REDUCTION OF AMMONIA EMISSIONS FROM LIVESTOCK HOUSING BY BIOTECHNOLOGICAL AGENTS

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Abstract. Livestock farming is one of the biggest sources of ammonia emissions, which are very dangerous for environment. There are many possibilities for ammonia emissions reducing. Using of biotechnological agents is one of the cheapest ways for ammonia emissions decreasing. This article describes the procedure and the results of emissions measurements in a pig house and in a poultry house, where one of enzymatic biotechnological agent was used. Ammonia emissions decreasing in both tests for more than 20 % was proved. Another benefit of the biotechnological agent was shown, too. The fattening period of broilers was reduced and the final weight of pigs was increased in comparison with the reference group without agent application. Better feeding conversions in both tests were proved.

Keywords: ammonia emission, livestock housing, biotechnological agent. enzyme, emission measurement

Introduction

A global trend of the friendlier environment behavior is also to agriculture production focused. In the year of 2013 in the Czech Republic a total amount of ammonia emissions of livestock was 49.9 kt of ammonia including application of manure to arable soil [1]. There were 1.4 million cattle, 1.6 million pigs and 21.4 million poultry in the Czech Republic in 2013 [2]. Overwhelming majority of these animals was bred on large farms with high concentration of animals. Many rules, including the Goetheberg protocol, obliged the Czech Republic to reduce the ammonia emissions from livestock housing by 20 % and from farmyard manure storing and application by 40 %.

There are various possibilities how to reduce the ammonia emissions of livestock farming [3; 4]. One of the cheapest methods is using of biotechnological agents. They can be easily added to feeding, to drinking water or they can be applied to manure. The biotechnological agents have usually some other positive benefits, for example, better feeding conversion, improved health, mortality decreasing and other [5; 6].

Our authorized laboratory measures ammonia emissions from livestock farming for many distributors and producers of biotechnological agents, too. They often use our test results for agent efficiency improving.

The agent efficiency is determined by comparing of emissions from housing where the agent was applied with the emissions from an identical housing without the agent. The 24 hours measurement duration is necessary because all influences of animal behaviours must be included.

The article describes our measurement methodology and biotechnological agent test results, which proved the ammonia emissions decreasing more than 20 % in pig housing and in poultry housing.

Materials and methods

We chose for tests phytase feed enzyme specially developed to increase the digestibility of phytin-bound phosphorus, calcium energy and amino acids in poultry and pig diets. It is supplied as an off-white to light tan, fine granular product. The agent is produced in accordance with the FAO/WHO JECFA and FCC recommendations. It has to be used at a rate of 0.025-0.1 $kg \cdot t^{-1}$ (0.0025-0.01 %) of finished feed, included directly via a premix.

Ammonia concentrations were measured by the Photoacoustic Gas-Monitor 1312 manufactured by INNOVA, Denmark [7]. It is a highly accurate, reliable and steady quantitative gas monitor. Its measurement principle is based on the photoacoustic infra-red detection method. Air-samples are sucked through Teflon tubes to the analyzer. Multipoint Sampler INNOVA1309 was used in conjunction with the gas monitor 1312 to provide a multi-channel monitoring system [8]. The INNOVA1309 greatly increases the monitoring capabilities of the gas monitor up to 12 different sampling tubes. Inlets of the tubes were placed in outlet air streams in outlet shafts with electric fans.

The 24-hour measurement duration was necessary to include all animals activities during all day (feeding, manipulating with manure etc.).

It was necessary to switch off the automatic control of ventilation before the measurements. The ventilations had to be adjusted manually for the whole measurement period because of the calculations of the air flow during the measurements. Ventilation was adjusted according to the external temperature and requirements of animals in each hall. The air flow of each outlet shaft was calculated as a product of the shaft cross-section and air velocity. The velocity was measured by an anemometer in several points on 2 perpendicular straight lines in each outlet shaft.

Emission mass flow is a product of the ammonia concentration and the air flow rate (1).

$$m = c \cdot v, \tag{1}$$

where m – emission mass flow, $mg \cdot s^{-1}$;
c – ammonia concentration, $mg \cdot m^{-3}$;
v – air flow rate, $m^3 \cdot s^{-1}$;

Specific production ammonia emission is calculated per year and animal (2).

$$SPE = m \cdot 3600 \cdot 24 \cdot 365 \cdot n^{-1} \cdot 10^{-6}, \tag{2}$$

where SPE – specific production ammonia emission, $kg \cdot year^{-1} \cdot animal^{-1}$;
m – ammonia emission mass flow, $mg \cdot s^{-1}$;
n – number of animals in the housing.

Efficiency of the agent is calculated by the formula (3).

$$EFF = \frac{SPE_{REF} - SPE_{APL}}{SPE_{REF}} \cdot 100 \tag{3}$$

where EFF –ammonia decreasing efficiency of the agent, %;
SPE_{REF} – specific production ammonia emission in the reference hall, $kg \cdot year^{-1} \cdot animal^{-1}$;
SPE_{APL} – specific production ammonia emission in the hall with applied agent, $kg \cdot year^{-1} \cdot animal^{-1}$.

