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Reduction of nitrous oxide and carbon dioxide in the pig barn piggery by different ventilation system intensities

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Abstract. Agriculture, especially animal production, is one of the most important factors influencing greenhouse gases in the atmosphere and causing global warming. The ventilation system in a piggery has a significant impact to carbon dioxide (CO_2) and nitrous oxide (N_2O) concentrations. The concentrations of these gases in pig housing also affect the air quality and welfare of animals. The aim of the paper was to analyze the effect of ventilation system intensity on the concentration of CO_2 and N_2O in a piggery. An experiment was carried out at the Experimental Centre for Livestock at the Department of Animal Husbandry, Faculty of Agrobiology and Food Resources, the Slovak University of Agriculture in Nitra, Slovakia. The concentrations were measured by a photoacoustic field gas monitor INNOVA 1412 connected to a multipoint sampler INNOVA 1309. Three levels of ventilation system intensity were used: low, medium and high. Fattening pigs, the Large White breed were housed in the piggery. For our experiment, three sensors were used inside and two sensors outside the barn. Based on the gathered data, statistically significant differences were found between different ventilation system intensities at a 95.0% confidence level. The concentration of gases fluctuates during day time interval and, based on the results, it is possible to set up a ventilation system intensity to create the best possible air quality in a building for pigs.

Key words: carbon dioxide, concentration, nitrous oxide, pig, ventilator.

INTRODUCTION

Agriculture contributes significantly to polluting gases such as greenhouse gases and ammonia (Kroupa, 2003; Monteny et al., 2006; Aneja et al., 2007; Dubeňová et al., 2011b; Dubeňová et al., 2012). Approximately 20 to 35% of greenhouse gas emissions come from agriculture (IPCC, 2001). Livestock is the source of many pollutants such as gases, odours, dust and microorganisms. 136 gases were found in livestock buildings (Karandušovská et al., 2011). Ventilation systems reduce and control the dust concentration in pig houses (Topisirovic & Radivojevic, 2005; Topisirovic, 2007). According to the European Environment Agency (2010), pig production in Europe represents close to 25% of the livestock emissions. Greenhouse gases like carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) participate in global warming and climate change (IPCC, 2007). Agriculture in general, and livestock production in particular, contribute to global warming through emissions of the greenhouse gases: nitrous oxide (N_2O) and carbon dioxide (CO_2). Air pollution is the third largest threat to our planet after biodiversity loss and climate change (most affected by CO_2). The global atmospheric concentrations of these two most important greenhouse gases have increased significantly over the last 150 years (IPCC, 2001) and it affects the atmospheric environment – increased greenhouse emissions (Zavattaro et al., 2012). Nitrous oxide is related to the nitrogen (N) cycle with chemical fertilizers and manures as the most important sources. Nitrous oxide production only takes place under specific conditions since it results from combined aerobic and anaerobic processes nitrification and denitrification, respectively. Normally, conditions in manure are strictly anaerobic and nitrification and denitrification processes will not occur (Monteny et al., 2006). Most of the N_2O is produced in the field conditions by soil tillage (Šima et al., 2013c; Šima & Dubeňová, 2013), from the manure excreted during grazing, animal manure and chemical fertilizers application to land (Šima et al., 2012b; Šima et al., 2013a; Šima et al., 2013b), and also from animal houses where straw of litter is used (Brown et al., 2001; Freibauer & Kaltschmitt, 2001). The nitrous oxide warming potential is 290 to 310 times higher in comparison with the carbon dioxide warming potential (IPCC, 2007). It can usually be estimated that the carbon dioxide produced by livestock is compensated by the photosynthesis of the plants used as feed (Philippe et al., 2011; Šima et al., 2012a). Carbon dioxide emissions differ from one rearing system to another, e.g. weaning and fattening of pigs (Dubeňová et al., 2011a; Dubeňová et al., 2013; Philippe et al., 2007a; Philippe et al., 2007b; Cabaraux et al., 2009). Production of gases, especially CO_2, and wastes by animals are an essential parameter for the ventilation rate estimation using a mass balance method (Pedersen & Ravn, 2008). The methods of manure removal affect the production of harmful gases in the evaluated piggeries for fattening pigs (Mihina et al. 2011). The process of releasing greenhouse gases into the atmosphere depends on the methods of livestock husbandry, nutrition conditions, slurry and manure management and their storage and land application (Palkovičová et al., 2009), number and weight of animals, method and time of manure removal, temperature in the barn, moisture, pH reaction of litter, C:N ratio, etc. The type and power of the ventilation system significantly affect the gas concentration in the pig building (Topisirovic et al., 2010a; Topisirovic et al., 2010b). The gaseous emissions from livestock houses are thus dependent on the housing and the floor systems (Cabaraux et al., 2009).

