doi: 10.17221/21/2015-RAE

Impact of construction and technological solution of dairy cows housing on production of ammonia and greenhouse gases in winter

I. Karandušovská[1], Š. Mihina[2], M. Bošanský[1]

[1]*Department of Structures, Faculty of Engineering, Slovak University of Agriculture in Nitra, Nitra, Slovak Republic*

[2]*Department of Production Engineering, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovak Republic; National Agricultural and Food Centre, Nitra, Slovak Republic*

Abstract

Karandušovská I., Mihina Š., Bošanský M. (2015): **Impact of construction and technological solution of dairy cows housing on production of ammonia and greenhouse gases in winter**. Res. Agric. Eng., 61 (Special Issue): S13–S20.

The aim of this experiment was to analyze the changes of ammonia production and greenhouse gases in frequent type of stables for dairy cows in winter. Two analyzed stables were situated side by side, one of which is after reconstruction of housing and ventilation technology and the second stable remained in original state. Variances of the mass concentration of gases differed significantly ($P < 0.05$), and the production of all gases monitored in winter was higher in the original stable. The average ammonia production was 2.45 ± 1.9 mg/m^3 in the reconstructed stable, while in the original stable it was 5.1 ± 2.7 mg/m^3. Average CO_2 production was nearly twice higher in the unreconstructed building, namely 2,045.5 ± 862.3 mg/m^3, while in the renovated facility it was 1,254.2 ± 416.2 mg/m^3 ($P < 0.05$). The described type of reconstruction provides increased comfort for animals, which gives rise to a significant increase in production parameters, but also allows up to twice the reduction of hazardous pollutants such as CO_2 and ammonia.

Keywords: pollutants; methane; dairy housing; microclimate

The negative consequences of intensive livestock production are excessive waste products such as manure, slurry, poultry droppings and gaseous emissions. Thus, agriculture is a major producer of toxic ammonia and greenhouse gases CH_4, CO_2, N_2O, NO_x, H_2S and other odorous gases (Knížatová et al. 2007). Increasing demands on the quality of animal products make it necessary to deal with the improving of animal housing conditions, which include mainly microclimate conditions of the environment such as temperature and humidity (Balková, Pogran 2009). Monitoring and reduction of emissions of greenhouse gases must also be ensured (Pogran et al. 2011). Technological and construction solutions affect the emission generation secondarily, but they have a significant impact on the formation of the internal environment, which is characterized by air space of stall, indoor temperature and indoor humidity. It is possible to choose few different procedures to

Supported by the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences – VEGA, Grants No. 1/0609/12 and No. 1/0575/14. The photoacoustic multi-gas monitor used for continuous measurement of gas concentrations was purchased through the project Operational Programme Research and Development NFP 26220220014 – ITEPAG.

doi: 10.17221/21/2015-RAE

influence the production of pollutants in stalls. An appropriate housing technology and microclimate control can influence one or more factors that play a role in the production and release of ammonia (Knížatová et al. 2006). Boďo (2013) reports the analysis results concerning the impact of ventilation technology on reduction of emissions, indicating the importance of optimizing the flow of air in the building. The source of gaseous emissions, however, is the animal itself and the processes of digestion, excrement decomposition and breathing. In stalls for cattle, ammonia is composed primarily of urea contained in urine (Aarnik et al. 1993). Ruminants cannot utilize the nitrogen of feed effectively and its excess is excreted in urine and feces. About 25–35% of nitrogen received from feed is stored in the milk (Chase 1994; Chandler 1996) and almost all the remaining nitrogen is removed from the body by excrements. Ammonia is considered a threat to the environment. By prolonged exposure at high concentrations it has a negative impact on animals and staff and due to emissions into the environment it influences the acidity of rainfall. Ammonia concentrations and greenhouse gases in the barn air mainly depend on the age and live weight of animals, the composition of feed and microclimate conditions (Knížatová et al. 2006).

MATERIAL AND METHODS

The photoacoustic multi-gas monitor (Innova AirTech Instruments, Ballerup, Denmark) with multi-channel sampling system 1309 was used to mesure gas concentrations. This equipment was installed in two buildings, one of which was reconstructed and the other is in original condition. One measuring device was used; it was installed separately in each stable. Both stables are oriented towards northeast–southwest along the longitudinal axis and the distance between them is 18 m. In Fig. 1 is shown ground plan of reconstructed dairy cows housing.

