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Indoor climate in pigsty with deep litter system in winter

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Abstract. Pig keeping on deep litter system is becoming widely practiced in large reconstructed and newly built pigsties, either in heated or unheated buildings. As animal keeping technologies have an impact on the productivity of animals and the efficiency of tending performed, it is necessary to study the working environment and indoor climate of pigsties. In order to find out the impact on indoor climate during wintertime with methods of animal keeping on deep litter system either in heated or unheated buildings, air temperature, relative humidity, air velocity, and contents of oxygen, carbon dioxide, and ammonia were measured on a daily basis at the height of 1.5m above the pigsty floor and also at the height of 0.1, 0.5, 1.5, and 2.0m above the places where pigs were tended (pens and tending passages). Simultaneously, outdoor air temperature and relative humidity were measured. Data Logger equipment with relevant sensors and Gas Monitor Pac III were used for studying the parameters of indoor climate. HygroLog equipment was used for measuring the temperature and relative humidity of outdoor air. Measurement results were statistically processed by using computer programmes AMR Win Control, HW3, and MS Excel.

Key words: Deep litter pigsty, heating, without heating, working environment, pig-pen, tending passage, keeping technology, air temperature, air velocity, relative humidity, oxygen, carbon dioxide, outdoor climate, Data Logger.

INTRODUCTION

A pig farm represents the biotechnical system ‘man-machine-animal’, which together with the indoor climate of buildings or premises constitutes a work environment for producing animal products. Indoor climate parameters of working environment have impact on the human capacity for work (ASHRAE, 2001; Liiske et al., 1998; Sada & Reppo; Liiske, 2002) and the productivity of animals (ASHRAE, 1997; Mothes, 1977; Liiske, 2002). Humidity and ammonia have more harmful effect on premises (Tuunanen & Karhunen, 1986), whereas indoor climate depends on various factors such as applicable tending technology, the number of animals, systems for providing animals with forage, water and removal of manure, use of litter, and season or outdoor climate (MWPS-33, 1989; Mothes, 1973; Kender et al., 1998; Sada & Reppo, 2006).

Indoor climate quality of the pig keeping environment and its influence upon the productivity of pigs has been studied in laboratories (climatic chambers) with limited number of pigs or in real operating pigsties, which is more complicated due to the multitude of different factors. As large pigsties have been operated, where pigs are kept on deep litter in unheated premises or in pigsties with heated floors, using liquid manure system, the present study envisaged its goal in investigating the correspondence of the numerical values of indoor climate parameters of these pigsties to the pig-keeping standard norms in winter. The mean numerical values of daily parameters are dealt with. The pigs' daily gain (meat-forming) is a steady process independent of hourly climate fluctuations, the conditions of which can be restored round the clock. Also the formation of such indoor climate parameters as temperature, relative humidity and gas content in different air zones (altitudes) by pig-keeping and in human workplaces was of interest.

Research on piggeries has mostly been focused on the air temperature, relative humidity, air velocity and – to a certain extent – gas composition (Tuunanen & Karhunen, 1986; Karhunen, 1994; Mothes, 1973), providing a basis for designing ventilation systems for relevant premises. Generally, such research has been carried out in small piggeries for up to 500 pigs and in customized laboratories (Tuunanen & Karhunen, 1986). Gas composition, its variation on a daily basis and its dependence on applicable animal-keeping methods and technologies have been studied to a lesser extent.

Study results provide further information about indoor climate in deep-litter piggeries either in heated or unheated buildings, allowing the selection of the animal keeping method which would be least harmful for the tending environment.

MATERIALS AND METHODS

Indoor climate was studied in piggeries for 1,600 and 600 fattening pigs, which are hereinafter referred to as Piggery 1 and Piggery 2 (Table 1). Piggeries are made of silicate bricks and reinforced concrete. Fattening pigs were fed with dried fodder delivered by automatic conveyor from automatic feeders. Automatic conveyor Big Dutchman was used. In Piggery 1 fattening pigs were kept on straw litter (50 pigs per pigsty), where manure was removed with shovel-loader after replacing fattening pigs in the pigsty. In Piggery 2 hot water radiators for central heating system were installed under the ceiling of buildings and the manure was removed with shovel-loader. Bite-type device was used for drinking in both piggeries. Ventilation was regulated by automatic forced ventilation controlled by temperature.