The aim of the paper was to analyze the effect of the ventilation system intensity on the concentration of CO_2 and N_2O gases in the investigated piggery.

MATERIAL AND METHODS

The experiment was carried out during spring period at the Experimental Centre for Livestock at the Department of Animal Husbandry, Faculty of Agrobiology and Food Resources, the Slovak University of Agriculture in Nitra, Slovakia. A piggery for fattening pigs was investigated, with 2 groups housed in each pen and 1 group of pigs in the last one. Every single pen had a drinking bowl and a feeder. The floor in all of the pens consisted of a bedded system (full floor) and a slatted floor for liquid manure (removed as appropriate). For solid manure removal, conventional technology was used once per day (manually removal). The total capacity of the piggery is 80 fattening pigs. During the experiment, 15 fattening pigs of the Large White breed were used of the average weight of 25.4 kg. Drinking water was provided ad libitum. The fattening pigs were fed ad libitum, all pigs had access to the same feed mixture. The average temperature in the piggery was 27.5°C, the average humidity was 56.2%. The average temperature outside of the piggery was 19.8°C.

During the investigations, 3 sensors were used inside and 2 sensors outside for the gases concentration measurement. The ventilator ran 48 hours for each ventilation system intensity, i.e. Low, Medium and High. The air circulations for Low, Medium and High ventilation system intensities were 0.006, 0.013 and 0.022 $m^3 s^{-1}$ per m^2 of floor surface, respectively. Measurements were always taken in the second half of the measuring time interval. The air circulations values for all ventilation system intensities are shown in Table 1. It means that the first 24 hours was not measured and then the next 24 hours were included in our analysis. Measurement without switching on the ventilator was not performed for the concerns of animal welfare, in order to not unnecessarily stress the animals.

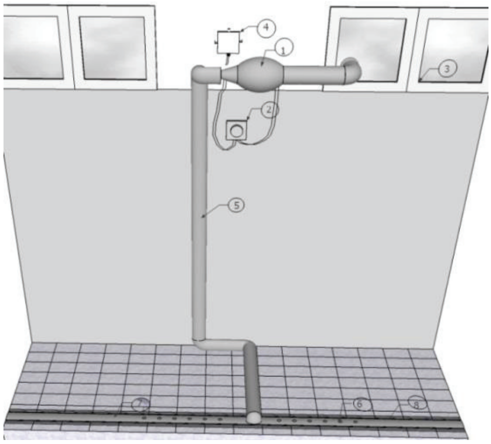

Figure 1. Ventilation system; 1 – ventilator, 2 – control of the intensity of suction (0, I, II, III, IV, V), 3 – window, 4 – electrical supply, 5 – pipe, 6 – holes for the waste air exhaust, 7 – pipe, 8 – grate.

Innova devices (LumaSense Technolgies, Inc., Denmark) were used for the measurement of the concentration of gases. The abovementioned measuring system consists of the following main parts: INNOVA 1412 – a photoacoustic field gas-monitor the measurement system of which is based on the photoacoustic infrared detection method. Gas selectivity is achieved by the use of optical filters and the detection limit is typically in the ppb (part per bilion) region; INNOVA 1309 – a multipoint sampler used for transportation of gas from sampling points to the photoacoustic field gas-monitor INNOVA 1412 for gas analysis. This device includes a 12-channel multiplexer, enabling gas samples to be drawn from up to 12 different sampling locations; the last main part is a computer with software supplied by the manufacturer where the data were saved.

