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EVALUATION OF THE SELECTED MICROCLIMATE PARAMETERS IN A FULLY-SLATTED PIGGERY[1]

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ABSTRACT

The microclimate in livestock buildings is very important for health and welfare of farm animals, as well as for the efficiency of livestock production. The aim of the study was to evaluate the microclimate based on measurements of the selected parameters in a two-storey, fully-slatted piggery from July to October 2013. For five selected days, temperature and relative humidity inside the building, the concentration of NH_3, CO_2 and N_2O and air exchange were recorded. The evaluation of temperature and humidity conditions showed that in the monitored piggery, pigs can be exposed to heat stress. The duration of adverse conditions can be as high as 80% of the day in the summer season. Mean daily NH_3 concentrations ranged from 5.92 to 19.51 ppm, and were lower than the limit of 20 ppm. The analysis of the daily distribution of ammonia concentrations showed that in the autumn they were higher than the limit for 40% of the day. Daily average values of CO_2 concentrations ranged from 1092 to 2407 ppm, and were lower than the limit of 3000 ppm. Average daily N_2O concentrations ranged from 0.48 to 0.82 ppm, and did not negatively affect the comfort of the animals.

Introduction

Microclimate in inventory buildings is of particular significance for welfare and health of livestock and influences the efficiency of animal production (daily increase of body mass, milk yield etc.) The existing microclimate conditions in rooms for animals result from a complex influence of many factors, such as: animal species, structure and technical equipment of a building, maintenance system and meteorological conditions (Kołacz and Dobrzański, 2006; Głuski, 2008). Microclimate is a set of climatic factors which directly determine living conditions of an organism or a group of organisms. Its most important parameters include: temperature and relative moisture of air, concentration of harmful gases, air volume stream (exchange of air), lighting and noise (Lewandowski, 1997; Augustyńska-Prejsnar and Ormian, 2012).

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Intensive animal production in changing weather conditions requires stable microclimatic conditions, which are maintained with the use of advanced control systems and techniques of controlling devices (Soldatos et al., 2005). Failure to ensure appropriate microclimate in the building for animals may cause heat stress, which is a body defensive response as a result of unfavourable environmental conditions which disturb the state of homeostasis. For regular course of animals' physiological functions it is necessary to maintain optimal temperature and relative moisture of air, regardless the season of the year (Traczykowski, 2008). These parameters should be considered together since the body reaction on the existing temperature is strictly related to moisture. High humidity and temperature cause lower demand for feed, bigger thirst and difficulties in cooling the body, which reduces daily increases (Witte et al., 2000; Żelazny, 2005; Hoha et al., 2013). On the other hand, low humidity may lead to breathing disorders and may cause the growth of dust concentration. Too low temperature causes an increased demand for feed; however a great part of energy contained therein is used for heating a body and not for the increase of the body mass.

In Europe, the litter systems are thought to better meet the requirements for welfare than non-litter systems (Lyons et al., 1995; Scott et al., 2006). However in the industrial production scale, traditional litter maintenance systems are abandoned. Thus, costs related to ensuring high amounts of straw and work expenditures are reduced. Moreover, by keeping animals in non-litter systems, their hygiene is improved and heat stress is reduced through elimination of manure (litter, which is not only an isolation material, which impedes heat removal by pigs but also is the source of heat (Kołacz and Dobrzański, 2006; Hoha et al., 2013).

The aim of the undertaken research was to asses the selected parameters of microclimate in a piggery with a slatted floor during one production cycle during summer and in the beginning of autumn.

Material and methods

The object of the research was a piggery with a slatted floor, located in Wielkopolskie Voivodeship. It was a modernized two-storey building, where previously fattening was carried on a shallow litter, and the attic served as a feed storage. After it was modernized, pig breeding in a non-litter system was carried out on two storeys (Fig. 1, 2). Comparing it with newly constructed objects, cubic capacity per one pig was considerably lower, which affected the microclimate in a piggery. Manure was stored in containers under the slatted floor. Measurements of microclimatic parameters were carried out on the lower storey of the building, whose technical parameters have been presented in Table 1.

Maintained pigs were fed “wet” and feed was supplied 4 times a day. The building was equipped with a mechanical, temperature controlled, underpressure fan system. There were 3 fans mounted in a piggery with a dimension of 50 cm and a nominal capacity of 7850 $m^3 \cdot h^{-1}$ each.