The methods of the study were based on the Health Protection Act of the Republic of Estonia (https://www.riigiteataja.ee...25048, Veinla, 1987) and Finnish standards (Karhunen, 1992), according to which the numerical values of indoor climate parameters of work environment can be measured at the height of 1.5m in case of human workplace. In order to study daily changes in the indoor climate of piggeries in view of outdoor climate, methods for animal keeping, performance of technological processes, activities of the tenderer and animal behaviour, air temperature, relative humidity, air velocity, and contents of oxygen, carbon dioxide and ammonia were measured on a daily basis at the interval of 60 seconds in the central part of piggeries at the height of 1.5m from the floor of the pigsty in winter (27.01–28.03.2008). For the purpose of determining numerical values for indoor climate parameters in the air zones of humans and animals in upright position and animals in lying position, these parameters were measured at the heights of 0.1, 0.5, 1.5, and 2.0m from the floor with the interval of 10 seconds during one minute each. Measurements were taken during tending works in the central part of pigsties within the entire cross-section of premises (in tending passages, pens) and diagonally at the ends of the pigsties. Indoor climate parameters were measured at 8 locations both in Pigsty 1 and in Pigsty 2.

Simultaneously outdoor air temperature and relative humidity were measured during 24 hours. ALMEMO Data Logger 8990-8 equipment with relevant sensors was used for studying the indoor climate.

Table 1. Data on pigsties.

Item	Pigsty 1	Pigsty 2
Number on pigs	1,600 fatlings (25...100kg)	600 fatlings (15...80kg)
Way of handling	Deep-litter	Deep-litter
Ventilation	Compulsion ventilation	Compulsion ventilation
Air flow control	Automatical	Automatical
Heating	Missing	Central heating
Fodder delivery	Dry food automatic system Big Dutchman	Dry food automatic system Big Dutchman
Manure disposal	With tractor	With tractor
Watering	Nipple	Nipple
Litter	Straw	Straw

ALMEMO Data Logger 8990-8 equipment with relevant sensors was used for studying the indoor climate. Air temperature and relative humidity were measured with AMR-manufactured sensor FH646-1 with measurement area -20–+80°C (measuring accuracy 0.01°C) and 5–98% (measuring accuracy 0.1%), respectively. Oxygen sensor FY 9600-O_2 and ZA9000-AK2K are manufactured by AMR and their measurement area is 0–100% and their measuring accuracy was 0.01%. Carbon dioxide content was measured with sensor FY A600-CO_2 with measurement area 0–2.5% and measuring accuracy 0.01%. Air velocity was measured by using thermo-anemometer FHA645TH2 with measurement area 0–2.0$m{\cdot}s^{-1}$ and resolution 0.001$m{\cdot}s^{-1}$. Ammonia content was measured with Gas Monitor Pac III equipment manufactured by Dräger Safety AG & Co KGaA, its measurement area was 0...250 ppm and measuring accuracy 1 ppm. HygroLog device manufactured by Rotronic and HygroClip S sensor were used for measuring outdoor temperature and relative humidity (measurement area -40–+85°C and 0–100%, accuracy ±0.3°C and ±1.5%, respectively). Measurement results were analysed by using computer programmes AMR WinControl, Pac III Software 3.nn, HW3 (AHLBORN, 2007; Dräger, 2001). Statistical processing of the research data by using computer program AMR WinControl, Pac III Software 3.nn, HW3 made it possible to determine the min, max and mean values of indoor climatic parameters; standard deviation (s.d.), standard error of mean (s.e.) were determined by program MS Excel (Kiviste, 1999).