The cows in this stable stable, with the same floor size and height of the roof, are housed in comfortable cubicle lyings with a length of 2.5 m and a width of 1.2 m, which are located at the external walls in two rows and the manure corridor is between them. The feeding passes are in the middle of the stall. The width of manure corridors was reduced from the original 2.6 m to 2.2 m, and straw bedding was replaced by the solid part of separated slurry. The produced liquid manure and urine are continuously removed by a hydraulic blade scraper into the cross-channel and from there to the two-chamber pumping sump and then to a slurry separator where the liquid is separated from the solid part. The liquid part – slurry is pumped into above-ground storage tanks and the solid part is sprinkled from the separator into the transport mechanism and is used as litter for the cubicle lyings in the cowshed. The reconstructed building has longitudinally opened walls, and all large openings are protected by a net against birds and windy weather with the system of six hexagonal holes. New "windows" are closable by the controllable system from a height of 600 mm above the ground. The natural ventilation system

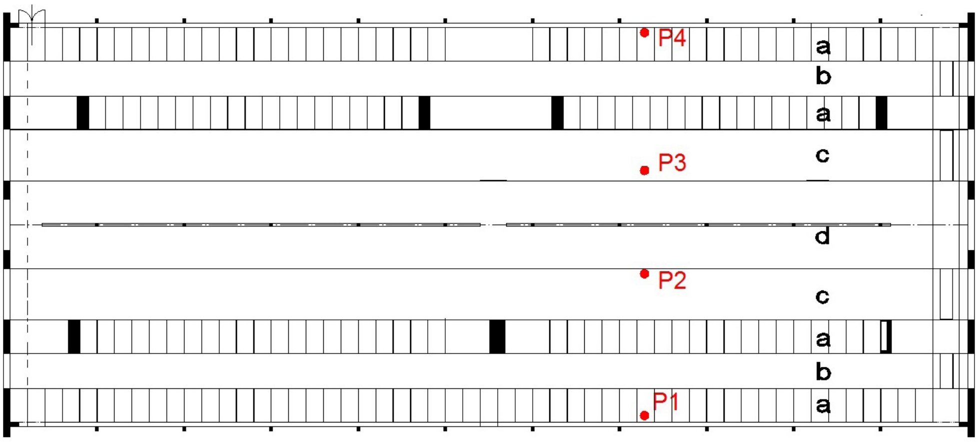

Fig. 1. Ground plan of reconstructed dairy cows housing with air sampling locations

a – cubicles; b – manure corridor; c – feeding area (with liquid manure); d – feeding passage; P1 – measuring point in the cubicle; P2 – measuring point in the feeding area (with liquid manure); P3 – measuring point in the cubicle; P4 – measuring point in the manure corridor

doi: 10.17221/21/2015-RAE

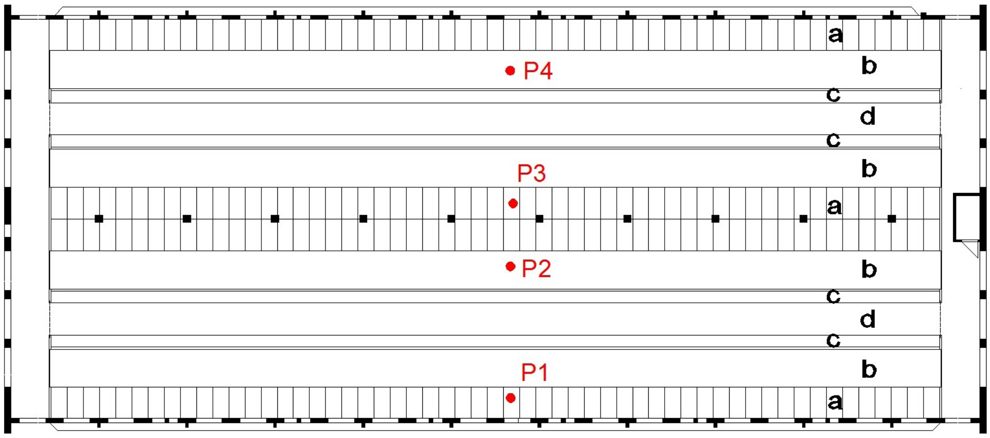

Fig. 2. Ground plan of unreconstructed dairy cows housing with air sampling locations