For five selected days throughout two days from July to October 2013, every 30 minutes the following were registered: temperature and relative moisture of air inside the building (recorder TESTO 175-H2), concentration of ammonia (NH_3), carbon dioxide (CO_2) and nitrous oxide (N_2O) (photo-accoustic spectometer Multi Gas Monitor 1312 by INNOVA). Measurements of temperature and relative humidity took place in four measurement points at the height of 1.5 m, whereas concentration of gases in one point at the same height (Fig.3). Exchange of air was measured constantly and half-hour averages were recorded by the climate controller SK-1D2M (Wesstron, Poland).

Figure 1. View of the piggery

Figure 2. Ground floor of the piggery

Table 1
Selected technical parameters of the investigated ground floor of the piggery

Parameters	Unit	Mean
Dimensions of a storey (length/width/height)	(m)	29.3/9.4/2.3
Cubic capacity	(m^3)	633.5
Number of pigpens	(pcs)	10
Dimensions of a pigpen (length/width)	(m)	8.5/2.7
Pigpen stock	(pcs)	30
Cubic capacity for one piece	($m^3 \cdot pcs.^{-1}$)	2.1
Cubic capacity for one piece	($m^2 \cdot pcs.^{-1}$)	0.77

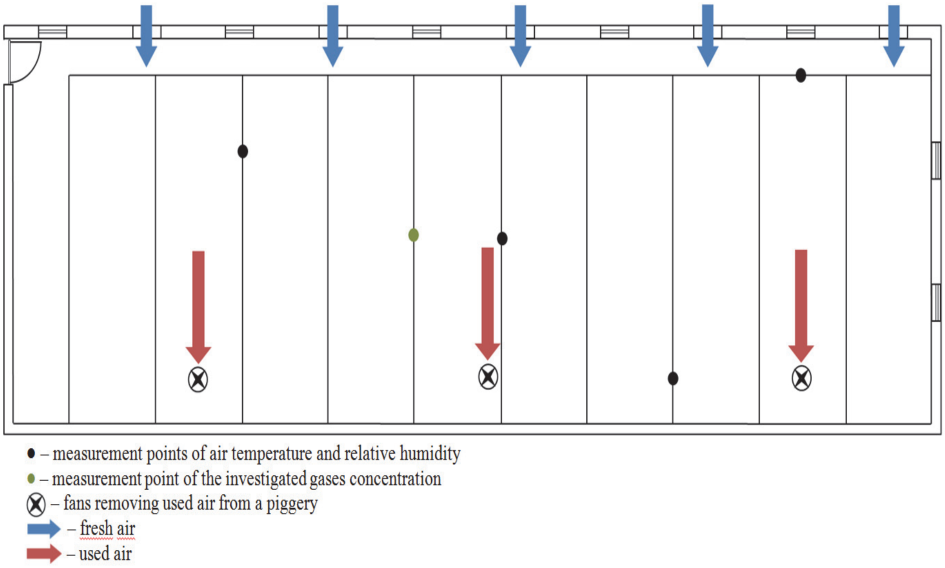

Figure 3. Plan of investigated part of piggery

For assessment of microclimate conditions in the aspect of heat stress, two methodologies were applied. The first one developed by the *National Research Council* in Oklahoma (NRC 1971), based on the temperature and humidity index (THI):

$$.. \quad 1.8 \quad 32 \quad 0.55 \quad 0.0055 \quad 1.8 \quad 26 \qquad (1)$$

where:

T – air temperature in the building, (°C)
W – relative air humidity, (%)

THI value equals 72 and was assumed as a border of heat comfort for pigs (Chase, 2004). The second one described by Romaniuk and Overby (2005), which assumes that temperature and humidity conditions in the building are optimal, if the sum of temperature value and relative humidity of air is at the level from 85 to 90.

Results and discussion

The period of research covered one production cycle carried out in the summer season and early fall. On each measurement day the number and average mass of animals maintained in a piggery was determined (Table 2).

