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THE INFLUENCE OF THE VENTILATION SYSTEM IN THE ROOM FOR REARING PIGS AND THE TYPE OF FEEDING ON THE INDICATORS OF MICROCLIMATE AND PRODUCTIVITY OF PIGS

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Abstract

The article investigated the influence of systems for creating a microclimate with uniform pressure and geothermal negative pressure in combination with liquid and dry feeding systems on the parameters of the microclimatic environment in the piglet rearing room and the intensity of their growth. For this purpose, four groups of 150 pigs each were formed, two of which were kept with a uniform pressure ventilation system and two with negative pressure geothermal ventilation. For each ventilation system, one group was fed dry granulated compound feed, and two groups were fed liquid mixtures based on the same compound feed with an addition of 2.7 liters of water per kilogram of feed. The pigs were kept under the same conditions and were fed a diet that was equivalent in composition and nutritional value. Group I included piglets that received dry feed and were raised in a room with uniform pressure ventilation. The animals in the group II were kept in the same room, but consumed liquid feeds. Pigs in the III and IV groups were kept in rooms with geothermal ventilation. Piglets in the III group were fed dry feed, while piglets in the IV group were fed liquid feed. The results of the study showed that the ventilation system has an influence of 76.48% on relative humidity, 76.96% on ammonia content, 65.77% on carbon dioxide content and 65.07% on hydrogen sulfide content. The feeding system only affects the hydrogen sulfide content with a strength of 5.79%. Better microclimate parameters were provided by uniform pressure ventilation. Higher average daily gains, higher feed consumption, better feed conversion and lower cost per 1 kg gain were found in groups of pigs fed liquid feed and kept with geothermal ventilation.

***Key words**: pig rearing, feed conversion, microclimate, method of feeding, cost*

INTRODUCTION

The influence of microclimate on animals consists of a complex of factors of external environment: temperature, humidity, speed of air movement, chemical composition, microbial colonisation and dust load of air, lighting [11, 19].

The most important parameter of microclimate is the temperature of indoor air [1]. It has the greatest influence on the health status and productivity of animals [38]. The hygienic value of temperature is that it makes an impact on the thermoregulation of the body [39]. At the same time, temperature directly affects the relative humidity in the pig house [7]. The effects of relative humidity on animal health and productivity should be considered in close relation to temperature. An increase in the level of relative air humidity in the room leads to a slowing down of the evaporation of moisture droplets through the respiratory organs of animals, as the decrease in the partial pressure of water vapor balances with the value of the elasticity of water vapor on the surface of the mucous membranes of the nasopharynx and respiratory tract [9, 30]. In addition, humidity saturating indoor air alters its heat capacity and thermal conductivity, leading to the deposition of condensate and the development of pathogenic microflora [21]. High relative humidity (85% and higher) negatively affects and reduces heat transfer and thus feed consumption at both high and low ambient temperatures [32].

The hygienic value of humidity is that it affects the body of the animals both directly and indirectly [10]. Cold, moist air, which retains and conducts more heat, increases heat loss from the body (Renaudeau), lowers body temperature, forces excessive food intake and causes colds [41]. Humid air at high temperatures inhibits heat transfer due to reduced evaporation of sweat from the body surface, resulting in overheating of the body, deterioration of appetite [20] and reduced productivity [26]. The indirect effect of humidity on animal organisms is determined by an increase in the accumulation of harmful gases [35], microorganisms in the air [4, 37], a decrease in the heat-shielding properties of the external enclosures of the room [6], corrosion of metal equipment [16], deterioration of feed preservation, quality products [40].

A change in relative humidity from 70 to 95% leads to an increase in mortality in pigs from 0.05 to 17.5%. High indoor relative humidity reduces the digestibility of nutrients. The average daily gain of rearing pigs is 653 g at 85% relative humidity and at 91.8% – only 553 g [14]. The unsatisfactory condition of the microclimate of livestock premises leads to a decrease in productivity by up to 15% with a simultaneous increase in feed costs by 10–15% [7]. Excessive feed expenditures to support heat exchange processes at low temperatures and high humidity lead to a decline in pig farming efficiency, especially on farms with small herds. And the survival rate of suckling piglets increases by 10.6% when normal humidity is maintained [27]. In contrast, however, other authors report no effect of relative humidity on average daily gains or feed intake of pigs [22].

Here, the humidity depends not only on the indoor and outdoor temperature, the external relative humidity of the environment [28], but also on the available sources of moisture in the centre of the room for keeping pigs. An additional increase in humidity occurs from the pigs' respiration and evaporation from their bodies [8], as well as evaporation from the surface of the manure in the pits [25], from the transport systems, feed distribution and watering [34]. Relative humidity, the type of feeding and the composition of the ration also affect the gas composition of the internal environment, which is related to the functioning of the pigs' organisms and the release of gases [3, 13, 42].

Both dry and liquid feeding of pigs are widely used in industrial pig farms. Each feeding method has its advantages and disadvantages that can increase or decrease the overall productivity of pigs [23]. Liquid feeding usually uses the same feedstuffs as dry feeding, but with additional hydration or fermentation of the ration ingredients [29]. Liquid feed can be easier to digest and provide a wide range of nutrients. As a result, pigs fed liquid feed mixtures may have a higher growth rate in both the growing and fattening phases [24]. Liquid feeds tend to be more palatable, resulting in higher consumption compared to dry feeds. Pigs generally absorb feeds with a liquid preparation method better, resulting in higher consumption compared to dry feeding methods [18]. However, feeding with liquid feed increases the humidity in the room. Liquid feed mixtures are a source of additional humidity, either directly through the evaporation of water from feeders and feed pipes [17] or indirectly - through the evaporation of moisture from the slurry pits and the floor [25], as the use of liquid feed often leads to a more liquid slurry content in pigs [12]. Liquid power systems of older designs, equipped with pumps with low efficiency and have a large number of bends in transport pipelines require excessive hydration in water-to-feed ratios to reduce the viscosity of mixtures. This results in reduced pig growth and poor feed conversion due to reduced feed intake, which is limited by the pig's intake capacity, and the energy expended to release excess water [36]. In addition, the use of a liquid feeding system leads to increased manure production and therefore higher costs for fumigation and transport and storage of slurry due to the diluted nutrient content [2, 33].