a – cubicles; b – manure corridor; c – feeding gutter; d – feeding passage; P1 – measuring point in the cubicle; P2 – measuring point in the manure corridor; P3 – measuring point in the cubicle; P4 – measuring point in the manure corridor

was made more effective by changing the original skylight ridge to a continual ridge opening 0.850 m wide, 56 m in length, which was covered by a shelter against rainfall. Compared to the original roof vents – the area for discharging of pollutants by roof covering is eightfold increased. Doors in the gable wall were enlarged across the board by 31% summarily; the window opening area is seven times larger. There occurred up to 4.7 times improvement in removal of pollutants from the building by increased air exchange (at a speed of 0.2 m/s). At the time of the experiment, there were housed 140 heads of dairy cows with an average weight of 600 kg. The measuring points of livestock gases production were at four locations: P1 – cubicle, P2 – feeding area (with liquid manure), P3 – cubicle, P4 – manure corridor (Fig. 1).

In the original stable, is shown in Fig. 2, with a ground floor of 66.2 m × 27.3 m, height of the side walls 2.9 m, and ridge height of 4.7 m, dairy cows were housed in four rows of loose cubicle lying, two are located at the circumferential walls with dimensions of 1.1 × 2.1 m and two opposed rows are in the middle of the housing with dimensions of 1.1 × 2.15 m. There were installed 19 windows (with dimensions of 0.9 × 0.8 m) on each side of the building at a height 1.6 m. Natural ventilation was provided by 12 openings (0.7 × 0.7 m) in skylight in the roof ridge. Six equal doors (2.7 × 3.1 m) were installed on both gable walls that allow improving the natural ventilation by their partial opening in the transition period, and at complete removal in summer. There were housed 140 dairy cows with an average weight of 600 kg. The manure corridors with a width of 2.6 m are along the boxes, from which manure is removed by a universal loader to drained concrete surfaces in front of the building, followed by shoveling of manure. Feeding is situated opposite the cubicle lyings. The width of the feeding gutter is 0.95 m. Through corridors of width 2.2 m are between the feeding gutters. It is loose housing with straw litter. The measurement of gas production was conducted at four locations: P1 – cubicle, P2 – manure corridor, P3 – cubicle, P4 – manure corridor (Fig. 2). Measurement locations were chosen with regard to the construction dispositional solution of each stable and by expecting the largest gas production in selected points. The distance of measuring points from the gable wall of the building was therefore not the same in both buildings, but places was chosen predominately in the highest concentration of animals.

RESULTS AND DISCUSSION

In the reconstructed loose housing system for dairy cows with the litter of separated slurry, concentrations of ammonia (NH_3) and greenhouse gases (CO_2, N_2O, CH_4) were obtained in four monitored locations P1, P2, P3 and P4. At the same time, indoor temperature and indoor humidity were recorded using the Comet system. Measured data were stored in a database continuously at five-minute intervals during the experiment. Table 1 gives an overview of the average, max. and min. values of monitored gas concentrations evaluated from all observed points in the renovated building. The

doi: 10.17221/21/2015-RAE

Table 1. Evaluation of monitored gas concentrations in the measuring points P1–P4 in the reconstructed stable /mg/m^3)

		NH_3	CO_2	N_2O	CH_4
P1 – cubicle	mean value	1.98	1,186.08	1.14	11.23
	standard deviation	1.08	326.62	0.17	10.03
	minimum	0.40	668.94	0.79	1.22
	maximum	11.28	3,700.30	2.23	156.63
	number	1,868	1,868	1,868	1,868
P2 – feeding area (with liquid manure)	mean value	3.20	1,261.56	1.17	15.30
	standard deviation	3.46	523.99	0.34	24.29
	minimum	0.64	787.00	0.84	1.71
	maximum	47.15	4,916.80	10.09	612.68
	number	1,868	1,868	1,868	1,868
P3 – cubicle	mean value	1.77	1,205.43	1.18	10.48
	standard deviation	0.81	464.53	0.20	11.43
	minimum	0.56	799.95	0.88	1.25
	maximum	10.83	4,520.60	3.68	134.99
	number	1,867	1,867	1,867	1,867
P4 – manure corridor	mean value	2.86	1,363.57	1.20	15.59
	standard deviation	1.52	277.62	0.14	8.82
	minimum	0.54	815.95	0.87	1.66
	maximum	22.13	2,194.00	1.79	65.48
	number	1,867	1,867	1,867	1,867