Table 2
The number and average mass of fattening pigs in the investigated part of piggery

Parameters	Measurement day				
	09/10.07	23/24.07	13/14.08	04/05.09	02/03.10
Number of porkers	291	291	291	291	291
Average mass of a porker	30	45	60	80	105

Results of daily monitoring of temperature and relative humidity of air and exchange of air in the piggery were defined with the use of basic descriptive statistics: arithmetic mean, standard deviation and coefficient of variability (table 3) and daily distribution of recorded values were carried out (fig. 4 and 5).

Table 3
Average daily values of temperature, relative humidity and ventilation rate in the investigated part of piggery

Parameters	Measurement day				
	09/10.07	23/24.07	13/14.08	04/05.09	02/03.10
Air temperature (ºC)	25.5	25.2	23.1	23.9	22.1
Standard deviation (ºC)	1.1	0.9	1.0	0.7	0.6
Coefficient of variation (%)	4.4	3.7	4.0	2.8	2.9
Relative humidity of air (%)	61.6	51.8	62	61.5	58.2
Standard deviation (%)	3.9	7.0	5.4	3.3	4.7
Coefficient of variation (%)	6.3	13.5	8.7	5.4	8.1
Exchange of air ($m^3 \cdot h^{-1} \cdot pcs.^{-1}$)	55.7	53.1	38.9	38.8	20.9
Standard deviation ($m^3 \cdot h^{-1} \cdot szt.^{-1}$)	11.3	9.4	7.0	7.2	6.5
Coefficient of variation (%)	20.3	18.2	18.1	18.6	31.0

Air temperature in the investigated piggery was at the higher level than the recommended optimal values: 18-22ºC at the weight of 30-100 kg (Romaniuk and Overby, 2005). Daily, its fluctuations were very low which is proved by the value of the coefficient of variation which is within 2.8 to 4.4%. Relative humidity of air was more varied (coefficient of variation 5.4-13.5%). Its average values were within 51.8 and 61.6%, which in majority corresponds to optimal values presented in literature (Romaniuk and Overby, 2005; Nawrocki and Klimkiewicz, 2003). In the investigated period daily average exchange of air was within 20.9 and 55.7 $m^3 \cdot h^{-1} \cdot pcs.^{-1}$, which should be considered correct which is proved by the recorded values of carbon dioxide concentration.

Temperature and relative humidity of air inside the inventory building are strictly related and shape the existing microclimate. Thus, these parameters should not be assessed separately. Full assessment of temperature and humidity conditions was carried out based on the value of THI index and according to methodology by Romaniuk and Overby (2005). THI value equal to 72 is considered as a border of heat comfort for porkers (Chase, 2004). Romaniuk and Overby (2005) assume that microclimate in a piggery is optimal, if the sum of temperature and relative humidity value does not exceed 90. Results of assessment were presented in Table 4.

Based on the computed average values of THI index, it was found out that temperature and humidity conditions were maintained at the level insignificantly higher or lower than the thermal comfort limit. Analysis of the diurnal distribution of THI showed that in the summer during hot days, unfavourable conditions may occur for 80% of a day.

Taking into consideration average daily values of T+W, according to the methodology by Romaniuk and Overby (2005), pigs maintained in a piggery within this period were not exposed to heat stress. Analysis of instantenous (half-hour) results of measurements proved that the exceeds of the thermal comfort limit were from 2.1 to 18.8% of a day and they were decisively lower than the computed ones based on the THI index.

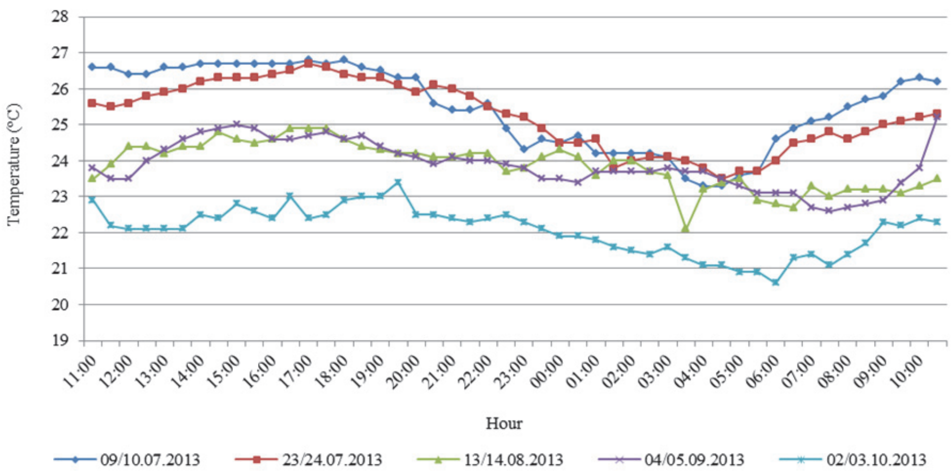

Figure 4. Diurnal variation of air temperature in the investigated part of piggery

