring range for CO_2 0–10 000 ppm (±2 500 ppm), for NH_3 0–28.18 ppm (±7.05 ppm), for H_2S 0–21.12 ppm (±3.52 ppm).

Data analysis

The obtained results were analyzed using Excel 2010. Results were expressed as mean values, standard deviations, and standard error of the mean in the tables. The dissemblance significance ($P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$) between the microclimate parameters (n = 36) was analyzed by the Student's t-test.

Results

Estimation of microclimate parameters in premises for suckling sows with piglets with different types of microclimate systems in winter allowed us to identify that the air velocity in the farrowing room with the geothermal type of ventilation was lower than in the room equipped with a valve type of ventilation by 0.04 m s^{-1} or 36.36% ($P < 0.05$) (Table 2). This led to a decrease in air exchange in the farrowing section. Thus, in the control farrowing room, the air exchange was 1.93 m^3 s^{-1}, while in the farrowing room with geothermal ventilation it was 0.71 m^3 s^{-1} smaller. A study of microclimate indicators created by different systems of its creation and maintenance in sows in the spring season found a higher velocity of air in the farrowing room using a valve system of microclimate by 0.07 m s^{-1} or 38.89% ($P < 0.05$). This caused an increase in air exchange in it by 1.22 m^3 s^{-1} and, as a result, a lower level of concentration of harmful gases there.

Table 2. Indicator microclimate parameters during the seasons of the year, n = 36

Indicator	Winter	Spring	Summer	Autumn
Group I (valve type ventilation)				
Indoor air temperature, °C	20.1 ± 0.37^{A}	20.3 ± 0.21^{A}	27.9 ± 0.31^{aB}	25.6 ± 0.21^{C}
Air temperature in the area of piglets activity, °C	27.3 ± 0.16^{A}	24.9 ± 0.11^{B}	28.2 ± 0.30^{C}	26.9 ± 0.18^{A}
The temperature of piglet's lair, °C	31.4 ± 0.12^{A}	32.9 ± 0.16^{B}	34.9 ± 0.19^{C}	33.1 ± 0.28^{D}
The temperature of the sow's lair, °C	23.9 ± 0.14^{A}	24.0 ± 0.19^{AC}	25.9 ± 0.19^{B}	24.4 ± 0.14^{C}
Air velocity, m s^{-1}	0.11 ± 0.012^{aA}	0.18 ± 0.018^{aBD}	0.35 ± 0.024^{aC}	0.21 ± 0.022^{D}
Volume speed of air movement, m^3 s^{-1}	1.93	3.15	6.20	3.68
Relative air humidity, %	55.2 ± 0.59^{A}	61.3 ± 0.65^{B}	45.9 ± 0.45^{aC}	64.2 ± 0.73^{aD}
Indoor air characteristics:				
CO_2, ppm	$1\,200.0 \pm 80^{A}$	$1\,200.0 \pm 130^{A}$	800.0 ± 60^{bB}	$2\,300.0 \pm 190^{C}$
NH_3, ppm	6.72 ± 1.250^{A}	5.93 ± 0.758^{A}	2.22 ± 0.210^{B}	9.78 ± 0.620^{C}
H_2S, ppm	2.11 ± 0.025^{A}	2.17 ± 0.073^{A}	1.29 ± 0.008^{B}	2.47 ± 0.056^{C}
Group II (geothermal type ventilation)				
Indoor air temperature, °C	23.0 ± 0.21^{AB}	22.4 ± 0.17^{AB}	23.1 ± 0.19^{bAB}	22.7 ± 0.19^{AB}
Air temperature in the area of piglets activity, °C	27.9 ± 0.18^{A}	27.0 ± 0.13^{B}	26.8 ± 0.19^{B}	25.8 ± 0.19^{C}
The temperature of piglet's lair, °C	35.2 ± 0.10^{A}	34.8 ± 0.15^{A}	34.8 ± 0.21^{A}	34.0 ± 0.24^{B}
The temperature of the sow's lair, °C	26.8 ± 0.14^{A}	23.9 ± 0.18^{B}	25.3 ± 0.19^{C}	24.6 ± 0.15^{D}
Air velocity, m s^{-1}	0.07 ± 0.011^{bA}	0.11 ± 0.020^{bA}	0.16 ± 0.036^{bB}	0.15 ± 0.019^{B}
Volume speed of air movement, m^3 s^{-1}	1.22	1.93	2.8	2.63
Relative air humidity, %	52.1 ± 0.55^{A}	62.4 ± 0.48^{B}	52.1 ± 0.54^{bA}	57.1 ± 0.69^{bC}
Indoor air characteristics:				
CO_2, ppm	$1\,800 \pm 100^{A}$	$1\,500 \pm 160^{B}$	$1\,200 \pm 70^{bC}$	$2\,000 \pm 200^{A}$
NH_3, ppm	8.46 ± 1.154^{A}	7.13 ± 0.944^{A}	5.28 ± 0.168^{B}	8.21 ± 0.943^{A}
H_2S, ppm	3.59 ± 0.061^{A}	2.63 ± 0.074^{B}	2.76 ± 0.014^{B}	3.33 ± 0.062^{C}