Executed measurements

The agent applied in pig housing. The agent was applied in the hall 10D in concentration 0.006 % to feeding. There were 325 pigs in the hall 10D. They were 77 days old with average weight 82 kg. The identical hall 9A was the reference hall without agent application. There were 328 pigs 75 days old in the hall 9A with average weight 78 kg. The dimensions of the halls were 24 x 14 x 2.7 m. There were 9 outlet fans with 500 mm diameter in each hall in the roof. 6 sampling tubes were placed to the fans No. 1, 2, 4, 6, 8, and 9. The other ventilators were switched off.

The agent applied in broiler housing. The agent was applied in the hall No.1 in concentration 0.004 %, the hall No.2 was the reference hall without agent application. There were 38 530 broilers in the hall No.1. They were 27 days old with average weight 1.06 kg. In the hall No.2 there were 38 515 broilers 27 days old with average weight 1.05 kg. The measurement was done in the 21 day feeding period. There were 10 outlet fans with 700 mm diameter in each hall in the roof. 3 sampling tubes were placed to the fans No. 3, 6 and 9. All other fans were switched off because of low outside temperature.

The 24-hour measurement duration was necessary during all tests to include all animal activities during all day. Both livestock houses were typical production fattening houses in the Czech Republic.

Results and discussion

The agent applied in pig housing

Fig. 1 shows the curves of ammonia concentration of all sampling points during the measurement in the hall 10D with agent application and Fig. 2 shows the curves of ammonia concentration during the measurement in the reference hall 9A.

