EFFECT OF MICROCLIMATE PARAMETRES ON THE CONCENTRATION OF HARMFUL GASES DURING VARIOUS PERIODS OF THE DAY IN DAIRY CATTLE HOUSING

ANDREA STRMEŇOVÁ[1]*, JANA LENDELOVÁ[2], ŠTEFAN MIHINA[1,2], ŠTEFAN BOĎO[2], ĽUBOMÍR BOTTO[1], MATÚŠ BOŠANSKÝ[2], RASTISLAV JURČÍK[1], JAN BROUČEK[1], MICHAL UHRINČAŤ[1]
[1]*National Agricultural and Food Centre - Research Institute for Animal Production Nitra, Hlohovecká 2, 951 41 Lužianky, Slovakia*
[2]*Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia*

This study was conducted to determine the impact of climate parameters (temperature-T, relative humidity-RH) on concentrations of harmful gases (carbon dioxide-CO_2, methane-CH_4), and ammonia-NH_3 which have negative impact on atmosphere. We performed the measurements during 2 days in spring in an open barn for Holstein dairy cows. Two measuring places were focused. The first measuring place (MP1) was located between heads of animals in the lying area (calm, urinating). The second measuring place (MP2) was in the feeding area (activities, draft). Concentrations of gases were recorded by INNOVA Multi Gas Monitor 1312. Microclimate parametres were measured by two instruments located in MP1 and MP2. We chose 3 hypotheses: Has T and RV negative impact on concentration of harmful gas? Will significant differences incurred by comparing two measuring places? Will significant differences incurred by comparing all periods? We divided recorded daily data into 2 parts: daytime (8am-8pm) and nighttime (8pm-8am) measurements and we compared them with each other. There were found, that T and RH had regression significant relationship with the concentration of CO_2, NH_3 and CH_4 on the second day in MP1 (T:$P<0.01$; RH:$P<0.05$). Ammonia was significantly impacted by T and RH also in MP2 (T:$P<0.01$; RH:$P<0.05$). Subsequently, we found statistically significant differences by comparing all four periods in CO_2 and CH_4 ($P<0.05$). The nightime period of both days had significant differences only for ammonia concentration. Comparing the measuring place, there were found statistically significant differences in methane ($P<0.05$) and ammonia concentrations ($P<0.001$). Hypotheses were partially confirmed. We concluded that increasing T and RV has negative effect on the concentration of gases in dairy cow housing. This research has also shown the importance of the location of dairy cows in the barn, which decides about what concentration of gas, at that location, could have an adverse impact on dairy cow.

Keywords: harmful gases, carbon dioxide, ammonia, methane, greenhouse effect

INTRODUCTION

The impact of livestock production on emissions growth is undeniable. In 2012, agriculture produced emissions expressed in terms of CO_2 equivalents accounted for only 7.3 % of all greenhouse gas emissions in SR (without LULUCF), thus it can be concluded that agriculture is only a minor contributor to greenhouse gas emissions (Kročková, 2015). The most significant harmful gases include carbon dioxide, methane (global warming effect), and ammonia (without influence on climate change), which has negative effect for health of animals and staff.

Greenhouse gases have mechanically, immunosuppressive, infection, or allergenic impact on animals. These effects may even worsen climatic conditions such as temperature and humidity (Vučemilo et al., 2007).

Microclimate and ventilation is important factor that identify quality of air in livestock buildings. Particularly in terms of removing harmful gases and ensure thermal comfort and control environment by ventilation. Such ventilation affects indoor microclimate parameters and assits the maintenance of a comfortable environment for dairy cattle (Teye, 2008).

Ventilation emissions from livestock could be regarded as a pollution source since it is during the ventilating proces that ammonia and other contamminants are transferred into the atmosphere by exhausted air throught of forced or natural ventilation (Jongebreur et al., 2003).

The temperature can be treated as a key factor due to its higher positive impact on ammonia emission if compared to that frequency of manure removal, floor condition and cleaning, feeding cow activity (Zhang et al., 2005) The emission rates were dependent on floor type and manure-handling method. The lowest ammonia emission was found for buildings with solid floors with smooth surface, drain and scraper (Zhang et al., 2005). The microclimate, or surrounding air, contains oxygen for the cow's metabolism and is the medium for the transport of excess heat, water vapour, and gases emitted by the animals, and of gases from the decomposition of manure, and other particulate matter.

To reduce NH_3 emission from cowshed, it is important to manage air circulation and optimize the inner temperature control, especially at higher temperatures, preventing the warm ambient air from blowing straight to manure. Decrease in mean annual temperature of 1 °C would reduce the annual ammonia emission of 5.0 % (Bleizgys et al., 2013). Moreover, the application of chemical agents is also proposed as a mean to reduce emissions from manure at high temperatures (Van der Stelt et al., 2007). Reduction of dairy building temperature will reduce pH and biological activities that create ammonia in the manure (Teye & Hautala, 2008).