The use of liquid feeding, which is becoming more widespread among pig producers, may therefore have certain advantages for increasing the efficiency of pig farming, but also for meeting hygienic requirements in terms of microclimate indicators, especially the level of relative humidity in the room. Therefore, the study of the interrelation between the relative humidity in the room for keeping pigs and the type of feeding is important.

The aim of our work was to investigate how liquid and dry feeding of pigs affects the level of relative humidity in the housing space and to investigate the dependence of indicators of pig productivity on the feeding method and indicators of microclimate in the pig complex.

MATERIALS AND METHODS

Piglets from half-breed sows of the landrace and the large white English breed as well as from boars of the synthetic terminal line PIC 337 were used for the study.

The aim of the study was to investigate the productive characteristics and efficiency of piglet rearing under the conditions of different systems for creating a microclimate and different systems for preparation, transportation, distribution and supply of feed. For this purpose, four piglet groups of 1,200 animals each were formed in the commercial breeder of LLC "NVP "Globinsky Pig Complex" in Kremenchutsk district of Poltava region. After the suckling period, the piglets were weaned from the sows, weighed and sent for rearing. During rearing, four groups of pigs were formed according to the scheme of the experiment (Table 1).

Two control pens were set up in each individual group to weigh the animals. Individual weighing of the animals was carried out in these pens on the day of their entry into the experiment and at the changeover to a new feed ration on the 41st day of life and after completion of rearing on the 70th day of life.

The piglets of all experimental groups were kept under identical conditions, each group being housed in a pen with an area of 51 m^2, with 0.33 m^2 per piglet, while each animal had a warm floor of 0.1 m^2 at its disposal. The excrements were cleaned using a vacuum-gravity system, with faeces removed from the underground troughs twice during the growing period. To ensure free access to water, height-adjustable nipple pumps and cup pumps were used, which were located at a height of 20 cm above the slatted floor.

Table 1. Scheme of research

Indicator	**Uniform pressure ventilation**		**Geothermal ventilation of negative pressure**	
Feeding system	Spotmix II	Spotmix II	Tube-O-Mat	HydroMix
Method of feeding piglets	Dry	Liquid	Dry	Liquid
Number of piglets per pen, head	150	150	150	150
The average age of piglets at the time of placement for rearing, days	21	21	21	21
Average age of piglets when transferred to fattening, days	70	70	70	70

Source: own calculations.

The animals were fed a complete ration of granulated feed. From the day of weaning and until the piglets reached an average weight of 9 kg, they were given pre-starter pelleted feed, which was also used during the weaning phase. They were then switched to the cheaper pre-starter feed, which was used until the piglets reached a weight of 12 kg. After that, they were transferred to feed with starter feed produced at the Globino feed plant until the end of rearing on day 70 (Table 2).

Table 2. Nutrient content in the diet of growing pigs

Indicator	**Units of measurement**	**Prestarter up to 9 kg**	**Prestarter 9-12 kg**	**Starter up to 70 kg**
Exchange Energy	mJ	13.89	13.58	13.25
Raw protein	%	20.5	18.99	18.32
Crude fiber	%	2.6	3.2	4.4
Raw Fat	%	1.8	3.36	3.4
Lactose	%	8.405	–	–
Lysine	%	1.6	1.15	1.03
Methionine	%	0.45	0.36	0.32
Methionine cyst.	%	0.8	0.68	0.64
Threonine	%	1.1	0.776	0.69
Calcium	%	0.65	0.82	0.84
Phosphorus	%	0.5	0.53	0.47
Sodium Na	%	0.15	0.24	0.24
Chlorine Cl	%	0.3	0.39	0,39
Magnesium	%	0.16	0.18	0.20
Potassium	%	0.95	0.86	0.80
Vitamin A	M.O.	17,452.94	12,975.35	12,935.32
Vitamin D	M.O.	3,452.92	2,331.28	2,328.73
Vitamin E	mg/kg	51.58	41.73	42.4
Vitamin B_1	mg/kg	7.64	5.46	5.39
Vitamin B_2	mg/kg	14.98	8.32	8.32
Vitamin B_6	mg/kg	10.97	9.73	10.19
Vitamin B_{12}	µg/kg	57.18	34.98	34.93
Vitamin K	mg/kg	1.73	1.17	1.16
Iron	mg/kg	182	180	180
Manganese	mg/kg	89	86	86
Zinc	mg/kg	126	115	115
Copper	mg/kg	24	24	24
Iodine	mg/kg	0.38	0.38	0.38
Cobalt	µg/kg	870	350	350
Selenium	mg/kg	0.55	0.50	0.50

Source: own calculations.

It is important to note that the difference between the control and experimental groups was the use of different systems for creating a microclimate and methods for preparing, feeding and distributing feed to the piglets. Feed accounting was done using the portion feeding control processor and duplicated in the primary documentation. In addition, leftover feed was checked daily, and if present, it was weighed and subtracted from the total amount of feed eaten.

The pigs of the 1st and 2nd groups were kept in the rearing room of the rearing farm No. 3, which was equipped with a system for generating uniform pressure ventilation from the Big Dutchman company (Demydivka village, Kremenchuk district, Poltava region). Within the framework of this microclimate support system, the intake of outdoor air was carried out through intake shafts D 630 (Photo 1, Fig. 1, pos. 1), located in the central part of the gable roof of the building, and the discharge through exhaust shafts D 630 (cross-sectional area S=0.30 m^2, Ukraine) (Photo 1, Fig. 1, item 3) in the number of 22 shafts, located in the ridge part of the roof and equipped with three-phase exhaust fans Ø 63 cm Deltafan Lat (Poland).