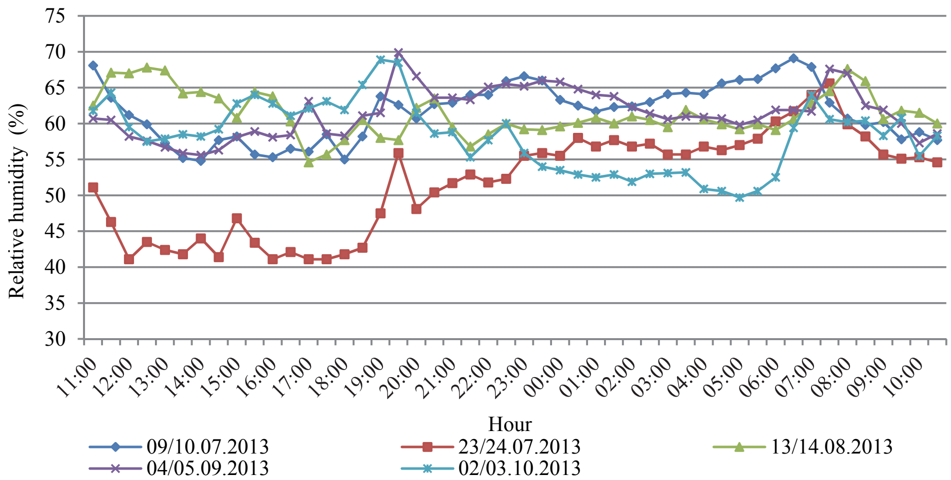

Figure 5. Diurnal variation of air relative humidity in the investigated part of piggery

Table 4
Average daily values of THI and T+H

Parameters	Measurement day				
	09/10.07	23/24.07	13/14.08	04/05.09	02/03.10
THI	73.7	72.2	71.4	71.4	68.6
T+W	87.1	77.0	85.2	85.4	80.3
Exceeding THI (% of a day)	79.2	71.0	29.2	29.2	0.0
Exceeding T+W (% of a day)	18.8	2.1	10.4	6.3	4.2

When comparing results obtained on the basis of two methods one may notice that they differ considerably from each other. It impedes an objective assessment of thermal and humidity conditions in a piggery, thus for a more complete assessment watching animals' behaviour and production results is necessary.

Average values of concentration of the investigated greenhouse gases and ammonia in a piggery were presented in table 5 and their diurnal distribution was presented in figures 6 to 8.

Table 5
Average daily values of greenhouse gases and ammonia concentration in the investigated part of piggery

Parameters	Measurement day				
	09/10.07	23/24.07	13/14.08	04/05.09	02/03.10
Ammonia NH_3 (ppm)	6.13	5.92	8.72	6.62	19.51
Standard deviation (ppm)	1.76	2.01	1.69	1.16	1.56
Coefficient of variation (%)	28.7	34.0	19.4	17.5	8.0
Carbon dioxide CO_2 (ppm)	1092	1222	1471	1113	2407
Standard deviation (ppm)	280	418	229	195	313
Coefficient of variation (%)	25.6	34.2	15.6	17.5	13.0
Nitrous oxide N_2O (ppm)	0.48	0.52	0.53	0.50	0.82
Standard deviation (ppm)	0.07	0.06	0.04	0.04	0.06
Coefficient of variation (%)	14.2	12.1	7.3	7.1	7.9

In the investigated period, average daily concentration of ammonia was from 5.92 to 19.51 ppm and was lower than the admissible value (20 ppm) determined in the Ordinance of the Minister of Agriculture and Rural Development of 2010. Analysis of daily distribution of concentration of this gas was reported only on one day and it was approximately 40% of a day. On this day, average daily air temperature was the lowest which limited air exchange, but porkers' mass was the highest.