RESULTS AND DISCUSSION

Indoor air temperature, relative humidity and ammonia content were major parameters affecting the indoor climate of animal-keeping premises (MWPS, 1989; Kender et al., 1998; Reppo et al., 2003). Recommended minimum indoor air temperature for fattening pigs and young pigs was 7–15°C, maximum temperature 25–27°C and optimal temperature 15–22°C depending on the age and live weight of animal. The daily temperature variation in pigsties should not exceed 2–3°C (CIGR, 1984; Rosti, 1988; Maatalouden…, 1990; Tuunanen and Karhunen, 1984). Recommended relative humidity was between 60–80%, also 60–85% (Brent, 1991), but should not exceed 85%, because in that case other indicators of microclimate have also deteriorated (Veinla, 1987). Excess moisture generated drip water, mould and fungi at the structures of the building. Low air humidity content (less than 55%) can cause drying of oral mucous membrane of animals and generate dust on the premises (Mothes, 1976; Veinla, 1987; Rosti 1988).

In case of low outdoor temperature measured at Pigsty 1 –0.4–(+2.9)°C the indoor temperature was between 11.1–14.2°C during 24 hours, which still remained in lower limits of the norms for fattening pigs (Maatalouden…, 1990). The lower the air temperature (compared to optimal temperature) the worse are the fattening or growth results (ASHRAE, 1997; CIGR, 1984; Liiske, 2002). In order to prevent such deterioration the pigsty needs to be heated.

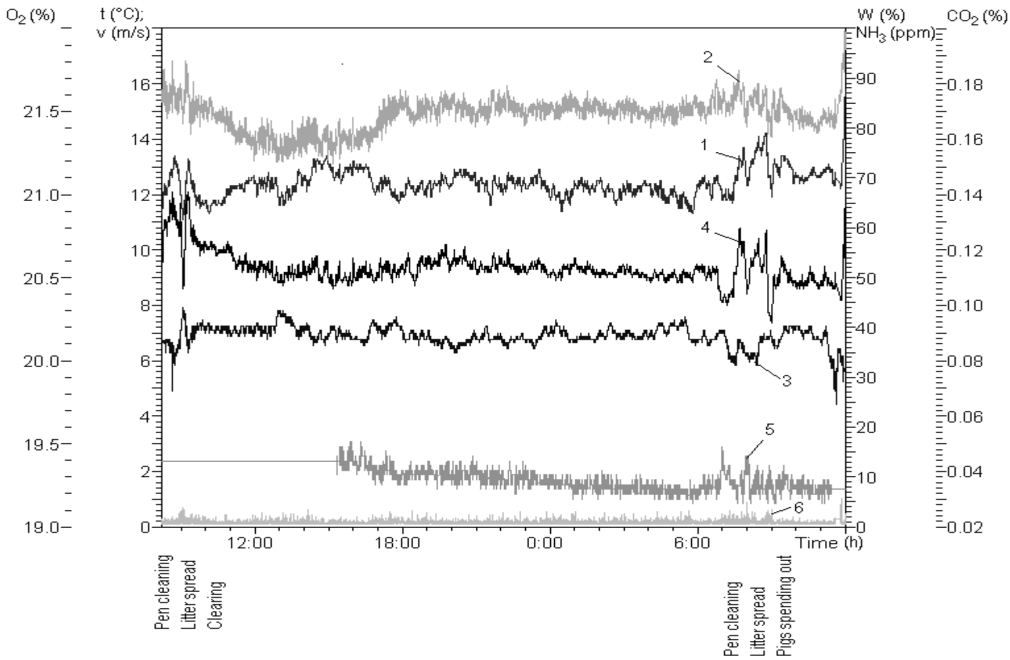

Figure 1. Daily change in numerical values of indoor climate parameters in Pigsty 1: 1 – temperature, 2 – relative humidity, 3 – oxygen, 4 – carbon dioxide, 5 – air velocity, 6 – ammonia.