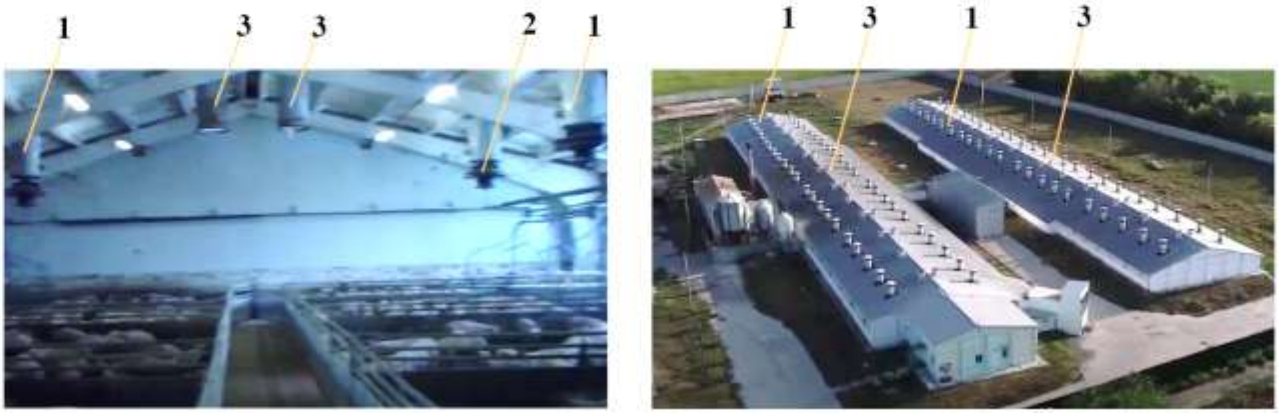

Photo 1. General view of the farm for raising pigs using the uniform pressure microclimate system of pig complex No. 3 (Demydivka village)
Note: 1 – tidal shaft; 2 – humidification and air system; 3 – exhaust shaft.
Source: processed photo of LLC "Globinsky Pig Complex"

The premises were heated with water-heated floors in the cold season. Additional cooling of the interior of the pig complex was provided by forced humidification of the air (Photo 1, Fig. 1, item 2).

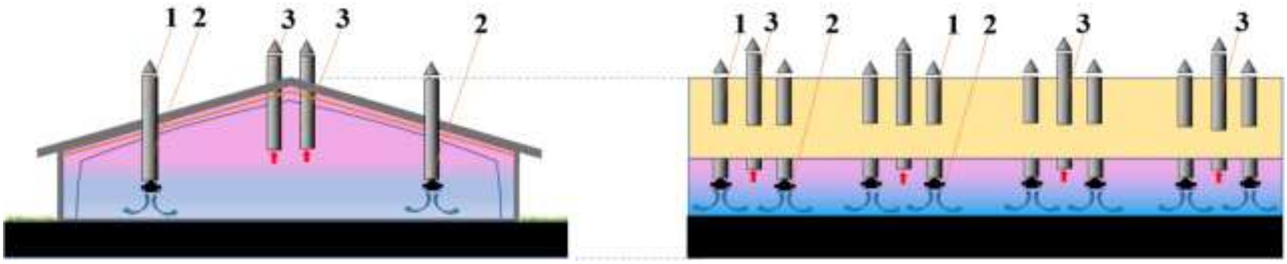

Fig. 1. Scheme of air movement of the system for creating a microclimate of uniform pressure in pig complex No. 3 (Demydivka village)
Note: 1 – tidal shaft; 2 – humidification and air system; 3 – exhaust shaft.
Source: Own determination.

Pigs of the first control group were fed using the Spotmix II system of the Austrian company Schauer (Photo 2). This system made it possible to feed animals with dry fodder. Transportation of feed mixtures to the feeders was carried out through the pipeline with the help of compressed air and a system of revolving connections in dry form.

Photo 2. Spotmix II feeding system (Schauer) for the preparation of dry fodder for pig complex No. 3 (Demydivka village)
Source: processed photo of LLC "Globinsky Pig Complex".

Piglets in the II group were fed the same Spotmix II feeding system from the Austrian company Schauer (Photo 3), which was configured to prepare liquid feed. Dry feed was also added to the feeder in this group, where it was moistened with water via high-pressure nozzles. A portion of dry feed with a moisture content of 14% contained 2.7 liters of water.

The feeding front of piglets in these groups was 15 cm per head. The feed was distributed 12 times a day. If there was uneaten feed in the feeders, the feeder filling sensor was activated and the system skipped the next feed distribution to these feeders.

Photo 3. Spotmix II feeding system (Schauer) for the preparation of liquid feed for pig complex No. 3 (Demydivka village)
Source: processed photo of LLC “Globinsky Pig Complex”.

Pigs of experimental groups III and IV were kept during rearing in pig farms No. 2 (Babichivka village, Kremenchug district, Poltava region) and No. 4 (Obiznivka village, Kremenchug district, Poltava region), which had buildings typical for all rearing farms and were equipped with the same negative pressure type geothermal ventilation systems of the negative pressure type. Outside air entered the premises for keeping animals through an intake shaft (Photo 4, Fig. 2, pos. 1, 3) placed outside on the ground surface near the supporting wall of the building. Through the air duct buried in the ground (Fig. 6, pos. 5), the air entered the underfloor ducts (Fig. 2, pos. 4) located in the piglets' living area, where it spread through the perforated floor (Fig. 2, pos. 2) into the interior of the pigsty. Exhaust air was discharged by means of under-ceiling exhaust air shafts D910 (cross-sectional area S=0.66 m^2, Ukraine) (Photo 4, item 1 and Fig. 2, item 3) in the number of 16 shafts per room, equipped with Deltafan three-phase fans Ø 91 cm (Poland). Thanks to the movement of underground ducts and subfloor buried channels, the outside air was cooled in the summer and additionally heated in the winter.