difference in the amount of NH_3, CO_2, N_2O, and CH_4 concentrations produced in individual measuring points was statistically verified using Statistica. The Tukey's HSD test (Table 2) confirmed a statistically significant difference in the amount of NH_3 concentrations in individual measuring points at the significance level $P < 0.05$. On the basis of test, it can be stated that the variances of the mass concentration of carbon dioxide (Table 2) were significantly different in three places of measurement; significant differences were not recorded in the cubicles (points P1 and P3). In the places P2 (feeding area with liquid manure) and P3 (cubicle), there were no significant differences in the production of nitrous oxide (Table 2). The variances of the mass concentration of methane (Table 2) differed significantly at two monitored points, significant differences were not recorded in the places P1 (cubicle) – P3 (cubicle) and P2 (feeding area) – P4 (manure corridor).

The average concentrations of ammonia during the experiment were below the limit value of 17.6 mg/m^3 = 25 ppm recommended for the environment of animals and workers, but the max. values sometimes exceeded this limit. The min. ammonia concentration (0.40 mg/m^3 = 0.57 ppm) was recorded in the cubicle at 3:00, and the highest ammonia concentration was in the feeding area

Table 2. Differences of amount of NH_3, CO_2, N_2O, and CH_4 concentrations produced in individual measuring points in the reconstructed stable, Tukey's HSD test (*$P < 0.05$)

Amount (mg/m^3)	Measuring point	Average*
NH_3	P3	1.770
	P1	1.9847
	P4	2.8582
	P2	3.2003
CO_2	P1	1,186.0827
	P3	1,205.4331
	P2	1,261.5581
	P4	1,363.5737
N_2O	P1	1.1406
	P2	1.1657
	P3	1.1776
	P4	1.2026
CH_4	P3	10.4843
	P1	11.2339
	P2	15.3043
	P4	15.5886

doi: 10.17221/21/2015-RAE

Table 3. Evaluation of monitored gas concentrations (mg/m^3) in measuring points P1 – P4 in unreconstructed stable

		NH_3	CO_2	N_2O	CH_4
P1 – cubicle	mean value	3.56	2,184.12	1.48	31.28
	standard deviation	1.85	1,216.29	0.56	21.41
	minimum	0.92	893.77	0.85	2.62
	maximum	10.55	9,657.70	9.05	205.48
	number	2,209	2,209	2,209	2,209
P2 – manure corridor	mean value	6.96	1,932.28	1.37	33.43
	standard deviation	2.98	651.18	0.26	16.49
	minimum	1.90	974.31	0.85	4.89
	maximum	25.63	8,099.40	3.51	170.88
	number	2,209	2,209	2,209	2,209
P3 – cubicle	mean value	6.52	2,045.85	1.43	36.62
	standard deviation	1.87	288.05	0.14	8.62
	minimum	2.48	1,050.20	0.92	6.67
	maximum	14.74	3,004.60	2.56	67.28
	number	2,208	2,208	2,208	2,208
P4 – manure corridor	mean value	3.00	2,019.99	1.43	28.18
	standard deviation	1.36	977.69	0.46	21.09
	minimum	1.14	841.68	0.82	3.44
	maximum	10.24	8,878.40	10.38	549.14
	number	2,208	2,208	2,208	2,208

(P2) at early hours 7:44 and it was up to 47.15 mg/m^3, i.e. up to 66.67 ppm. Increased values of ammonia were observed regularly at the time of movement of dairy cows to the milking parlours. Average CO_2 concentrations were below the recommended value of 4,582 mg/m^3 = 2,500 ppm at all measuring points. The min. value of carbon dioxide 668.94 mg/m^3 (364.57 ppm) was recorded at the P1 position – in the cubicle at 16:00. The max. carbon dioxide concentration 4,916.80 mg/m^3 (2,680 ppm) was recorded in the point P2 – feeding area, so it slightly exceeded the recommended threshold limit, and in the point P3 – cubicle the max. value was 4,520.60 mg/m^3 (2,464 ppm). Indoor air temperature at the time of measurement ranged from –4.3°C to 9.0°C, and indoor relative humidity ranged from 51.3% to 83.7%.