The mean relative air humidity in pigsties was 82.63 and 75.53%, it did not exceed the recommended norms (Table 2; Fig. 1). From the investigation of Pigsty 1 indoor climate it is obvious (Fig. 1 and 2) that the influence of outdoor temperature and relative humidity on the indoor climate is considerable. Animal respiration and the processes occurring on the surface of manure cause the generation of carbon dioxide and ammonia, which are considered harmful gases (Rosti, 1988). The sources of reference and standards provide different information concerning the concentration limits of carbon dioxide. According to German researcher Mothes (1976) the maximum allowed concentration of carbon dioxide is 0.35% in the air zone of animals and 0.50% in human work zone, whereas pursuant to Finnish data (Maatalouden..., 1990) human evaluation of air deteriorates already in case of concentration of 0.1% and ventilation is necessary in case of 0.25%.

Table 2. Indoor climate parameter values in the Pigsties.

Measured parameters	Min	Max	Mean	*s.d.*	*s.e.*
	Pigsty 1				
Temperature t (°C)	11.10	14.20	12.38	0.466	0.008
Relative humidity W (%)	72.8	93.4	82.63	3.145	0.038
Oxygen O_2 (%)	19.80	20.32	20.15	0.051	0.001
Carbon dioxide CO_2 (%)	0.09	0.14	0.11	0.005	0.0001
Ammonia NH_3 (ppm)	4	17	8.9	2.083	0.024
Air velocity v (m s^{-1})	0.08	0.93	0.15	0.057	0.001
Outdoor temperature t_1 (°C)	-0.4	2.9	0.91	0.871	0.021
Outdoor relative humidity W_1 (%)	76.9	100.0	88.45	13.049	0.321
	Pigsty 2				
Temperature t (°C)	16.42	18.70	17.53	0.517	0,078
Relative humidity W (%)	66.2	83.7	75.86	3.922	0.591
Oxygen O_2 (%)	18.54	18.90	18.68	0.083	0.012
Carbon dioxide CO_2 (%)	0.09	0.15	0.11	0.014	0.002
Ammonia NH_3 (ppm)	14	69	37.6	17.593	2.683
Air velocity v (m s^{-1})	0.13	0.33	0.18	0.052	0.002
Outdoor temperature t_1 (°C)	5.2	11.6	9.20	1.174	0.080
Outdoor relative humidity W_1 (%)	27.3	56.4	34.3	2.111	0.482

Pursuant to the occupational health and safety requirements, the carbon dioxide content of 0.50% is considered harmful for humans (Seppänen O. and Seppänen M., 1998). Pursuant to the standards applicable in the Republic of Estonia (http://riigiteataja...73153, 2002), the content of carbon dioxide allowed in the air of human environment is up to 0.50%.

Daily measurement showed that the mean concentration of carbon dioxide in the air of the pigsties was 0.11%, increasing during tending works in Pigsty 1 to 0.14% and in Pigsty 2 to 0.15%, corresponded by simultaneous decrease in air oxygen (Fig. 1; Table 2). According to Jürgenson (1949), in winter we have to cope with the carbon dioxide concentration higher than 0.17%, but if possible, it should be lower than 0.17%.

The information also varies in case of the highest concentration of ammonia in the air. The allowed concentration of ammonia in the air is up to 20 ppm in the European Union (CIGR, 1984). Estonian standards (http://riigiteataja.ee...73153, 2002) and authors (Tuunanen and Karhunen, 1984) refer to 20 and 25 ppm as the allowed average standard limit in the air inhaled in human working zone. The data provided by several authors (Mothes, 1976; Einberg, 2001; Pals et al., 2003) reveal that the air emission of ammonia on the premises used for animal keeping depends on the handling of manure, air temperature, and relative humidity. It was observed that the emission of ammonia from the manure was higher in the case of high temperature and high relative humidity of the indoor air.