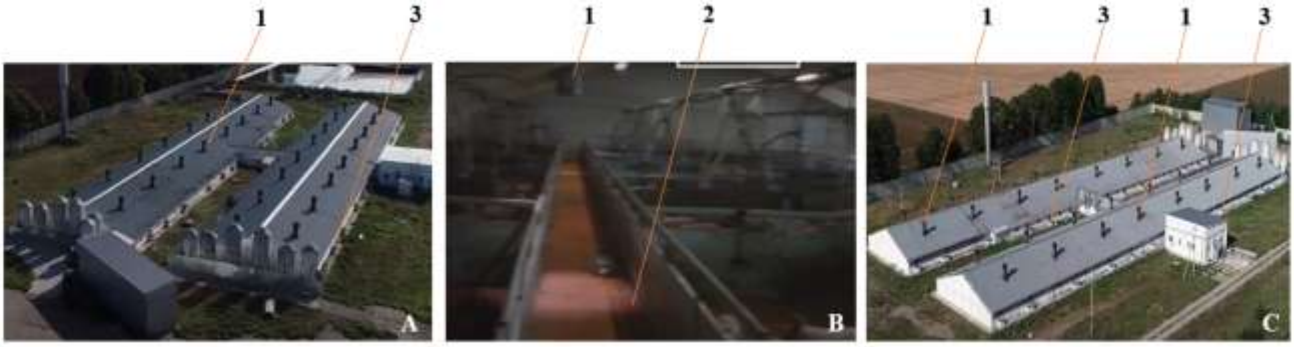

Photo 4. General view of farms for raising pigs using the microclimate system of geothermal type pig complex No. 4 (Obiznivka village) and pig complex No. 2 (Babichivka village)
Note: 1 – exhaust shaft; 2 – perforated floor; 3 – tidal mine, A – pig complex No. 4 (Obiznivka village), B – general view of the room for rearing, C – pig complex No. 2 (Babichivka village)
Source: processed photo of LLC “Globinsky Pig Complex”

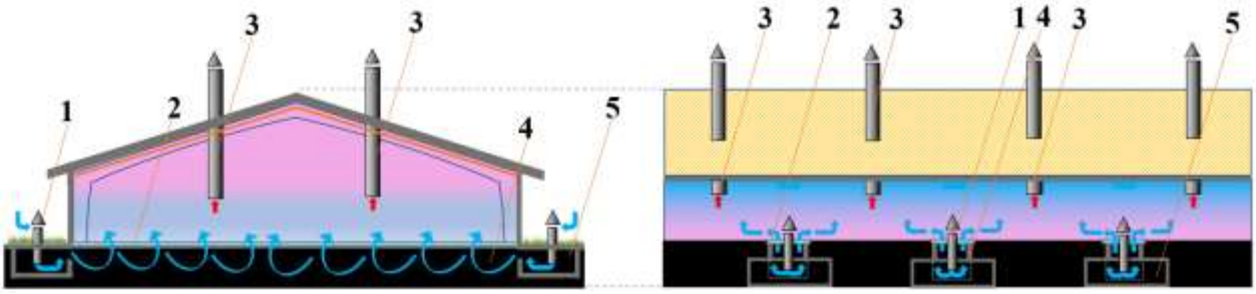

Fig. 2. Scheme of air movement of the geothermal system for creating a microclimate of pig complex No. 4 (Obiznivka village) and pig complex No. 2 (Babichivka village)
1 – tidal shaft; 2 – perforated floor; 3 – exhaust shaft; 4 – underfloor channel; 5 – underground duct
Source: Own determination.

Piglets of the group III were fed in pig farm No. 2 (Babichivka village, Kremenchug district, Poltava region) with Tube-O-Mat automatic feeders of the Danish manufacturer Master Trading (Photo 5). The feeding front was 2.5 cm per animal. Each feeder was equipped with two feed spreaders, with the help of which the piglets moistened the dry feed in the troughs of the feeders to the desired moisture level. During the first week after being housed in the rearing group, the piglets were fed from a floor mat in the pen. The feed was accounted for automatically using sensors on the torsion scales of the storage hoppers. Stainless steel nipple drinkers are located on the sides of the feeder. There are wells for water in the drinker. Water is supplied from the central water supply to the automatic feeder via hoses.

Photo 5. Tube-O-Mat feeding system (Master Trading) for the preparation of dry fodder for pig complex No. 2 (Babichivka village)
Source: processed photo of LLC “Globinsky Pig Complex”.

For feeding the pigs of the research group IV of the pig complex No. 4 (Obiznivka village, Kremenchuk district, Poltava region), the HydroMix feeding system of the Big Dutchman company with residue-free feed distribution and pipe flushing was used (Photo 6). In this system, two small tanks serve simultaneously as mixing and dispensing tanks. For this purpose, the total required feed quantity is divided into several small portions. While the feed is mixed in one container, the contents of the second container are dispensed simultaneously. At the beginning of feed distribution, the computer sets the required amount of the main mixture for each valve for further distribution to each individual pen with piglets. Cup and teat valves with a teething ball were used for piglet feeding to reduce water loss.

The measurement of microclimatic parameters included the determination of the internal temperature in the living area of the piglets, relative humidity, ammonia, hydrogen sulfide and carbon dioxide content.

The determination of microclimatic indicators was performed twice a week (every Tuesday and every Friday) during the experiment for each group.

Photo 6. HydroMix (Big Dutchman) feeding system for the preparation of liquid fodder for pig complex No. 4 (Obiznivka village)
Source: processed photo of LLC “Globinsky Pig Complex”.

The soil temperature in each of the pen was determined at seven points using a Testo 805 pyrometer (measuring range: -25...+250 °C, accuracy: ±1 °C (-2...+40 °C), Germany). The velocity of air movement and its temperature were measured with a Testo 425 m thermal anemometer (measuring range: 0...30 m/s, accuracy: ±0.03 m/s (0...20 m/s), Germany). The content of ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) in the air was determined using the DOZOR-CM4 gas analyzer (Ukraine). The measurement ranges and measurement errors of the "DOZOR-CM4" were as follows: for carbon dioxide measurement range: 0–10,000 ppm, accuracy: ±2.500 ppm; for ammonia measurement range: 0–28.18 ppm, accuracy: ±7.05 ppm; for hydrogen sulfide measurement range: 0–21.12 ppm, accuracy: ±3.52 ppm). The value of relative humidity was determined using a Testo 605 thermohygrometer (measuring range: 5–95% RH, accuracy: ±3.0% RH, Germany).

Both ventilation systems were controlled by the same microclimate control modules 307PRO L15CE6 (Denmark).

Information about changes in microclimate parameters in the room was received by the control module from the connected temperature sensors DOL 12 (measuring range –10…+40 ° C, accuracy: ±0.5 °C, Denmark), relative humidity sensor DOL 114 (measuring range 17–100% RH, accuracy: ±3% RH (10–95%), Ukraine), vacuum sensor DOL 18 (measuring range 6.89–68.9 KPA, accuracy: 0.5" (100 Pa), Denmark), CO_2 sensor DOL 19 (measuring range 0–10,000 ppm, output signal 0–10V/4–20mA, Denmark), NH_3 sensor DOL 53 (measuring range 0–100 ppm, output signal 0–10V, Ukraine). The information on the parameters of external climatic conditions comes from meteorological stations located on the territory of the pig complex.