Air exchange rates in some buildings depend on the temperature gradient and the wind. The release rates of pollutants may depend on external and uncontrollable parameters such as wind speed (Ngwabie et al, 2009). Fluctuation of seasonal temperature and initial surface pH played important roles in the amount of NH_3 volatilized (J. Mulvaney et al., 2008)

Specific risk occurs when temperature exceeds 20 °C, an increase in temperature of 1 °C contributes to the intensity of ammonia emission by 17 $mg.m^{-2}.h^{-1}$ (Bleizgys et al., 2013).

In the past decade, interest in cold naturally ventilated dairy buildings has increased because of their lower investment, construction and maintenance costs (Kivinen et al., 2004)

The velocity profile and gas distribution measurements showed that a insulated roof is needed in naturally ventilated dairy buildings to prevent recooling and re-circulation of the air in the building. Suitable roof insulation can´t only prevent the condensation of moisture at the roof level, which leads to rust and mold in dairy cows buildings, but it can improve the exchange of air in the building as well. (Teye, 2008).

MATERIALS AND METHODS

Experiment was held from 4.6 to 6.6 2013 in uninsulated cowshed. The stall, contained of 750 cows, was divided to 4 sections with dimensions- 14 x 65 m. There were wind barriers, on the sides, that ensure thermal and comfort behavior and of animals. Days were divided into two 12 hours long periods, where period 1 and 3 amounted day time (DT) and 2 and 4 was nigh time (NT). We distributed detectors of noxious gases on 2 places measuring place 1 (MP1) and measuring place 2 (MP2). MP1 was in the right feeding place, MP2 in the middle of 2 rows of cowshed. To measure c of CO_2, NH_3 and CH_4 we use Multigas Monitor-INNOVA1312. Since we also measured air T, air velocity, and RV we used the Comets. We have set three hypothese: Temperature (T) and relative humidity (RH) have the effect of increasing c of harmful gases in the stable. Various gas c affect on animals at various places in the stable. Gas c are different between different periods of the day.

RESULTS AND DISCUSSION

We focused on measuring and comapring concentrations of CO_2, NH_3 and CH_4, during 2 normal spring days. In Tayes experiment (2008), the average indoor air concentration for carbon dioxide was 950 ppm, for ammonia 5 ppm, for methane 48 ppm, for relative humidity 70 % (Teye & Hautala, 2008).

Our measured average concentration of carbon dioxide was 978.9 ppm, for ammonia it was 6.67 ppm, for methane it was 46.7 ppm and average of relative humidity was about 72.39 %. Measurements were quite similar.

Although the concentrations of NH_3 and CH_4 did not reach high values as CO_2, It is important to notice, when there was an increase in concentrations that reached an unacceptable level and we might not prevent it.

There were found, that T and RH had regression significant relationship with CO_2, NH_3 and CH_4 on the 2nd day in MP1 (T:P<0.01; RH:P<0.05). Ammonia was significantly impacted also in MP2 (T:P<0.01; RH:P<0.05) (MP1- T:c: 17,04±2,11 vs. 10,89±4,69, P<0,05). In our research had these two gases also similar increasing and decreasing trend.

Subsequently, we found substantial differences by comparing all four periods in CO_2 and CH_4 (P<0.05). Only for ammonia concentrations had the nightime period of both days significant differences. Powel (2008) said that cooler nighttimes did not result in lower ammonia emissions than daytime temperatures. We evaluated the opposite. Colder nights have been shown to lower concentrations in all gases and both days (Tab 1.).

Table 1.: Average concentracions of noxious gases in daytime and nightime period (x ± SD) ($mg.m^{-3}$)

	DT average ± SD	NT average ± SD	Significance between periods
CO_2	2420,50±658,97	1716,50±525,11	0,0447 *
NH_3	15,43±9,11	6,89±3,55	0,0069 **
CH_4	61,93±29,89	25,61±12,13	0,0013 ***

SD = standard deviation *P<0.05; **P<0.01, ***P<0.001, DT- day time period, NT- night time period

Cumulative CO_2 emissions were about 14-58 % of total deposited C and the cumulative CH_4 emissions were significantly higher at 25 °C than at all other temperatures in research of Pereira (2012). It was concluded that increasing temperature from 5 to 35 °C significantly increased potential NH_3, CO_2 and CH_4 emissions but did not significantly influence N_2O emissions. Temperature increasing and RH decreasing in our experiment, caused an increase in the concentrations of all gases. With decreasing values occured the decrease of concentration.

Throught the analysis of variance by comparison of MP1 and MP2 there were detected statistically significant differences in methane (1. day - MP1:MP2 - 45,88±19,54 vs. 29.74±9.33, P<0.001, 2. day – MP1:MP2 - 44.271±28.689 vs. 30.01±15.67, P<0,05) and ammonia concentrations (1. day – MP1:MP2 - 10.889±4.6961 vs. 3.6054±0.8853, P<0.001, 2. day – MP1:MP2 - 11.159±8.0635 vs. 3.4079±0.4808, P<0.001).