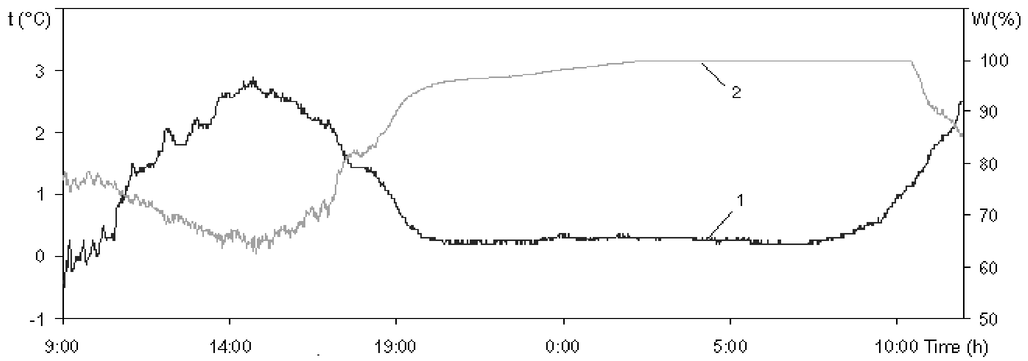

Figure 2. Outdoor air temperature (1) and relative humidity (2) near Pigsty 1.

The study also revealed that due to higher indoor temperature in Pigsty 2, the daily average ammonia content (37.6 ppm) was higher than in unheated Pigsty 1 (8.9 ppm), but due to proper ventilation (average air velocity 0.18 and $0.15 m \cdot s^{-1}$, respectively) virtually remained within the allowed standard limits (Table 2).

During the tending works when the pigs were awake, moving around, treading the manure and carrying it around, the air emission of ammonia increased. Therefore it is necessary to increase ventilation in pigsties during tending works, especially when cleaning the pig pens.

While the indoor climate's daily mean numerical values (excl. relative humidity) of the pigsties were practically within the norms (Table 2), the measured values obtained in pig pens and tending passages (at the tender's working zone) at different altitude levels showed variations from the daily mean, the values of relative humidity and ammonia content actually exceeded the recommended values (Figures 3 and 4).

The study of indoor climate parameters in pig pens (Figure 3) revealed that in Pigsty 1 the temperature was higher at the surface of deep-litter when measured at the height of pigs (+16.4°C) than at the height of 2.0m (+15.2°C). In Pigsty 2, where fatlings were kept on central heated building, the indoor air temperature fluctuations at different height zones were smaller. The carbon dioxide concentrations (0.13 and 0.12%) in both pigsties at the height of pigs were within the norms. As the pigs were awake (as also during the tending work), it caused considerable relative humidity and the carbon dioxide together with steam evaporated, thus affecting the oxygen content in the air upper layers of the room (Figure 3).