The volume velocity of air movement through an exhaust shaft was measured using the following formula:

$$Q = V*S \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where:
Q is the volume flow rate in m^3/s;
V is the flow velocity in the cross-section in m/s (measured with a Testo 425 m thermal anemometer);
S is the cross-sectional area of the exhaust shaft, m^2.

The cross-sectional area of the exhaust shaft is determined by the following formula:

$$S = \pi r^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where:
$\pi = 3.14;$
r is the radius of the circle, where:

$$r=D/2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where:
D is the cross-sectional diameter of the exhaust shaft.

The volume velocity of air movement for the entire space was determined by multiplying the volume velocity of air movement for one exhaust shaft by the number of exhaust shafts.

Statistical processing of the experimental data was performed using biometric methods in the Microsoft Excel environment. The difference between the mean values of the measured and calculated values was considered statistically significant at the first threshold of $p<0.05$, at the second threshold of $p<0.01$, and at the third threshold of $p<0.001$ using Student's t-test. The applied method of two-factor analysis of variance was also calculated using Microsoft Excel. The rules for the treatment of animals in our experiments corresponded to the current legislation on the protection of animals from suffering and pain, namely the EU Directive "On the protection of farm animals" of the Council of the EU Directive 2010/63/EU [5]. The Commission for Bioethics and Treatment of Animals in Scientific Experiments of the Sumy National Agrarian University granted ethical permission (No. BT-23-02/02-01).

RESULTS AND DISCUSSIONS

The study of the difference of microclimate indicators in a room for pig farming with uniform pressure ventilation allowed to detect a higher internal temperature when dry compound feed was used in comparison with rooms where a liquid type of feeding was used, by 1.0 °C or 4.8% ($p<0.05$). At the same time, the internal temperature in a room with geothermal ventilation was 1.5 °C or 7.6% higher than in the experimental room when dry feed was used ($p<0.05$).

The comparison of indoor temperature in dry feeding between two types of microclimate systems showed that their values were 0.8 °C or 3.9% higher in rooms with uniform pressure ventilation than in rooms with geothermal ventilation ($p<0.05$). In the case of liquid feeding, the study of the values of indoor temperature showed that their values in the rooms with geothermal ventilation were higher than in the rooms with uniform pressure ventilation, by 1.7 °C or 8%. With the liquid method of feeding, the study of the values of the internal temperature showed that its values were higher in the room with the geothermal type of ventilation than in the room with the uniform pressure type of ventilation by 1.7 °C or 8.0% ($p<0.05$).

Table 3. Indicators of the microclimate in the room for keeping pigs depending on the method of their feeding, n = 14

Indicator	**Uniform pressure ventilation**		**Geothermal ventilation of negative pressure**	
	Dry feeding method	**Liquid feeding method**	**Dry feeding method**	**Liquid feeding method**
Internal temperature °C	20.5 ± 0.18^{bA}	19.5 ± 0.44^{aA}	21.2 ± 0.50^{bB}	19.7 ± 0.28^{aA}
Relative humidity % vol	69.8 ± 1.59^{aA}	74.1 ± 1.23^{bA}	71.3 ± 1.91^{aB}	74.3 ± 0.99^{aA}
Air velocity m/s	0.13 ± 0.020^{aA}	0.14 ± 0.021^{aA}	0.07 ± 0.019^{aB}	0.08 ± 0.017^{aB}
Volumetric velocity of air movement for one shaft m^3/s	0.039 ± 0.0291^{aA}	0.042 ± 0.0325^{aA}	0.046 ± 0.0294^{aA}	0.052 ± 0.0441^{aA}
Volumetric velocity of air movement for the entire room m^3/s speed	0.858 ± 0.0541^{aA}	0.924 ± 0.0622^{aA}	0.736 ± 0.0436^{aA}	0.832 ± 0.0511^{aA}
Ammonia (NH_3) content, mg/m^3	13.5 ± 1.20^{aA}	12.9 ± 1.01^{aA}	13.0 ± 1.43^{aA}	12.4 ± 0.97^{aA}
Carbon dioxide (CO_2) content, % vol	0.3 ± 0.02^{bB}	0.2 ± 0.02^{aA}	0.2 ± 0.01^{aA}	0.3 ± 0.02^{bB}
Hydrogen sulfide (H_2S) content, mg/m^3	3.1 ± 0.27^{bB}	2.1 ± 0.14^{aA}	2.2 ± 0.14^{aA}	2.3 ± 0.16^{aA}

aa – there is no significant difference between indicators for different feeding systems and the same ventilation system ($p>0.05$); ab – there is a significant difference between indicators for different feeding systems and the same ventilation system ($p<0.05$); AA – there is no significant difference between indicators for the same feeding systems and different ventilation systems ($p>0.05$); AA – there is a significant difference between the indicators for the same feeding systems and different ventilation systems ($p<0.05$).
Source: own calculations.

The value of relative humidity in the room with the type of ventilation of equal pressure when using the liquid feeding method was 8.3% vol and 12.6% higher, respectively, compared to the group in which dry feed mixtures were used ($p<0.001$). At the same time, no difference in relative humidity was observed in a room equipped with a geothermal system to support the microclimate.

Relative humidity during dry feeding was not the same in the rooms with both types of ventilation. In particular, in the groups where liquid pig feeding was used, the relative humidity in the room with the geothermal pressure microclimate system was 5.5% vol or 8.3% ($p<0.05$) higher than in the room with uniform pressure ventilation. At the same time, the relative humidity indicator for a liquid feeding system was the same among the different systems for creating a microclimate.

Air movement velocity was 0.06 m/s or 46.1% higher in the room with uniform pressure ventilation and dry feeding than in the room with geothermal ventilation and dry feeding ($p<0.05$). Similarly, the air movement velocity in the room with uniform pressure ventilation and liquid feeding was 0.06 m/s or 42.8% higher than the air velocity in buildings where negative pressure ventilation with underground outdoor air supply and liquid feeding of breeding pigs was used ($p<0.05$).