Table 2.: Average concentration of noxious gases on MP1 and MP2 (x ± SD) ($mg.m^{-3}$)

	MP1 average ± SD	MP2 average ± SD	Significance between periods
CO_2	2121,50±587,88	1856,50±391,74	NS
NH_3	10,89±4,69	3,6±0,89	0,0000 ***
CH_4	45,88±19,54	29.74±9.33	0,0007 ***

SD = standard deviation *P<0.05; **P<0.01, ***P<0.001, MP1 – measuring place 1, MP2 – measuring place 2, NS – non significant

In (Tab 2.) is reported average concentration of noxious gases on MP1 and MP2 . We conclude that, in most cases, MP1 (in the feeding area) had higher concentrations of all gases, mainly on the ground that there were constantly identify cows in the feeding area, while there were staying cows especially after feeding and at night in lying area. When concentrations showed about the same level on both places in some cases, we tried ambulatory measurement of air velocity and found that at larger drafts the higher higher concentrations from MP1 was scattered into space of cowshed. A strong positive correlation was found between the enhanced CO_2 and CH_4 concentrations (Ngwabie, 2009). In our research had these two gases also similar increasing and decreasing trend.

CONCLUSION

We recorded the impact of the relative humidity to increase c of noxious gases so that when T increased and RH decreased, gas c rised. We found that under the impact of emissions on animals, there is a difference in the c of harmful gases between MP1 and MP2. Also, we found the difference in concentrations during the day and at night. The farmers would be substantial to reduce the effect of these gases on animals and improve air quality in stabling, thus ensuring sufficient welfare and health, for Which animals "reciprocate" the quality products. Hypotheses were partially confirmed.

Acknowledgement

This article was supported by the Ministry of education, Science, Research and Sport of the Slovak Republic by the grant Vega and also by the Slovak Research Development Agency under the contract No. APVV-0632-10.

LITERATURE

Bleizgys, R., Bagdonienė, I., BaleDentienė L, 2013, Reduction of the livestock ammonia emission under the changing temperature during the initial manure nitrogen biomineralization. The Scientific World Journal, Volume 2013, 7 p.

Jongebreur, A.A., Monteny, G.J., Ogink, N.W.M, 2003, *Livestock Production and Emission of Volatile Gases. In International Symposium on Gaseous and Odour 1 Emissions from Animal Production Facilities, 1-4 June 2003, 11-30. Horsens, Denmark: CIGR, EurAgEng, NJF.*

Kivinen, T., 2004, Visions for buildings and systems for dairy production in Finland in year 2010. In NJF – Report No. 337 Seminar No. 337-Technology for milking and housing of dairy cows Hamar, Norway, 11 – 13 Feb 2002, 2004.

Kročková, B., 2015, Emisie skleníkových plynov z poľnohospodárstva, Bratislava:SHMÚ. Available on the internet:http://enviroportal.sk/indicator/detail?id=704&print=yes (2015-01-15).

Mulvaney, M.J., Cummins, K.A., Wood C.W., Wood, B.H., Tyler, P.J., 2008, Ammonia Emissions from Field-Simulated Cattle Defecation and Urination. J. Environ. Qual. 37, p. 2022–2027.

Ngwabie, N.M., Jeppsson, K.H, Nimmermark, S., Swensson, C., Gustafson, G. 2009. Multi-location measurements of greenhouse gases and emission rates of methane and ammonia from a naturally-ventilated barn for dairy cows. Biosystems Engineering, Volume 103, Issue 1, p. 68-77.

Pereira, J.L., Misselbrok, T.H., Chadwick, D.R., Coutinho, J., Trindade, H., 2012, Effects of temperature and dairy cattle excreta characteristics on potential ammonia and greenhouse gas emissions from housing: A laboratory study. Biosystem Engineering, Volume 112, Issue 2, p. 138-150.

Powell, J. M., Misselbrook, T.H., Casler, M.D., 2008, Season and Bedding Impacts on Ammonia Emissions from Tie-stall Dairy Barns, Journal of Environmental Quality, Volume 37, . 37:7–15

Teye, K.F., Hautala, M., 2008, Adaptation of an ammonia volatilization model for a naturally ventilated dairy building. Atmospheric Environment, 42(18), p. 4345-4354.

Teye, K.F., 2008, Microclimate and gas emissions in dairy buildings: Instrumentation, theory and measurements. Helsinki University Printing House, p. 65.

Van der Stelt, B., Temminghoff, E.J.M., Van Vliet, P.C.J., Van Riemsdijk, W.H., 2007, Volatilization of ammonia from manure as affected by manure additives, temperature and mixing. Biosource Technology, Volume 98, Issue 18, p. 3449-3455.

Vučemilo, M., Matković, K., Vinković, B., Jakšić, S., Granić, K., Mas, K. 2007. The effect of animal age on air pollutant concentration in a broiler house, Czech J. Anim. Sci., roč. 52, 2007, č. (6), s. 170 – 174.

Zhang, G., Strøm, J. S., Li, B., Rom, H. B., Morsing, S., Dahl, P., Wang, C., 2005, Emission of Ammonia and Other Contaminant Gases from Naturally Ventilated Dairy Cattle Buildings. Biosystems Engineering 92, 355-364.