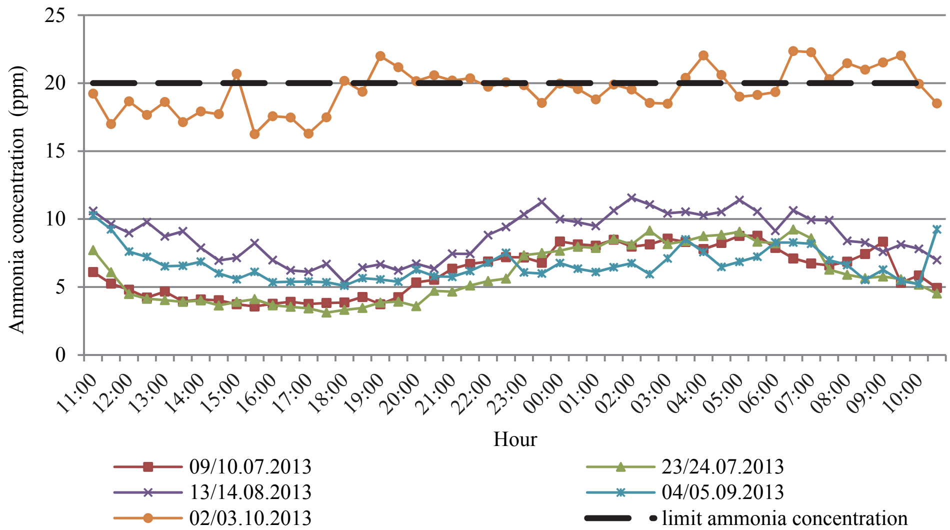

Figure 6. Diurnal variation of ammonia concentration in the invetsigated part of piggery

Instantaneous values of ammonia concentration were within 3.1 and 22.4 ppm. They are identical with majority of results presented in the published papers for pigs maintained on a slatted floor as well as on the deep litter (table 6).

Table 6
The list of ammonia concentration values for fattening pigs in the literature

Source	Maintenance system	Concentration of NH_3 (ppm)
Duchaine et al. (2000)	Slatted floor	1.9-25.9
Louhelainen et al. (2001)		11.7-26.0
Blanes-Vidal et al. (2008)		15.3-28.0
Kimet al. (2008)		7.3-21.4
Sada and Reppo (2008)		4.0-27.0
Ngwabie et al. (2011)		3.9-5.4
Mihina et al. (2012)		9.4-19.9
van Ransbeeck et al. (2013)		8.4-25.0
Sada and Reppo (2008)	Deep litter	6.0-43.0
Staicu et al. (2008)		7.0-25.0
Margeta et al. (2010)		8.0-11.0
Mielcarek and Rzeźnik (2014)		4.9-35.6

Average daily concentrations of carbon dioxide in the investigated piggery were within 1092 and 2407 ppm. They were comparable to results of measurements carried out by Mihina et al. (2012) – 1864-2811 ppm and van Ransbeeck et al. (2013) – 2069-2333 ppm. Insignificant differences may be caused by the stock size and the method of controlling ventilation. In summer the level of daily carbon concentration was decisively lower than the admissible value (3000 ppm) provided in the Ordinance (2010). It proves correctly selected ventilation system performance. Only, at the end of the production cycle, the limit value of CO_2 concentration, which were 4.2 % of a day was exceeded. Maximum concentration of carbon dioxide reported on this day was 3402 ppm and it was by approximately 13% higher than the admissible value.