The gas composition assessment showed that the ammonia content was the same for both the uniform pressurised ventilation system and the geothermal system when dry and liquid feeding methods were used.

The higher content of carbon dioxide by 0.1% vol or 33.3% ($p<0.01$) was for the dry method of feeding in the room with classical ventilation and for the liquid method of feeding in the room with the liquid method of feeding by 0.1% vol or 50.0% ($p<0.001$). With dry feeding, the CO_2 content was higher in the room with uniform pressure ventilation by 0.1% vol or 33.3% ($p<0.001$). In the liquid feeding system, the carbon dioxide content was higher than in the geothermal microclimate creation system by 0.1% vol or 33.3% ($p<0.01$).

The higher content of hydrogen sulfide was found in the room with uniform pressure ventilation when using dry fodder by 1.0 mg/m^3 or 32.2% ($p<0.01$). Whereas in rooms with a geothermal ventilation system, the H_2S content did not differ. The content of hydrogen sulfide when using dry fodder mixtures was higher in the room with a system for creating a microclimate of uniform pressure by 0.9 mg/m^3 or 29.0% ($p<0.01$).

Two-factor variance analysis of the data made it possible to state that both the method of feeding and the type of ventilation had an effect on the indicators of the microclimate, except for the temperature in the room (Fig. 9, Table 4).

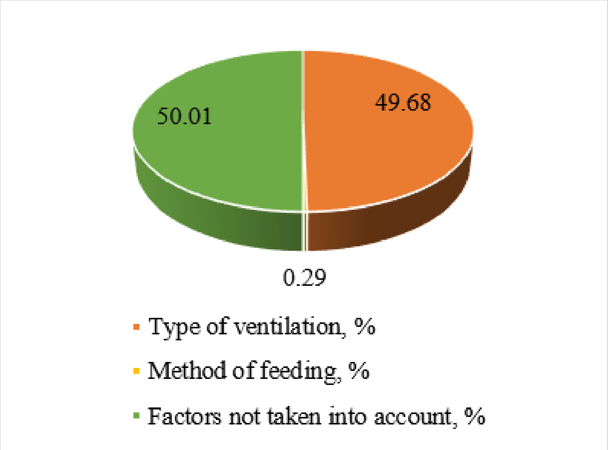

Fig. 9. Two-factor variance analysis of the influence of the method of feeding and the ventilation system on the temperature in the room, %
Source: own calculations.

Table 4. The influence of the method of feeding and the ventilation system on the temperature in the room, %

Source of Variation	SS	df	MS	F	P-value	F crit
Ventilation system	80.24	28	2.86	0.99	0.50	1.88
Method of feeding	0.47	1	0.47	0.16	0.68	4.19
Error	80.78	28	2.88			
Total	161.5	57				

Source: own calculations.

In contrast to the factor of the method of feeding pigs, the type of ventilation system influenced the indicator of relative humidity with a strength of 76.4% ($p<0.001$) (Fig. 10, Table 5).

Ammonia content had no significant dependence on the feeding method, however, the type of ventilation influenced its content in the air of the pig house with a strength of 76.9% (p<0.001) (Fig. 11, Table 6).

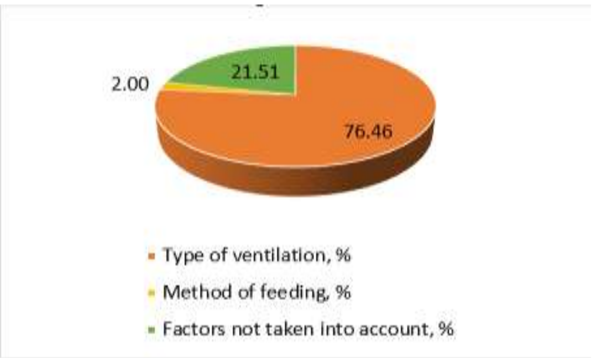

Fig. 10. Two-factor variance analysis of the effect of feeding method and ventilation system on relative humidity, kg
Source: own calculations.

Table 5. Influence of feeding method and ventilation system on relative humidity, kg

Source of Variation	SS	df	MS	F	P-value	F crit
Ventilation system	2,701.25	29	93.14	3.55	0.0005	1.86
Method of feeding	70.88	1	70.88	2.70	0.11	4.18
Error	759.81	29	26.20			
Total	3,531.95	59				

Source: own calculations.

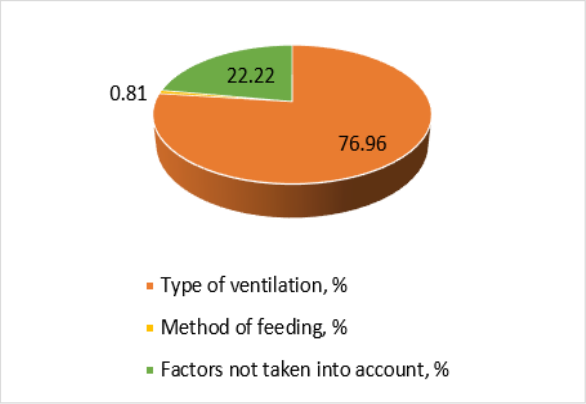

Fig. 11. Two-factor variance analysis of the influence of the feeding method and the ventilation system on the ammonia content, %
Source: own calculations.

Also, the type of ventilation had an effect on the content of carbon dioxide with a strength of 65.7% (p<0.05) (Fig. 12, Table 7). The level of carbon dioxide did not depend on the method of feeding.

Table 6. Influence of feeding method and ventilation system on ammonia content, %

Source of Variation	SS	df	MS	F	P-value	F crit
Ventilation system	1,318.65	29	45.47	3.46	0.0006	1.86
Method of feeding	13.88	1	13.88	1.05	0.31	4.18
Error	380.71	29	13.12			
Total	1,713.25	59				

Source: own calculations.