Different lowercase letters (a, b) indicate statistical differences between the ventilation systems at the level of $P < 0.05$. Different capital letters (A, B, C, D) indicate a statistical difference between the seasons at the level of $P < 0.05$.

Analysis of the parameters of microclimate systems in the sections for farrowing during the summer season showed that when valve ventilation was used, the value of indoor air temperature was higher by 4.80 °C or 17.20% ($P < 0.001$), the velocity of indoor air was higher by 0.19 m s^{-1} or 54.29% ($P < 0.001$), which caused a greater air exchange in it by 3.4 m^3 s^{-1} and, as a result, a decrease in relative air humidity by 6.20% RH ($P < 0.001$), CO_2 content by 400 ppm or 50.00% ($P < 0.01$). The study of microclimate indicators in the autumn months in farrowing rooms equipped with different types of ventilation found difference in the relative air humidity, which was higher in the farrowing room with a valve system to create a microclimate by 7.10% RH ($P < 0.001$).

Seasonal dynamics of microclimate indicators in farrowing premises revealed their diverse changes during the study period. Thus, the air temperature in farrowing rooms equipped with valve ventilation for sows and suckling piglets was significantly higher in the summer and autumn months compared to winter by 7.80 °C or 38.81% ($P < 0.001$) and 5.50 °C or 27.36% ($P < 0.001$). In the premises where geothermal ventilation was installed, there was no statistically significant difference between the indicators during all seasons of the year. Evaluation of the annual dynamics of air temperature in the area of piglets activity using a valve ventilation system found that in the spring it was significantly lower than in winter by 2.40 °C or 8.79% ($P < 0.001$) and in the summer it was significantly higher than in winter by 0.90 °C or 3.30% ($P < 0.05$), and there was no significant difference between its autumn and winter values. The temperature in the area of piglets activity kept in the geothermal microclimate system was probably the highest in the winter months, exceeding the spring season by 0.90 °C or 3.23% ($P < 0.01$), summer season by 1.10 °C or 3.94% ($P < 0.01$) and in the autumn season by 1.7 °C or 5.41% ($P < 0.001$).

A study of the temperature of piglets lair in the farrowing room with a valve system of microclimate found that in winter its values were the lowest and inferior to spring by 1.50 °C or 4.78% ($P < 0.001$), summer by 3.50 °C or 11.15% ($P < 0.001$), autumn 1.70 °C 5.41% ($P < 0.001$). In the same study period, the temperature of the piglet's lair in a farrowing room with a geothermal microclimate system in winter, spring and summer did not differ significantly, and in autumn it was lower than in winter by 1.20 °C or 3.41% ($P < 0.001$). The annual dynamics of sow's lair temperature in the control group were marked by the absence of a significant difference between its indicators in winter and spring, but in summer its values prevailed in winter by 2.00 °C or 8.37% ($P < 0.001$), and in autumn the advantage over winter values was 0.50 °C or 2.09% ($P < 0.05$). In the experimental group, the values of sow's lair temperature were the highest in the winter months, exceeding the indicators of the spring season by 2.90 °C or 10.82% ($P < 0.001$), summer season by 1.50 °C or 5.60% $P < 0.001$), the autumn season by 2.20 °C or 8.21% ($P < 0.001$).