In the original stable (unreconstructed) with free housing of dairy cows on straw litter, the measuring of ammonia (NH_3) and greenhouse gases (CO_2, N_2O, CH_4) production was also carried out at four points P1, P2, P3 and P4 (Fig. 2). Table 3 provides an overview of the average, max. and min. values of monitored gas concentrations evaluated from all monitored points in the unreconstructed building. The difference in the amount of NH_3, CO_2, N_2O, and CH_4 concentrations produced at individual measuring points was statistically verified using Statistica. The Tukey's HSD test confirmed a statistically significant difference in the amount of NH_3 concentrations (Table 4) in individual measuring

Table 4. Differences of amount of NH_3, CO_2, N_2O, and CH_4 concentrations produced in individual measuring points in the unreconstructed stable, Tukey's HSD test (*$P < 0.05$)

Gas	Measuring point	Average amount* (mg/m^3)
NH_3	P4	3.0009
	P1	3.5577
	P3	3.5179
	P2	6.9646
CO_2	P2	1,932.2770
	P4	2,019.9938
	P3	2,045.8510
	P1	2,045.8510
N_2O	P2	1.3683
	P3	1.4323
	P4	1.4328
	P1	1.4800
CH_4	P4	28.1805
	P1	31.2760
	P2	33.4259
	P3	36.6178

doi: 10.17221/21/2015-RAE

points at the significance level $P < 0.05$. The production of the mass concentration of carbon dioxide (Table 4) was statistically significantly different between the cubicle and manure corridor at the significance level $P < 0.05$; significant differences were not recorded in the cubicles situated in the middle of the building and manure corridor (points P3 and P4). The HSD test results of nitrous oxide mass concentration were comparable to the test result of CO_2. Variances of methane mass concentration were statistically significantly different in all monitoring points. Average ammonia concentrations were below the limit value of 17.6 mg/m^3 = 25 ppm; the max. value exceeded this threshold in the measuring point P2 – manure corridor. The min. ammonia concentration (0.92 mg/m^3 = 1.3 ppm) was recorded in the cubicle at 1:00 at night and the highest in the manure corridor (P2) in the morning – it was up to 25.63 mg/m^3, which is up to 36.2 ppm. It was in accordance with the results of Saha et al. (2014), where the average NH_3 and CH_4 emissions between 6:00 and 18:00 were by 66% and 33% higher than the average NH_3 and CH_4 emissions between 18:00 and 6:00 respectively for all seasons. Significant seasonal variations of emissions were found for NH_3 and because of the highest emissions in the summer time, it is important to design the max. ventilation rate according to summer requirements. According to Herbut et al. (2014), the lowest NH_3 concentrations were recorded in summer under high air temperatures, low humidity and increased exchange of ventilation rate. During severe frosts in winter, the highest ammonia concentration was noted, caused by limited ventilation. The average concentrations of CO_2 were below the recommended value of 4,582 mg/m^3 = 2,500 ppm in all measuring points in both our tested buildings. The min. value of carbon dioxide 841.68 mg/m^3 (459 ppm) was recorded in the position P4 – manure corridor. However, the max. values exceeded the recommended limit in the place P1 – cubicle, with recorded concentration up to 9,657.70 mg/m^3 (5,263 ppm). The max. value of 8,099.40 mg/m^3 (4,414 ppm) was recorded in the manure corridor (P2), and the max. value of 8,878.40 mg/m^3 (4,839 ppm) was in the manure corridor (P4). Indoor air temperature at the time of measurement ranged from –3.5°C to 10°C and relative humidity of the indoor air from 51.3% to 87.9%.