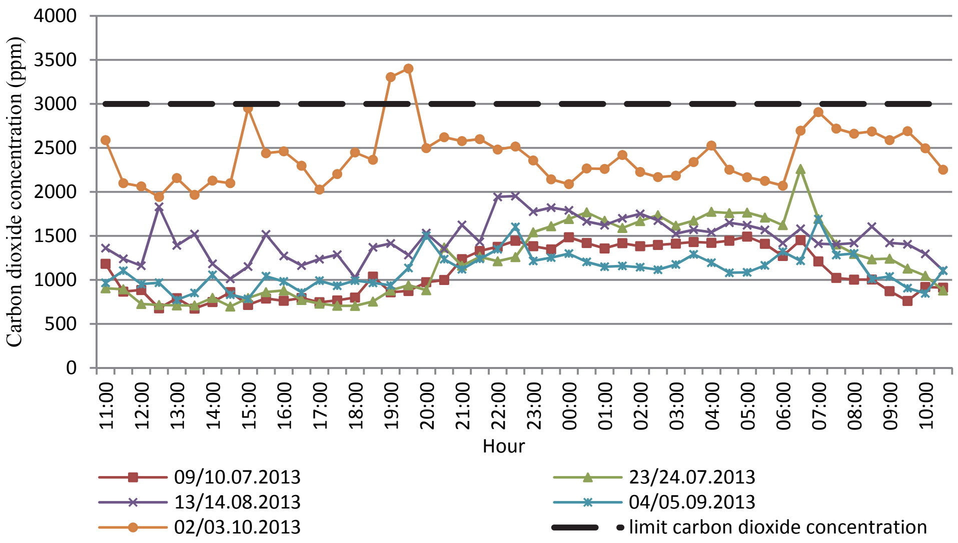

Figure 7. Diurnal variation of carbon dioxide concentration in the investigated part of piggery

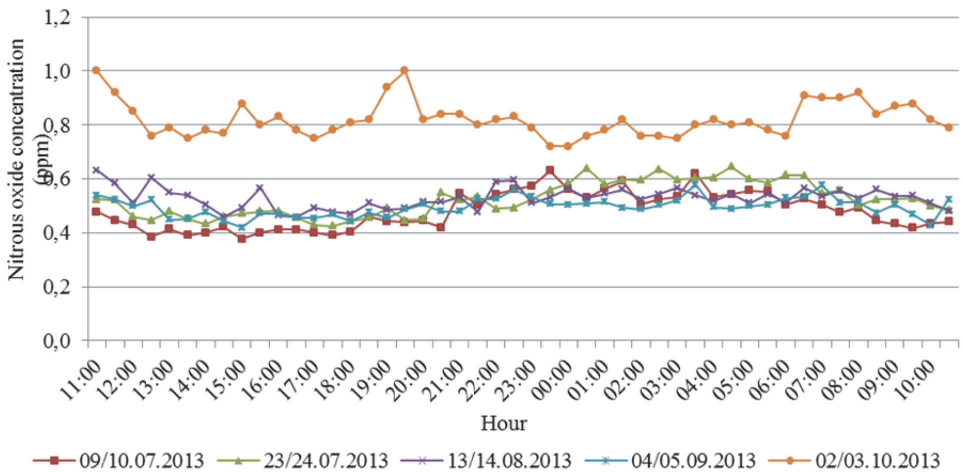

Figure 8. Diurnal variation of nitrous oxide concentration in the ivestigated part of piggery

In the investigated piggery average daily concentration of nitrous oxide was 0.48-0.82 ppm and was decisively lower than the limit value of 35 ppm provided by Nawrocki and Klimkiewicz (2003). Instantaneous values were within 0.38-1.00 ppm. Comparable results were obtained by Blanes-Vidali et al. (2008) – 0.72-0.94 ppm and van Ransbeeck et al.

(2013) – 0.44-1.65 ppm when carrying out measurements in a non-litter piggery. Only Mihina et al. (2012) obtained higher values – 0.81-4.47 ppm.

In summer daily distribution of concentration of the investigated gases have similar courses. At night, concentrations are higher than during the day. It results from the level of air exchange, which depends on the temperature. At night, due to lower temperature, air exchange is lower which causes increase of gas contamination concentration. In autumn, no relation between the concentration of the investigated gases and day were reported. It is caused by lower variability of air exchange during the day, which results from lower daily temperature amplitude.

Conclusion

1. Assessment of temperature and humidity conditions in a piggery showed that in the investigated object, pigs may suffer from heat stress and duration of unfavourable conditions may reach even 80% of a day in summer. Depending on the applied methodology, assessment of conditions in a piggery is varied, which does not allow clear determination of the level of the heat stress of animals. Thus, for more complete assessment, observation of animals' behaviour and production results is necessary.
2. Average daily concentration of NH_3 was within 5.92 and 19.51 ppm and was lower than admissible 20 ppm. Analysis of daily distribution of ammonia concentration proved, that only in autumn, in the final stage of fattening exceeds of approx. 40% of a day took place.
3. In the investigated piggery average daily concentration of CO_2 was within 1092 to 2407 ppm and was lower than admissible 3000 ppm.
4. Values of average daily concentration of N_2O were from 0.48 to 0.82 ppm and did not negatively affect the animal comfort.