The gathered data were analysed by using the Kruskal-Wallis Test after a normality test by using the Kolmogorov-Smirnov test and a homogeneity of variance by using the Levene's test. We have used the software STATGRAPHICS Centurion XVI.I (Statpoint Technologies, Inc.; Warrenton, Virginia, USA). Graphic presentation of the results was performed using the software STATISTICA 7 (Statsoft, Inc.; Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSIONS

Nitrous oxide

An effect of the ventilation system intensity on the N_2O concentration in the piggery was found. The obtained results are shown in the Table 1 and Fig. 2. Differences were found between the outside concentration, low suction and medium+high ventilation system intensities. There was no statistically significant difference between the medium and high ventilation system intensities.

Table 1. Selected parameters of summarized statistics of N_2O concentration

Intensity of ventilation	Count	Average	Coeff. of variation	Minimum	Maximum	Range
Outside	80	0.4269 ^{a}	7.8749%	0.3732	0.5522	0.1789
Low	119	0.7855 ^{c}	7.9747%	0.5636	0.9447	0.3811
Medium	119	0.6168 ^{b}	11.1326%	0.4617	0.8495	0.3878
High	119	0.6062 ^{b}	10.1061%	0.4246	0.7411	0.3165

Note: Different letters in the average value column ($^{a, b, c}$) indicate that the means are significantly different at $P < 0.05$ according to the LSD multiple-range test at the 95.0% confidence level.

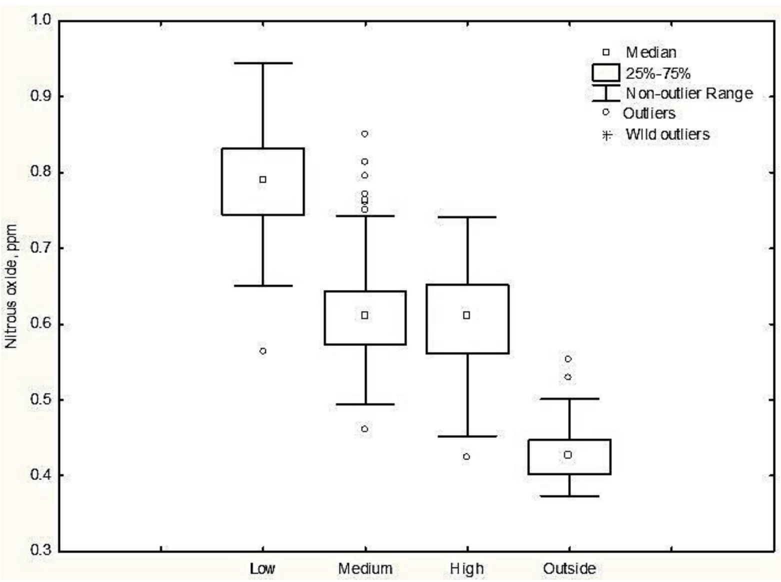

Figure 2. Nitrous oxide concentration in ppm.

Carbon dioxide

An effect of ventilation system intensity on the CO_2 concentration in the piggery was found. The obtained results are shown in the Table 2 and Fig. 3. Some differences were found between outside concentration, low, medium and high ventilation system intensities. Statistically significant differences were found between all ventilation system intensities. Increased ventilation system intensity reduces the carbon dioxide concentration in the pig barn.