The Tukey HSD test (Table 5) was carried out to assess the homogenity of variance of gas concentrations in both monitored stables. Based on the test, it can be concluded that the variances of the mass concentration of ammonia, carbon dioxide, nitrous oxide and methane were significantly different at the significance level $P < 0.05$. It means that the production of all gases monitored in winter was higher in the original, unrecostructed stable. The average value of ammonia was 2.45 mg/m^3 in the reconstructed stable, whereas in the original stable it was almost double 5.1 mg/m^3. Average CO_2 production was also higher in the unreconstructed building and it was 2,045.5 mg/m^3, in the rebuilt one 1,254.2 mg/m^3. Mean concentrations of N_2O and CH_4 were lower in the reconstructed housing system compared to the original stable. There was increased comfort of animals and significantly reduced size of the area polluted with exrements due to building reconstruction and changed housing technology. Originally, this area amounted to 1,013 m^2 with the manure storage area; emitting places after reconstruction represented the total area of 779.8 m^2. For practical measurements and calculations, it follows that air quality in terms of production of ammonia and other greenhouse gases was improved even without additional technological adjustments, filters, scrubbers and other (Mels et al. 2006). In accordance with Arogo et al. (2002), in cattle breeding, crucial is the size of areas contaminated with wet feces along with the frequency of manure removal from stables and also air temperature in the stable. The variability of air quality affects the quality of the work environment of dairymen (Žitňák 2011) as well as the litter quality, which also secondarily affects the welfare of animals (Lendelová et al. 2010). The modification of our test stable is based on the reduction of emitting surfaces, frequency of slurry

Table 5. Comparison of amount of NH_3, CO_2, N_2O, and CH_4 concentrations (mg/m^3) produced in the reconstructed and unreconstructed stable, Tukey's HSD test ($P < 0.05$)

Gas	Stabling facility	
	reconstructed	unreconstructed
NH_3	2.4536	5.0094
CO_2	1,254.1538	2,045.5639
N_2O	1.1701	1.4284
CH_4	13.1528	32.3750

doi: 10.17221/21/2015-RAE

Table 6. Allowable concentration values of gases

Gas	(ppm)	(mg/m^3)	Source
NH_3	25	17.6	Decree 230:1998
CO_2	2,500	4,582	Decree 230:1998
N_2O	98	180	Government Decree 45:2002
CH_4	1000	666	Atta (2004)

removal from the building, and temperature control and regulation of ventilation. By reconstruction the original window openings were replaced with large wall openings and ridge openings that allow proportionally improving the air exchange rate based on wind strength, which was elaborated by means of CFD simulations on similar production stables (Bournet et al. 2010). Although it is recommended to use fans in hot summer days to increase the lying time and milk yield (Calegari et al. 2014), the specified ventilation system designed in reconstruction satisfies dairy cows during the greater part of the year. It should be noted that the increased air flow increases the amount of ammonia produced (Bagdoniene et al. 2014). In the summer time in this type of reconstruction, it is possible to maximize the pollutant discharging outside the building throughout all the day.

CONCLUSION

The aim of this experiment was to compare the production of ammonia and greenhouse gases in two buildings of the cows' farm in winter. These stables are situated side by side, one of which is after reconstruction of the housing system and ventilation and the second stable remained in its original state. The purpose of reconstruction was to improve the conditions of animals held and to improve the ventilation and general climatic properties of the indoor environment. Animal welfare should be ensured by litter from separated slurry, rubber mats in the manure corridor, and manure removing by the hydraulic scraper every two hours. Based on the evaluation of measured data and processed analysis, it can be said that the production of ammonia and all monitored gases was higher in the original, unreconstructed housing system, whereby there was not recorded a significant difference in temperature and relative humidity of indoor air in these buildings during the experiment. Recommended limit amounts of gas were not exceeded. The present set of measurements confirmed the impact of construction and technological solutions on the internal environment of the stables and thus the production of harmful gases. From these results it is clear that adequate ventilation of indoor air removes excess carbon dioxide, harmful ammonia and odour gases and improves general climatic conditions.