References

Augustyńska-Prejsnar, A.; Ormian, M. (2012). Ocena mikroklimatu w budynku dla loch w różnych porach roku. *Problemy Inżynierii Rolniczej*, *2*(76), 95-101.

Blanes-Vidal, V.; Hansen, M.N.; Pedersen, S.; Rom, H.B. (2008). Emissions of ammonia, methane and nitrous oxide from pig houses and slurry: Effects of rooting material, animal activity and ventilation flow. *Agriculture, Ecosystems and Environment*, *124*, 237-244.

Chase, L.E. (2004). Climate Change Impacts on Dairy Cattle. Obtained from: http://www.climateand-farming .org/pdfs/FactSheets/III.3Cattle.pdf.

Duchaine, C.; Grimard, Y.; Cormier, Y. (2000). Influence of building maintenance, environmental factors, and seasons on airborne contaminants of swine confinement buildings. *American Industrial Hygiene Association Journal*, *61*, 56-63.

Ekkel, E.D.; Spoolder, H.A.M.; Hulsegge, I.; Hopster, H. (2003). Lying characteristics as determinants for space requirements in pigs. *Applied Animal Behaviour Science*, *80*, 19-30.

Głuski, T. (2008). Metody określania temperatury wewnętrznej w budynkach dla bydła. *Inżynieria Rolnicza*, *2*(100), 31-36.

Hoha, G.V.; Costăchescu, E.; Nica, A.; Dunea, I.B.; Păsărin, B. (2013). The influence of microclimates conditions on production performance in pigs. *Lucrări Ştiinţifice-Seria Zootehnie*, *59*, 165-169.

Kim, K.Y.; Ko, H.J.; Kim, H.T.; Kim, Y.S.; Roh, Y.M.; Lee, Ch.M.; Kim, Ch.N. (2008). Quantification of ammonia and hydrogen sulfide emitted from pig buildings in Korea. *Journal of Environmental Management*, *88*, 195-202.

Kołacz, R.; Dobrzański, Z. (2006). *Higiena i dobrostan zwierząt gospodarskich*. Wrocław, Wyd. AR, ISBN 83-60574-02-2.

Lewandowski, J. (1997). *Mikroklimat w obiektach inwentarskich dla trzody chlewnej i bydła*. Warszawa, IBMER, ISBN 83-86264-38-1.

Louhelainen, K.; Kangas, J.; Veijanen, A.; Viilos, P. (2001). Effect of in situ composting on reducing offensive odors and volatile organic compounds in swineries. *American Industrial Hygiene Association Journal*, *62*, 159-167.

Lyons, C.A.P.; Bruce, J.M.; Fowler, V.R.; English, P.R. (1995). A comparison of productivity and welfare of growing pigs in four intensive systems. *Livestock Production Science*, *43*, 265-274.

Margeta, V.; Kralik, G.; Hanzek, D.; Margeta, P. (2010). Deep-litter pig keeping (A review). *Acta Agraria Kaposváriensis*, *14*(2), 209-213.

Mielcarek, P.; Rzeźnik, W. (2014). *Badania parametrów mikroklimatu w tuczarni na głębokiej ściółce*. [W]: Aktualne problemy inżynierii biosystemów. Red. Lipiński M., Przybył J. Monografia. Poznań, Wydawnictwo UP, 207-218.

Mihina, Š.; Sauter, M.; Palkovičová, Z.; Karandušovská, I.; Brouček, J. (2012). Concentration of harmful gases in poultry and pig houses. *Animal Science Papers and Reports*, *30*(4), 395-406.

National Research Council (1971). *A guide to environmental research on animals*. National Academy of Science, Washington, DC.

Nawrocki, L.; Klimkiewicz, G. (2003). *Kodeks zaleceń i praktyk do utrzymania dobrostanu świń*. Warszawa, IBMER, ISBN 83-86264-92-6.