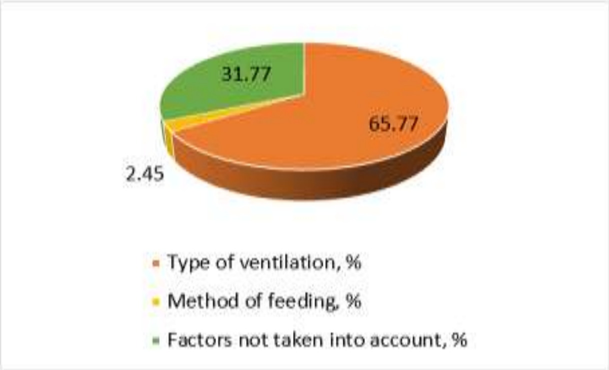

Fig. 12. Two-factor variance analysis of the influence of the method of feeding and the ventilation system on the content of carbon monoxide, %

Table 7. Influence of feeding method and ventilation system on ammonia content, %

Source of Variation	SS	df	MS	F	P-value	F crit
Ventilation system	0.24	29	0.008	2.07	0.02	1.86
Method of feeding	0.009	1	0.009	2.24	0.14	4.18
Error	0.11	29	0.004			
Total	0.37	59				

Source: own calculations.

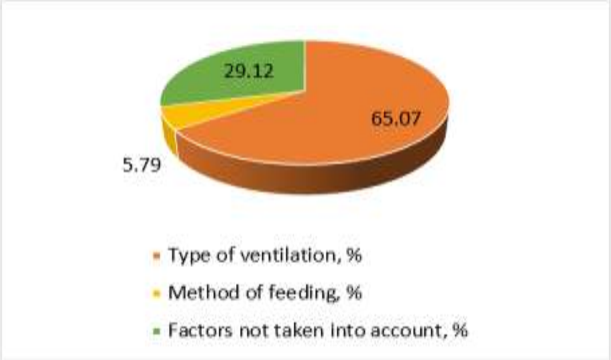

Fig. 13. Two-factor variance analysis of the influence of the feeding method and the ventilation system on the content of hydrogen sulfide, %
Source: own calculations.

The level of hydrogen sulphide probably depended on both the type of microclimate system by 65.0% (p<0.05) and the feeding method by 5.7% (p<0.05) (Fig. 13, Table 8).

Table 8. Influence of feeding method and ventilation system on hydrogen sulfide content, %

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Ventilation system	33.77	29	1.16	2.23	0.01	1.86
Method of feeding	3.00	1	3.00	5.76	0.02	4.18
Error	15.11	29	0.52			
Total	51.89	59				

Source: own calculations.

The study of piglet performance indicators showed that piglets had a higher weight at the end of their rearing with both types of ventilation when a liquid feeding method was used. Indeed, the higher weight of piglets at transfer to fattening in rooms with uniform pressure ventilation was 1.8 kg or 7.3% higher for piglets eating liquid feed compared to those eating dry feed mixtures by 1.8 kg or 7.3% (p<0.001). There was a similar advantage of 0.9 kg or 3.3% (p<0.05) for animals eating liquid feed compared to peers eating dry feed when geothermal ventilation of the room was used (Table 9).

At the same time, a comparison of the weight of piglets at the transition to fattening in animals fed dry feed but kept under different systems for creating a microclimate showed that their value was 2.8 kg or 11.4% higher when geothermal ventilation was used (p<0.001). Piglets that consumed liquid feed and were kept in rooms with different microclimates had a weight 1.9 kg or 7.2% higher at the end of rearing than piglets kept in a room with underground preparation and air supply to their habitat (p<0.001).

In a room with uniform pressure ventilation, the absolute growth rate of piglets raised on a liquid feeding system was 1.8 kg or 9.7% higher than piglets fed dry feed (p<0.001). At the same time, in the pig house where the geothermal ventilation system was in operation, absolute gains were observed to be 0.9 kg or 4.2% higher in piglets fed liquid feed (p<0.05). Raising pigs with dry feeding in a room with uniform pressure ventilation resulted in a lower indicator of piglet weight at the transition to fattening compared to the values in the housing with geothermal ventilation by 2.9 kg and 15.7%, respectively (p<0.001).

Absolute growth of liquid-fed pigs proved to be 2.0 kg or 9.9% better under geothermal ventilation than peers whose growth occurred under uniform pressure ventilation (p<0.001).

Based on the evaluation of average daily gains, it was found that pigs fed liquid feed grew 36.7 g or 9.7% better than those fed dry feed under uniform pressure ventilation (p<0.001). Examination of the effect of type of ventilation on piglet growth intensity revealed that animals fed dry feed in a pig house with geothermal ventilation gained 59.1 g or 15.7% more compared to their peers with uniform pressure ventilation (p<0.01). Pigs on liquid feed had higher average daily gains when housed under geothermal ventilation, by 40.8 g or 9.9% (p<0.05). The evaluation of feed consumption showed higher feed consumption when pigs were fed liquid in both a room with uniform pressurised ventilation and with geothermal ventilation.

Specifically, in rooms with ventilation of uniform pressure, liquid feeding consumed 2.7 kg more feed per piglet during the rearing period than dry feeding. In the groups where geothermal ventilation was installed, feed consumption per piglet was also 0.8 kg higher with liquid feeding than in the groups receiving dry feed mixes (Table 10).

When comparing feed consumption per piglet in dry feeding but different microclimate systems, 3.7 kg higher values for this indicator were found in animals kept in a room with a geothermal ventilation system. Liquid feeding pigs also showed 1.8 kg higher values of the indicator of feed consumption per piglet during the period in pigs raised in systems creating a geothermal-type microclimate.

It should be noted that the average daily feed intake also increased when liquid feed was used in microclimate systems of both types. In rooms with uniform pressure ventilation, piglets fed liquid feed consumed 0.05 kg more feed than their counterparts fed dry feed. The average daily feed consumption was also higher for piglets fed liquid feed than for piglets fed dry feed mixes in a room with geothermal ventilation. With geothermal ventilation, the average daily feed consumption was 0.07 kg higher for both dry feed and liquid feed. It was found that feed conversion was 0.04 kg worse when pigs were fed dry feed compared to feeding liquid feed under uniform pressure ventilation and 0.03 kg worse under geothermal ventilation. In dry feeding, feed conversion was 0.08 kg higher in animals using a uniform pressure ventilation system. Similarly, feed conversion was higher in the group using liquid feeding, where it was higher in the room with uniform pressure ventilation.