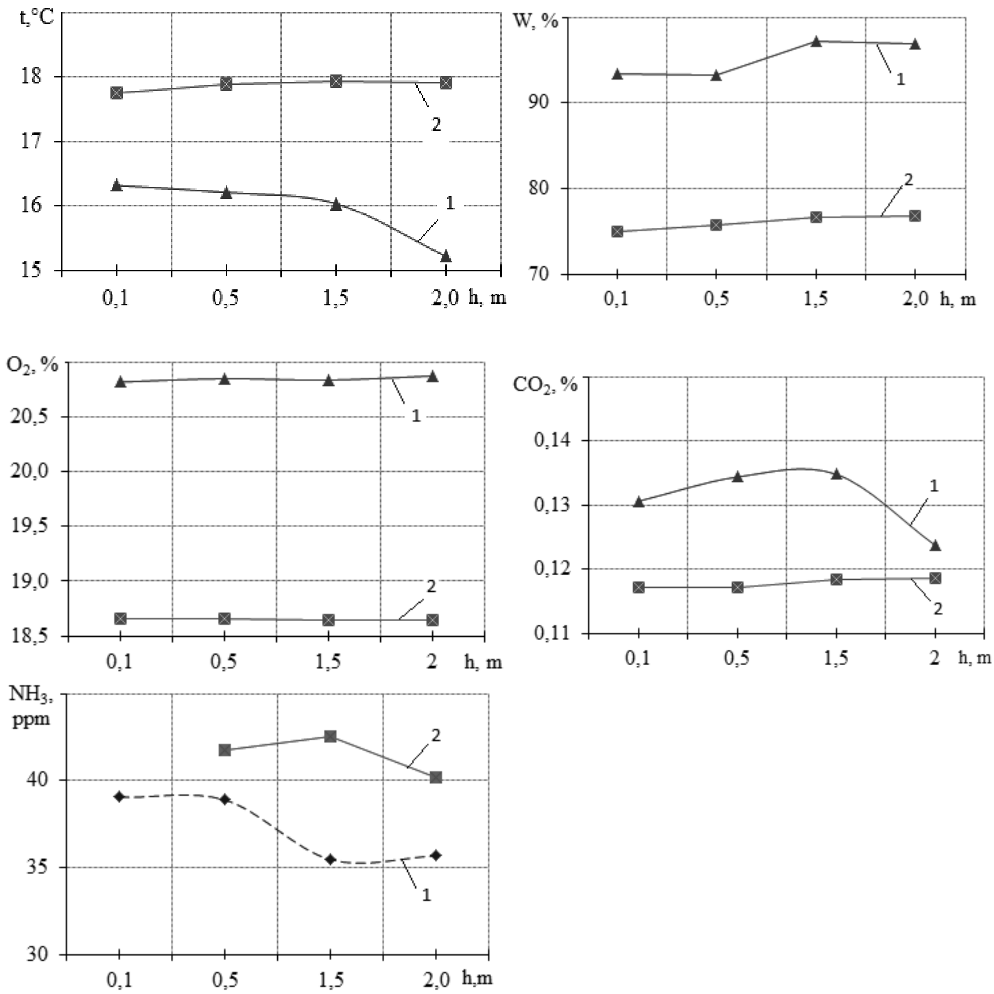

Figure 3. Mean numerical values of the indoor climate parameters in unheated 1 and heated 2 Pigsties measured in recreation area at different heights of air zones.

The research confirms that ammonia emission is dependent on the relative humidity of the work area; with the rise in the relative humidity percentage the ammonia content in the air also increases. It was observed (Einberg, 2001), that ammonia emission was rather high at dungy surfaces, especially high at the surface of liquid manure. It is maintained (Karhunen, 1992), that the ammonia content is higher in the air layers under the pigsty ceiling. Our research proves that the ammonia content is higher in the lower air layers because of the vicinity of origination. High ammonia content was measured in lower air layers in pig pens in Pigsty 1, yielding a mean of 39.0 ppm at the height of 0.1m (Figure 3). Partial transfer of drinking water to the rest area and insufficient straw supply caused an increase in relative humidity and air emission of ammonia. As the density of ammonia (0.7714kg m^{-3}) makes it lighter than air (1.2928kg m^{-3}), it goes up, but is well-soluble in water vapours by neutral reaction and is reduced in higher air layers (Mothes, 1976).