Ngwabie, N.; Jeppsson, K.H.; Nimmermark, S.; Gustafsson, G. (2011). Effects of animal and climate parameters on gas emissions from a barn for fattening pigs. *Applied Engineering in Agriculture*, *27*(6), 1027-1037.

Van Ransbeeck, N.; van Langenhove, H.; Demeyer, P. (2013). Indoor concentrations and emissions factors of particulate matter, ammonia and greenhouse gases for pig fattening facilities. *Biosystems Engineering*, *116*, 518-528.

Romaniuk, W.; Overby, T. (2005). Systemy utrzymania świń. Poradnik. Warszawa, IBMER, ISBN 83-86264-98-5.

Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 15 lutego 2010 r. w sprawie wymagań i sposobu postępowania przy utrzymywaniu gatunków zwierząt gospodarskich, dla których normy ochrony zostały określone w przepisach Unii Europejskiej. Dz.U. 2010 nr 56 poz. 344.

Sada, O.; Reppo, B. (2008). Indoor climate pigsty with deep litter and liquid system in summer. *Agronomy Research*, *6*(2), 67-78.

Scott, K.; Chennells, D.J.; Campbell, F.M.; Hunt, B.; Armstrong, D.; Taylor, L.; Gill, B.P.; Edwards, S.A. (2006). The welfare of finishing pigs in two contrasting housing systems: Fully-slatted versus straw-bedded accommodation. *Livestock Science*, *103*, 104-115.

Soldatos, A.G.; Arvanitis, K.G.; Daskalov, P.I.; Pasgianos, G.D.; Sigrimis, N.A. (2005). Nonlinear robust temperature–humidity control in livestock buildings. *Computers and Electronics in Agriculture*, *49*, 357-376.

Staicu, E.; Drăghici, M.; Bădic, L.; Ivanciu, C.; Mitrănescu, E. (2008). Research on monitoring microclimate chemical factors and their influence on the welfare of intensive swine rearing system. Bulletin UASVM, *Veterinary Medicine*, *65*(1), 222-224.

Traczykowski, A. (2008). Mikroklimat w chlewni. *Trzoda Chlewna*, *11*, 17-19.

Witte, D.P., Ellis, M., McKeith, F.K., Wilson, E.R. (2000). Effect of dietary lysine level and environment temperature during the finishing phase on the intramuscular fat content of pork. *Journal of Animal Science*, *78*, 1272–1276.

Żelazny, H. (2005). Wpływ modernizacji wewnętrznych powierzchni obudowy na temperaturę wynikową w tuczarni trzody chlewnej. *Inżynieria Rolnicza*, *1*(61), 193-199.

OCENA WYBRANYCH PARAMETRÓW MIKROKLIMATU W TUCZARNI Z PODŁOGĄ SZCZELINOWĄ

Streszczenie. Mikroklimat w budynkach inwentarskich ma szczególne znaczenie dla dobrostanu i zdrowia zwierząt hodowlanych oraz wpływa na wydajność produkcji zwierzęcej. Celem podjętych badań była ocena wybranych parametrów mikroklimatu w dwukondygnacyjnej tuczarni z podłogą szczelinową w okresie od lipca do października 2013 roku. Przez pięć wybranych dni monitorowane były: temperatura i wilgotność względna powietrza wewnątrz budynku, stężenie NH_3, CO_2 i N_2O oraz wymiana powietrza. Ocena warunków temperaturowo-wilgotnościowych w tuczarni wykazała, że w badanym obiekcie, u świń może wystąpić stres cieplny. Czas trwania niekorzystnych warunków może sięgać w sezonie letnim nawet 80% doby. Średnie dobowe stężenia NH_3 wynosiły od 5,92 do 19,51 ppm i były mniejsze niż dopuszczalne 20 ppm. Analiza dobowego rozkładu stężeń amoniaku wykazała, że w okresie jesiennym wystąpiły przekroczenia wynoszące około 40% doby. Wartości średnich dobowych stężeń CO_2 wynosiły od 1092 do 2407 ppm i były mniejsze niż dopuszczalna wartość 3000 ppm. Średnie dobowe wartości stężeń N_2O wynosiły od 0,48 do 0,82 ppm i nie wpływały negatywnie na komfort zwierząt.

Słowa kluczowe: mikroklimat, tuczarnia, stężenie gazów, system bezściółkowy