Table 2. Selected parameters of summarized statistics of CO_2 concentration

Intensity of ventilation	Count	Average	Coeff. of variation	Minimum	Maximum	Range
Outside	80	549.964 ^{a}	6.6877%	484.694	628.159	143.465
Low	121	816.341 ^{b}	9.5548%	709.136	1530.01	820.877
Medium	121	744.042 ^{c}	9.4594%	648.061	1239.21	591.15
High	121	714.032 ^{d}	8.2319%	529.032	867.433	338.402

Note: Different letters in the average value column ($^{a,\ b,\ c,\ d}$) indicate that the means are significantly different at $P < 0.05$ according to the LSD multiple-range test at the 95.0% confidence level.

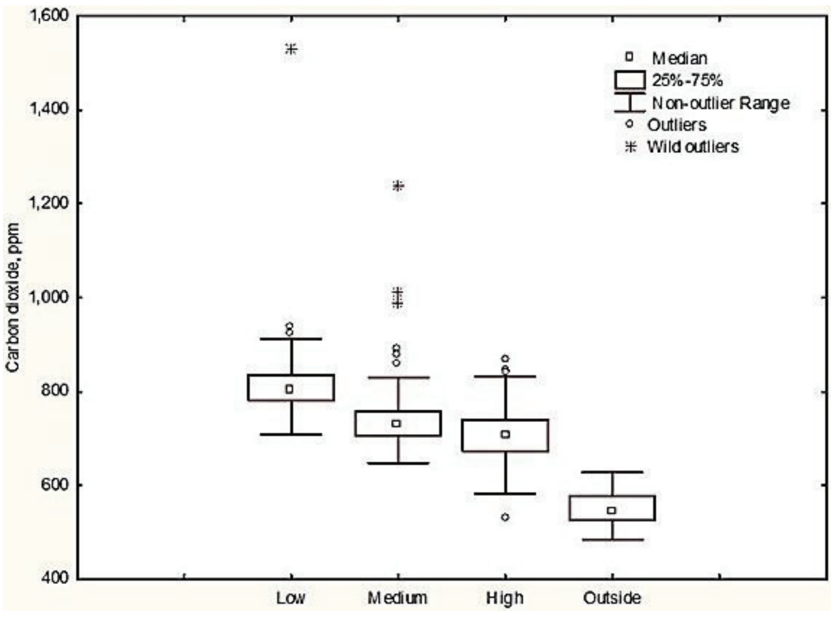

Figure 3. Carbon dioxide concentration in ppm.

Ventilation system intensity had a significant effect on the carbon dioxide and nitrous oxide concentrations in the piggery. Such results confirm our previous results (Dubeňová et al., 2011a; Dubeňová et al., 2011b) and the results obtained by Mihina et al. (2012), where the concentrations of the gases varied depending on the ventilation rate as well as Topisirovic (2007), where the dust concentrations were measured. Carbon dioxide was reduced by increasing the suction rate for all levels of intensity. Nitrous oxide was reduced by increasing the suction, but differences between the medium and high ventilation system intensities were not statistically significant. Similar effects were found (Dubeňová et al., 2013) for the ammonia gas concentration in the piggery for lactating sows with their piglets.

CONCLUSIONS

The paper covered analyses on the effect of ventilation system intensity on the concentrations of CO_2 and N_2O in the piggery for fattening pigs of the Large White breed at the Experimental Centre for Livestock at the Department of Animal Husbandry, Faculty of Agrobiology and Food Resources, the Slovak University of Agriculture in Nitra, Slovakia. A photoacoustic field gas monitor INNOVA 1412 connected to a multipoint sampler INNOVA 1309 were used for measurement of the nitrous oxide and carbon dioxide concentrations. Low, medium and high intensities of the ventilation system was used.

Ventilation system intensity showed a significant effect on the carbon dioxide and nitrous oxide concentrations in the piggery. Carbon dioxide was reduced by increasing the suction rate for all levels of intensity. Nitrous oxide was reduced by increasing the suction rate, but differences between the medium and high ventilation system intensities were not statistically significant. The results of our investigations confirmed that ventilation systems are useful in piggeries including the possibility to optimize gas concentrations and create better welfare for pigs.