A study of the annual dynamics of air velocity in a farrowing room equipped with a valve ventilation system was found to have the lowest values in the winter season, which were significantly inferior to the values of the spring months by 0.07 m s^{-1} or 63.64% ($P < 0.01$), summer months by 0.24 m s^{-1} or 218.18% ($P < 0.001$), autumn months by 0.10 m s^{-1} or 90.91% ($P < 0.01$), which caused a lower level of volume speed of air movement by 1.22, 4.27 and 1.75 m^3 s^{-1} in accordance. The dynamics of the rate of air movement in the farrowing room equipped with a geothermal ventilation system were similar. It was found that in summer the air velocity was higher than in winter by 0.09 m s^{-1} or 125.57% ($P < 0.05$), and in autumn – by 0.08 m s^{-1} or 114.29% ($P < 0.01$). It was established that in the summer the level volume speed of air movement in the farrowing room with geothermal type ventilation was higher than the winter value of this indicator by 1.58 m^3 s^{-1}, than the autumn value of this indicator by 1.58 m^3 s^{-1} and then the spring value of this indicator by 0.71 m^3 s^{-1}. No significant difference in the values of the indicator between spring and winter measurements was found.

Analysis of the annual values of air humidity in the room for keeping pregnant sows with a valve system to create a microclimate revealed that in winter this figure was lower than its spring and autumn values by 6.1% RH ($P < 0.01$) and 9.00% RH, respectively ($P < 0.001$), but higher than in summer by 9.3% RH ($P < 0.001$). In the farrowing room with a geothermal microclimate system, the air humidity in the spring exceeded winter values by 10.30% RH ($P < 0.001$), and in autumn – by 5.00% RH ($P < 0.001$). There were no significant differences between winter and summer air humidity values in the farrowing room.

A study of the gas composition in farrowing rooms where pigs were kept using the valve type of ventilation showed that there was no significant difference between the winter and spring values of CO_2 in the air. However, the content of carbon dioxide in the summer was lower than in winter by 400 ppm or 33.33% ($P < 0.01$), and in autumn, on the contrary, exceeded the winter by 800 ppm or 66.67% ($P < 0.01$). The dynamics of carbon dioxide content in the farrowing room using geothermal ventilation was manifested in the excess of winter values over spring and summer, respectively, by 1 700 ppm or 91.67% ($P < 0.001$) and 600 ppm or 33.33% ($P < 0.001$). In this case, the CO_2 content in the experimental group in the autumn and winter months did not differ significantly.

Assessment of the dynamics of ammonia content in the room for suckling sows with air supply through wall valves revealed no statistically significant difference between the winter, spring and autumn months, and in summer they were lower than in winter by 4.49 ppm or 66.88% ($P < 0.01$). The values of NH_3 content in the farrowing room with a geothermal type of microclimate system in the winter, spring and autumn seasons did not differ statistically significantly. In summer, the ammonia content in the experimental group was significantly lower than in winter by 1.59 ppm or 37.60% ($P < 0.05$).

It was found that using the classical type of ventilation in farrowing rooms, the hydrogen sulfide content did not differ significantly in winter and spring, but in winter it was higher than in summer by 0.82 ppm or 38.87% ($P < 0.001$), but lower than in autumn – by 0.35 ppm or 16.61% ($P < 0.001$). In the farrowing room where the geothermal ventilation system was used, the highest H_2S content was in the winter months, 3.59 ppm, which was 0.96 ppm or 26.81% ($P < 0.001$) higher than in spring, 0.83 ppm or 23.29% ($P < 0.001$) higher than in summer and 0.26 ppm or 7.44% ($P < 0.05$) higher than in autumn.

Discussion

The results of research confirm that in all seasons the supply and exhaust ventilation of uniform pressure provided the optimal temperature regime, but the concentration of carbon dioxide in all periods of the year, except summer, was higher than the maximum allowable (Ladyka *et al.*, 2020). It is known that exposure to carbon dioxide increases the incidence of stillbirths and abortions in pregnant sows (Huynh *et al.*, 2004). Other authors (Dubeňová *et al.*, 2013) have reported that CO_2 levels in the farrowing room ranged from 515.293 to 519.580 ppm. This did not coincide with our results, because with the use of valve ventilation, we had fluctuations in the level of CO_2 in the range of 800–2 300 ppm, and with the use of geothermal ventilation, CO_2 varied in the range of 1 200–2 000 ppm. However, our findings on carbon dioxide levels using geothermal ventilation are similar to results (Ostović *et al.*, 2009) on farrowing room CO_2 levels in spring 1 566.67 ppm and autumn 1 555.56 ppm.

The geothermal ventilation system provides more stable throughout the year indicators of temperature and humidity and the temperature of the lair of piglets and sows, compared with the valve ventilation. At the same time, it creates worse air pollution in the farrowing room (Mykhalko, Povod, 2020). We found like in our previous studies (Mykhalko, Povod, 2020), that geothermal ventilation maintains a more stable microclimate during all seasons of the year compared to valve-type ventilation.