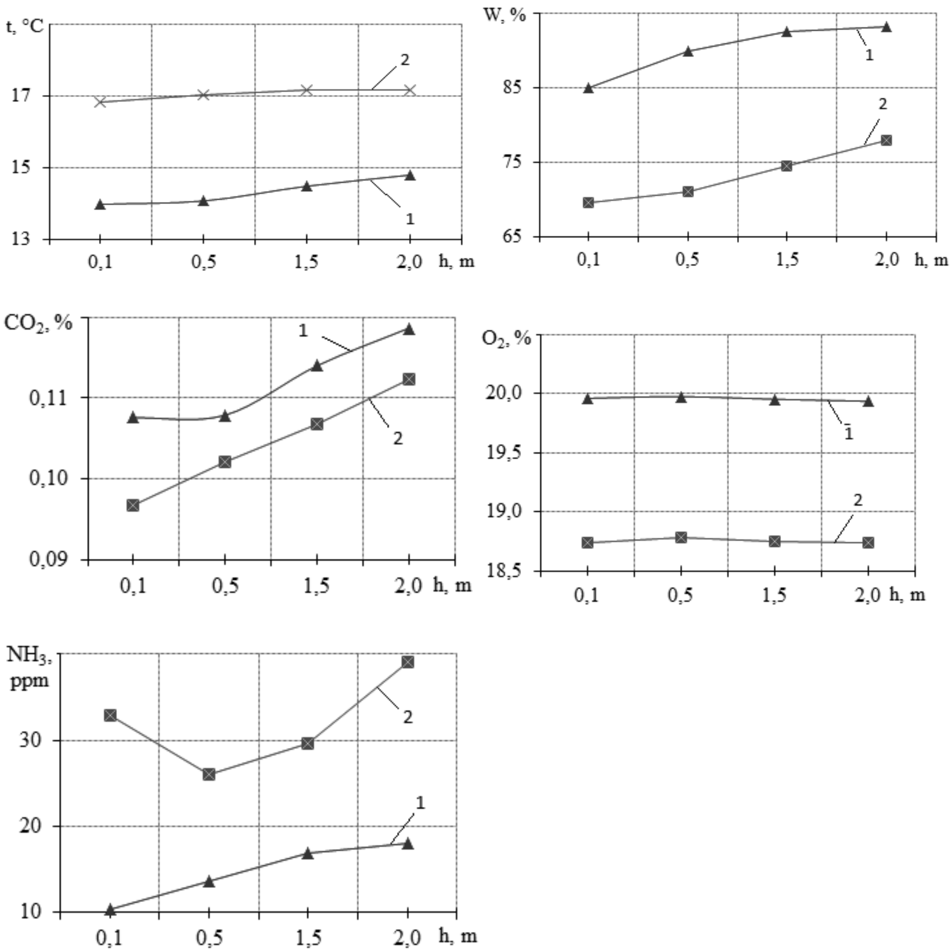

Figure 4. Mean numerical values of indoor climate parameters in unheated 1 and heated 2 Pigsties measured in tending passages at different heights of air zones.

It appeared that the air temperature measured in tending passages was higher in Pigsty 2, controlled by the central heating system with was installed under the celling of buildings (Figure 4).

Higher air layers of tending passage in Pigsty 1 also showed higher content of carbon dioxide, thus removing oxygen from these layers, whereas the air temperature and contents of carbon dioxide and oxygen remained within standard limits. At the same time at the height of 1.5–2.0m and high percentage of relative humidity the content of ammonia in the air was in Pigsty 2 non-permissibly high (39 ppm), indicating the need to reconsider ventilation.

CONCLUSIONS

In the course of the study, in winter the indoor air temperature, relative humidity and air velocity, contents of oxygen, carbon dioxide, and ammonia were measured during 24 hours at the height of 1.5m above the pig pens and also in the pig pens (in recreation area) and tending passages at the heights of 0.1, 0.5, 1.5, and 2.0m in pigsties with deep litter for heated and unheated system. Data Logger equipment, relevant sensors and computer programme AMR WinControl, Pac III Software 3.nn, HW3 were used for the study. In addition to the research of the indoor climate, outdoor air temperature and relative humidity measurements were simultaneously taken at the pigsties.

It turned out that the numerical values of the indoor climate parameters of pigsties were affected by the methods of animal keeping and tending works. Outdoor climate had greater impact on indoor climate in a pigsty which was unheated and with insufficient insulation. Mean outdoor temperatures were between 0.91 and 9.20°C. Mean air temperatures in pigsties were 12.38 and 17.53°C, thus remaining within the limits allowed for keeping animals. Measured relative humidity, 82.63 and 75.86%, did not exceed the recommended values. Air temperature was lower in the unheated deep-litter Pigsty 1, which was less insulated and with more relative humidity (82.63%). According to the study results the temperature measured at the height of animals in pigsties for fattening pigs was 16.2–16.4 and 17.8–17.9°C, respectively.

Daily mean carbon dioxide contents in pigsties were 0.11%, but mean measured ammonia contents in pigsties were 8.9ppm and 37.6ppm, and increased to 69ppm in Pigsty 2 during cleaning and tending works. Measurements at different altitudes in pig pens and tending passages revealed their difference from pigsties' daily mean and, in case of air relative humidity and ammonia content, exceeded the recommended values. It appeared that in order to improve the humidity conditions and gas composition of air in pigsties, more efficient ventilation is required in winter.

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