Table 9. Performance indicators of pigs in rearing with dry and liquid methods of feeding and different systems of room ventilation

Indicator	Uniform pressure ventilation		Geothermal ventilation of negative pressure	
	Liquid feeding method	Dry feeding method	Liquid feeding method	Dry feeding method
The weight of the piglets when they are placed for rearing, kg	6.1 ± 0.08^{aA}	6.1 ± 0.12^{aA}	6.0 ± 0.11^{aA}	6.0 ± 0.09^{aA}
Age of piglets when placed for rearing, days	20.7	20.7	20.5	20.7
Weight of piglets when transferred to fattening, kg	24.5 ± 0.29^{aA}	26.3 ± 0.32^{bA}	27.3 ± 0.28^{aB}	28.2 ± 0.31^{bB}
Age of piglets when transferred to fattening, days	70.4	70.4	70.2	70.2
Absolute growth, kg	18.4 ± 0.26^{aA}	20.2 ± 0.24^{bB}	21.3 ± 0.30^{aA}	22.2 ± 0.28^{bB}
Average daily increments, g	$375.5\ \pm10.2^{aA}$	$412.2\ \pm13.5^{bA}$	434.6 ± 12.2^{B}	453.0 ± 12.9^{B}
Preservation of piglets, %	98.3	97.8	97.5	97.7

aa – there is no significant difference between indicators for different feeding systems and the same ventilation system ($p>0.05$); ab – there is a significant difference between indicators for different feeding systems and the same ventilation system ($p<0.05$); AA – there is no significant difference between indicators for the same feeding systems and different ventilation systems ($p>0.05$); AA – there is a significant difference between the indicators for the same feeding systems and different ventilation systems ($p<0.05$).
Source: own calculations.

The feed cost for raising one animal was 1.24 EUR higher for liquid feeding than for uniform pressure ventilation and 0.36 EUR higher for negative pressure ventilation with underground supply of outside air. In rooms with a geothermal microclimate, the feed costs for rearing a piglet were 1.68 EUR and 0.18 EUR higher for both dry feeding and liquid feeding.

However, the feed cost per 1 kg of growth was higher by 0.017 EUR in piglets fed dry feed in the group where uniform pressure ventilation was functioning and by 0.012 EUR in the group where geothermal ventilation was installed, compared to peers fed liquid feed in both microclimate systems.

When geothermal ventilation was used in the premises, the feed cost for 1 kg of growth was lower than for both feeding systems, by 0.035 EUR – when dry feed was used and by 0.030 EUR – when liquid feed was used.

We can state that our conclusions regarding the increase in the preservation of piglets when the humidity in the room is reduced are in agreement with the reports of other authors [27], but only for the pig complex where the system was used to create a microclimate with uniform pressure.

However, it should be noted that our results agree with the reports [3, 13, 17, 31, 34, 42] on the influence of the feeding method on the humidity index in the room for rearing pigs. In our experiment, this indicator changed with a dry feeding method, when we compared rooms with different ventilation and using a system for creating a microclimate with uniform pressure, the influence of the feeding method on this indicator was found. However, when using a geothermal ventilation system, the relative humidity did not depend on the feeding method.

Table 10. Average daily consumption and consumption of feed for different feeding systems of piglets

Indicator	**Uniform pressure ventilation**		**Geothermal ventilation of negative pressure**	
	Dry feeding method	**Liquid feeding method**	**Dry feeding method**	**Liquid feeding method**
Absolute growth, kg	18.14	20.20	21.3	22.2
Spent fodder per head, kg	31.20	33.94	34.93	35.74
Average daily feed consumption, kg	0.63	0.68	0.70	0.72
Feed conversion, kg	1.72	1.68	1.64	1.61
The average price of 1 kg of compound feed, EUR	0.45	0.45	0.45	0.45
Fodder cost of growing 1 head, EUR	14.12	15.35	15.81	16.17
Feed cost of 1 kg of gain, EUR	0.77	0.76	0.74	0.72

Source: own calculations.

As in previous publications, we demonstrated in this experiment that the type of feeding affects the intensity of growth of piglets. In particular, contrary to the conclusions of [36], we found that when piglets were fed liquid, their average daily growth rate increased, which is consistent with the data obtained previously [29].

Similar to the results of [36], we also did not observe any deterioration in feed conversion when piglets consumed liquid feed, but on the contrary observed an improvement, which may be caused by better nutrient uptake when using a liquid feeding system and is in agreement with reports [24].

We could observe a higher feed intake when using liquid feeding, similar to the data of other researchers [18] who reported a positive effect of liquid feeding on this indicator.

We could only partially confirm the reports [2, 34] on the influence of the liquid feeding system on the increase of gas formation in the room. In particular, the ammonia content did not depend on the type of feeding, the amount of feed eaten, or the system used to create a microclimate, which is not consistent with the data of other authors [15] who observed the relationship between the release of this gas and the amount of feed consumed by the pigs. At the same time, carbon dioxide content and hydrogen sulphide content increased equally in dry feeding compared to liquid feeding of pigs in rooms with equal pressure ventilation and decreased equally in rooms with geothermal ventilation when pigs were fed dry feed mixtures.

CONCLUSIONS

The ventilation system probably has a strong influence on relative humidity and carbonation, while the feeding system probably only influences hydrogen sulphide.

The use of a geothermal ventilation system in combination with both feeding methods resulted in a higher velocity of air movement in the living area of piglets and its volumetric velocity, which led to a higher average daily feed consumption of the piglets, a higher intensity of their growth, a greater mass at transfer to fattening and a better feed conversion, which contributed to the reduction of the cost of 1 kg growth. At the same time, the carbon dioxide content, the hydrogen sulphide content, the temperature of the room air and its relative humidity were higher only in dry feeding, which contributed to better preservation of the piglets. The carbon dioxide content and the hydrogen sulphide content in the air, on the other hand, were higher with liquid feeding.

Uniform pressure ventilation resulted in lower absolute and average daily gains, average daily feed intake and poorer feed conversion in both liquid and dry feeding compared to the geothermal ventilation system, with a higher feed cost per 1 kg gain.

The combination of a geothermal system to create a microclimate with liquid feeding of piglets in rearing makes more economic sense and ensures an increase in the growth intensity of the animals and a reduction in rearing costs compared to combinations of this ventilation system with dry feeding of pigs and with combinations of a ventilation system with uniform pressure for both feeding types.

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