The speed of air movement in the area of life of animals plays an important role in ensuring their comfortable growing conditions. Air mobility as a parameter of the microclimate refers to the factors that have a direct impact on the thermoregulation of piglets and sows and the gas composition of the air in the farrowing room (Demchuk *et al.*, 2009). Exposure to hydrogen sulfide reduces the average daily gain and average daily feed intake and increases the incidence of diarrhoea in piglets. Increasing the hydrogen sulfide content in farrowing rooms may increase the number and diversity of the intestinal microbiota (Cui *et al.*, 2021). Its adverse effects are also well known in humans, including irritation of mucous membranes, especially eyes, olfactory paralysis, sudden but reversible loss of consciousness, pulmonary oedema, death, and genotoxic effects of high doses (Szabo, 2018). Published studies indicate that higher temperatures in the pig housing and lower air velocities have led to a significant increase in H_2S concentration (Ni *et al.*, 2002). Other studies have reported (Demchuk *et al.*, 2009; Jo *et al.*, 2020) that air mobility has a significant effect on the pollution of the farrowing room. This was confirmed by the results of our current experiment, which found that the higher amplitude of fluctuations in air velocity in the farrowing room, the lower the content of harmful gases and vice versa.

Exposure to ammonia can cause pathological changes in many tissues and organs of pigs (Rong, Aarnink, 2019; Xia *et al.*, 2021). Levels of 50 to 100 ppm affect productivity, especially daily gain, which can be reduced by 10% over long periods of exposure. At 50 ppm and above, the clearance of bacteria from the lungs of piglets is also impaired, and therefore animals are more prone to respiratory diseases (Houghton, 2021). Concentrations of ammonia and hydrogen sulfide were higher in piggeries using self-flowing manure removal systems from lattice pits with lattice floors and conventional ventilation than in pig housing with other types of ventilation (Kim *et al.*, 2008; Forcada, Abecia, 2019). Ammonia concentration and ventilation rate showed a weak negative correlation ($r = –0.13$). Ammonia emissions were more affected by ammonia concentration ($r = 0.88$) than ventilation intensity ($r = 0.31$). This suggests that reducing ammonia concentrations by accelerating indoor air movement can effectively reduce ammonia emissions (Jo *et al.*, 2020). The results of our studies on ammonia content in farrowing facilities did not coincide with the findings (Kim *et al.*, 2008; Forcada, Abecia, 2019), which reported higher levels in valves with valvular ventilation. We found the opposite situation when the ammonia content was lower using the valve microclimate system and higher using the geothermal one.

The scientific article results (Saha *et al.*, 2014) showed the concentration of NH_3 in the farrowing room varies seasonally depending on the values of outdoor temperature. Significant correlations were found ($P < 0.001$) of NH_3 concentration with external seasonal climatic fluctuations, including the outdoor temperature, humidity, wind speed and direction, hour of the day and day of the year. We did not establish such relationships, however, we found seasonal fluctuations in the ammonia content and noted a decrease in the summer months and an increase in the winter and autumn months.

Conclusions of experiments (Krommweh *et al.*, 2014; Islam *et al.*, 2016; Mun *et al.*, 2021) showed that a geothermal microclimate system has the potential to reduce emissions of CO_2 and other harmful gases. But our results do not coincide with this opinion and showed that with the use of a geothermal microclimate system in the farrowing room, the content of CO_2 and other harmful gases was higher than during the use of a valve microclimate system all year round, especially in autumn.

Conclusion

Both valve-type ventilation and experimental geothermal ventilation provide microclimate parameters that meet the veterinary standards for keeping pigs in farrowing facilities. However, the use of valve-type ventilation did not ensure the normal temperature in the farrowing room and allowed it to exceed the norms in summer and autumn by 3.90 °C and 1.60 °C, respectively.

Geothermal ventilation provides a more stable air exchange by normalizing the temperature and air movement in the farrowing room and, accordingly, ensures a normal level of humidity during all seasons of the year. The valve ventilation system better removes polluted air from the farrowing room, minimizing the negative impact of harmful gases on the reproductive qualities of sows and the growth rate of piglets.

Conflict of interest

We declare that there is no conflict of interest with financial or other organizations and with any person regarding the material published in this manuscript.

Author contributions

PM – organized an experiment in the enterprise;
MO, MP – processed data, summarized them and interpreted the results;
MO, KO – assessed the current problems of the manuscript;
MO, TV – performed statistical data processing;
SV, OS, KH, OL – performed critical revision and approve the final manuscript.

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