References

Aarnink A.J.A., Wagemans M.J.M., Keen A. (1993): Factors affecting ammonia emission from housing for weaned piglets. In: Verstegen M.W.A., den Hartog L.A., van Kempen G.J.M., Metz J.H. M. (eds): Nitrogen Flow in Pig Production and Environmental Consequences. Wageningen, Pudoc Scientific Publishers: 286–294.

Arogo J., Westerman P.W., Heber A.J., Robarge W.P., Classen J.J. (2002): Ammonia emissions from animal feeding operations. In: Animal Waste Management White Papers, North Carolina State University, Raleigh, NC (available on CD-ROM from MidWest Plan Service).

Atta A. (2004): Methane Safety. In: Agri-Facts. Practical Information for Agriculture industry. Alberta, Agriculture, Food and Rural Development, Agdex 729-2.

Bagdoniene I., Bleizgys R. (2014): Ammonia emissions from dairy cattle manure under variable ventilation rates. Annals of Animal Science, 14: 141–151.

Balková M., Pogran Š. (2009): Assessment of microclimate parameters in the object for heifers. Acta Technologica Agriculturae, 12: 15–18.

Boďo Š., Gálik R., Mihina Š. (2013): Impact of breeding technology to the production of ammonia emissions and greenhouse gases in buildings for poultry. 1st Ed. Nitra, SUA in Nitra.

Bournet P.A., Boulard T. (2010): Effect of ventilator configuration on distributed climate of greenhouses: A review of experimental and CFD studies. Computers and Electronics in Agriculture, 74: 195–217.

Calegari F., Calamari L., Frazzi E. (2014): Fan cooling of the resting area in free stalls dairy barn. International Journal of Biometeorology, 58: 1225–1236.

Decree of the Ministry of Agriculture No. 230/1998 Z.z. on livestock breeding and killing of animals for slaughter.

Chandler P.T. (1996): Environmental challenges as related to animal agriculture-dairy. In: Kornegay E.T. (ed.): Nutrient Management of Food Animals to Enhance and Protect the Environment. Boca Raton, CRC Press, Inc.: 7–19.

Chase L.E. (1994): Environmental considerations in developing dairy rations. In: Proc. Cornell Nutr. Conf. Feed Manuf., Rochester, Cornell University, Ithaca: 56–62.

doi: 10.17221/21/2015-RAE

Herbut P., Angrecka S. (2014): Ammonia concentrations in a free-stall dairy barn. Annals of Animal Science, 14: 153–166.

Knížatová M., Orság J., Mihina Š., Karandušovská I. (2006): Ammonia in terms a breeder. Modern Mechanization in Agriculture, 9(7).

Knížatová M., Šottník J., Mihina Š. (2007): Production of ammonia and methane emissions from livestock production in the Slovak Republic. In: Air 2007. Brno, Academy of Sciences: 234–238.

Lendelová J., Mihina Š., Pogran Š. (2010): Analysis of utilised bedding materials in cubicles. In: Trends in Agricultural Engineering, Prague, CULS Prague: 389–393.

Melse R.W., van Wagenberg A.V., Mosquera J. (2006): Size reduction of ammonia scrubbers for pig and poultry houses: Use of conditional bypass vent at high air loading rates. Biosystems Engineering, 95: 69–82.

Ordinance of the Government of the Slovak Republic No. 45/2002 Coll. on health protection at work with chemical substances.

Pogran Š., Bieda W., Gálik R., Lendelová J., Švenková J. (2011): The Quality of the Indoor Environment of Housing Objects. 1st Ed. Nitra, SUA in Nitra.

Saha C.K., Ammon C., Berg W., Fiedler M., Loebsin C., Sanftleben R., Amon T. (2014): Seasonal and diel variations of ammonia and methane emissions from a naturally ventilated dairy building and the associated factors influencing emissions. Science of the Total Environment, 468–469: 53–62.

Žitňák M., Lendelová J., Bureš Ľ. (2011): The working environment of milking personnel during the summer time. In: Rural Buildings 2011, Nitra: 165–172.

Recieved for publication March 23, 2015
Accepted after corrections November 16, 2015

Corresponding author:

Ing. Ingrid Karandušovská, PhD., Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Structures, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic; e-mail: ingrid.karandusovska@uniag.sk