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REFERENCES

Aneja, V.P., Blunden, J., James, K., Schlesinger, W.H., Knighton, R., Gilliam, W., Niyogi, D. & Cole, S., 2007. Ammonia assessment from agriculture: status and national needs. In: Monteny, G.-J., Hartung, E. (Eds.), Ammonia Emissions in Agriculture. Wageningen Academic Publishers, Wageningen, pp. 44–51.

Brown, L., Armstrong-Brown, S., Jarvis, S.C., Syed, B., Goulding, K.W.T., Phillips, V.R., Sneath, R.W. & Pain, B.F. 2001. An inventory of nitrous oxide emissions from agriculture in the UK using the IPCC methodology: emission estimate, uncertainly and sensitivity analysis. *Atmospheric Environment* **35**, 1439–1449.

Cabaraux, J.F., Philippe, F.X., Laitat, M., Canart, B., Vandenheede, M. & Nicks, B. 2009. Gaseous emissions from weaned pigs raised on different floor systems. *Agriculture, Ecosystems and Environment* **130**, 86–92 .

Dubeňová, M., Gálik, R., Mihina, Š., Boďo, Š. & Šima, T. 2011a. Vplyv hmotnosti ošípaných na koncentráciu amoniaku vo vybranom objekte počas zimného obdobia. *Technics in Agrisector Technologies 2011: Proceedings of Scientific Works*. FE SUA in Nitra, 20–24.

Dubeňová, M., Gálik, R., Mihina, Š. & Krištof, K. 2011b. Monitorovanie koncentrácie škodlivých plynov v objekte pre výkrm ošípaných. *Rural buildings 2011: Proceedings of Scientific Works*. FE SUA in Nitra. 26–30.

Dubeňová, M., Gálik, R., Mihina, Š. & Šima, T. 2012. Nitrous oxide and carbon dioxide concentration in farrowing pens with permanent limited range of motion for lactating sows. *Poljoprivredna tehnika* **37**, 101–109.

Dubeňová, M., Gálik, R., Mihina, Š. & Šima, T. 2013. Ammonia concentration in farrowing pens with permanent limited range of motion for lactating sows. *Res. Agr. Eng.* **59**, Special Issue, S9–S14.

European Environment Agency, 2010. European community emission inventory report 1990-2008 under the UNECE convention on long-range transbondary air pollution. European Environment Agency, Copenhagen, Denmark.

Freibauer, A. & Kaltschmitt. 2001. *Biogenic Greenhouse Gas Emissions from Agriculture in Europe*. University of Stuttgart, 220.

IPCC, 2001. In: *Houghton, J. T., et al. (Eds.), Climate Change 2001*: The Scientific Background, vol. 94. Cambridge University Press, Cambridge, UK.

IPCC, 2007. Climate Change 2007: The Physical Science Basic. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univesity Press, Cambridge, United Kingdom/New York, NY, USA.

Karandušovská, I., Mihina, Š., Boďo, Š. & Reichstädterová, T. 2011. Produkcia amoniaku a skleníkových plynov v zmodernizovanom objekte ustajnenia dojíc v letom období. *Rural buildings 2011: Proceedings of Scientific Works*. FE SUA in Nitra. 44–50.

Kroupa, S.V. 2003. Effects of atmospheric ammonia (NH_3) terrestrial vegetation: a review. *Environmental Pollution* **124**, 179–221.

Mihina, Š., Karandušovská, I., Lendelová, J. & Boďo, Š. 2011. Produkcia škodlivých plynov v objektoch pre výkrm ošípaných s rôznym spôsobom odstraňovania hnoja. *Rural buildings 2011: Proceedings of Scientific Works*. FE SUA in Nitra. 84–92.

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**. 395–406.

Monteny, G.J., Bannink, A. & Chadwick, D. 2006. Greenhouse gas abatement strategies for animal husbandry. *Agriculture, Ecosystems and Environment* **112**, 163–170.

Palkovičová, Z., Knížatová, M., Mihina, Š., Brouček, J. & Hanus, A. 2009. Emissions of greenhouse gases and ammonia from intensive pig breeding. *Folia Veterinaria* **53**, 168–170.

Pedersen, B. & Ravn, P. 2008. Characteristics of floors for pig pens: friction, shock absorption, ammonia emission and heat conduction. *Agricultural Engineering International: CIGR Ejournal,* 10.

Philippe, F.X., Laitat, M., Canart, B., Vandenheede, M. & Nicks, B. 2007a. Comparison of ammonia and greenhouse gas emissions during the fattening of pigs, kept either on fully slatted floor or on deep litter. *Livestock Science* **111**, 144–152.

Philippe, F.X., Laitat, M., Canart, B., Vandenheede, M. & Nicks, B. 2007b. Gaseous emissions during the fattening of pigs kept either on fully slatted floors or on straw flow. *Animal* **1**, 1515–1523.

Philippe, F.X., Cabaraux, J.F. & Nicks, B. 2011. Ammonia emissions from pig houses: Influencing factors and mitigation techniques. *Agriculture, Ecosystems and Environment* **141**, 245–260.

Šima, T., Nozdrovický, L., Krištof, K., Dubeňová, M. & Macák, M. 2012a. A comparison of the field and laboratory methods of measuring CO_2 emissions released from soil to the atmosphere. *Poljoprivredna tehnika* **37**, 63–72.

Šima, T., Nozdrovický, L., Krištof, K., Dubeňová, M., Krupička, J. & Králik, S. 2012b. Method for measuring of N_2O emissions from fertilized soil after the using of fertilizer. *Poljoprivredna tehnika* **38**, 51–60.

Šima, T., Nozdrovický, L., Krištof, K., Dubeňová, M. & Krupička, J. 2013a. Effect of the nitrogen fertiliser rate on the nitrous oxide flux from haplic luvisol soil in the laboratory experiment. *Agronomy Research* **11**, 97–102.

Šima, T., Krupička, J. & Nozdrovický, L. 2013b. Effect of nitrification inhibitors on fertiliser particle size distribution of the DASA® 26/13 and Ensin® fertilisers. *Agronomy Research* **11**, 111–116.

Šima, T., Nozdrovický, L., Krištof, K., Dubeňová, M. & Krupička, J. 2013c. Effect of the vertical and horizontal soil tillage technology to nitrous oxide flux from soil. *Trends in agricultural engineering 2013,* proceeding of CULS in Prague, 586–589.

Šima, T. & Dubeňová, M. 2013. Effect of crop residues on CO_2 flux in the CTF system during soil tillage by a disc harrow Lemken Rubin 9. *Res. Agr. Eng.* **59**, Special Issue, S15–S21.

Topisirovic, G. & Radivojevic, D. 2005. Influence of ventilation systems and related energy consumption on inhalable and respirate dust concentrations in fattening pigs confinement buildings. *Energy and Buildings* **37**, 1241–1249.

Topisirovic, G. 2007. Influence of underpressure forced ventilation systems on dust concentration distribution in weaning pigs. *DustConf 2007 How to improve air quality*. International Conference in Maastrich, The Netherlands 23–24 April 2007.

Topisirovic, G., Radojičic, D. & Dražic, M. 2010a. Mogućnosti poboljšanja efektada rada ventilacionog sistema u odeljenjima prasilište i odgajalište na farmi svinja 'Farkaždin'. *Poljoprivredna tehnika* **35**, 5–16.

Topisirovic, G., Radojičic, D. & Radivojevic, D. 2010b. Predlog poboljšanja ambijentalnih uslov u objektima za tov svinja na farmi 'Vizelj'. *Poljoprivredna tehnika* **35**, 17–25.

Zavattaro, L., Grignani, C., Acutis, M. & Rochette, P. 2012. Mitigation of environmental impacts of nitrogen use in agriculture. *Agriculture, Ecosystems and Environment* **147**, 1–3.