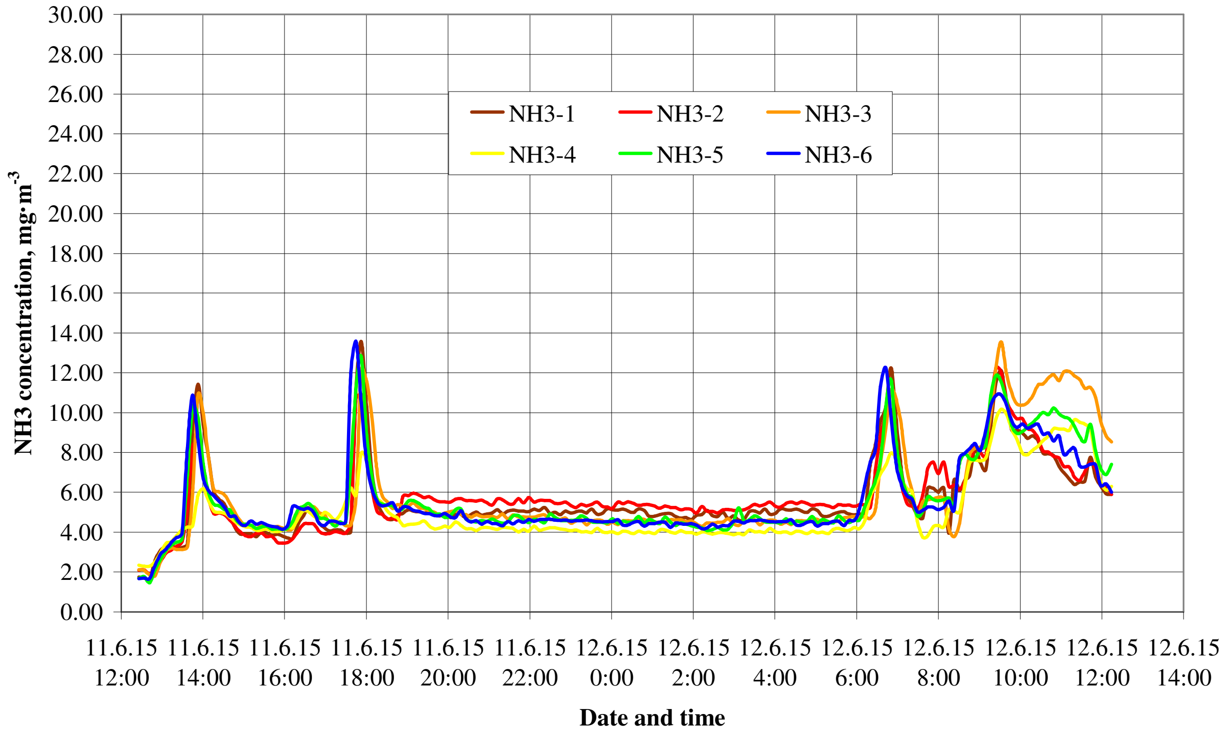

Fig. 1. **Ammonia concentration in the hall 10D**

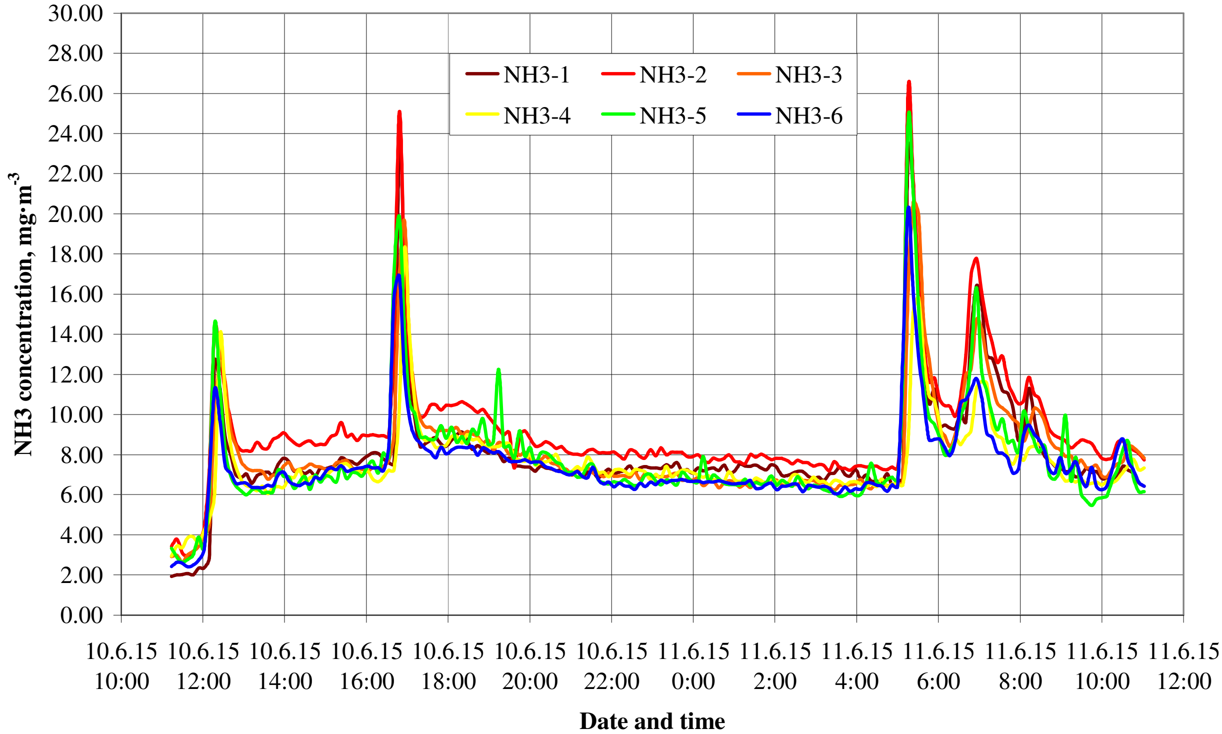

Fig. 2. **Ammonia concentration in the hall 9A**

The average ammonia concentrations, the air flow rates and calculated ammonia emission mass flows for each sampling point in the hall 10D with agent application are summarized in Table 1.

The average air flow rate during the measurement in the hall 10D was 15071 $m^3 \cdot h^{-1}$. The resultant ammonia emission mass flow was 22.20 $mg \cdot s^{-1}$. The resultant specific production ammonia emission (SPE) was **2.154 $kg \cdot year^{-1} \cdot animal^{-1}$** in the hall with applied agent.

The average ammonia concentrations, the air flow rates and calculated ammonia emission mass flows for each sampling point in the reference hall 9A are summarized in Table 2.

Table 1

Summarized data from ammonia emissions measurement in the hall 10D

Fan No.	**1**	**2**	**4**	**6**	**8**	**9**
Sampling point	S1	S2	S3	S4	S5	S6
Average speed, $m \cdot s^{-1}$	3.84	3.89	2.88	3.14	2.75	3.08
Air flow, $m^3 \cdot s^{-1}$	0.75	0.76	0.57	0.62	0.54	0.60
Average concentration, $mg \cdot m^{-3}$	5.68	5.77	5.94	5.09	5.71	5.63
Emission mass flow, $mg \cdot s^{-1}$	4.26	4.93	3.39	3.16	3.08	3.38

Table 2

Summarized data from ammonia emissions measurement in the hall 9A

Fan No.	**1**	**2**	**4**	**6**	**8**	**9**
Sampling point	S1	S2	S3	S4	S5	S6
Average speed, $m \cdot s^{-1}$	3.53	2.36	3.44	2.20	3.43	3.74
Air flow, $m^3 \cdot s^{-1}$	0.69	0.46	0.67	0.43	0.67	0.73
Average concentration, $mg \cdot m^{-3}$	8.07	9.24	8.09	7.59	7.84	7.48
Emission mass flow, $mg \cdot s^{-1}$	5.58	4.25	5.42	3.27	5.25	5.45

The average air flow rate during the measurement in the hall 9A was 18936 $m^3 \cdot h^{-1}$. The resultant ammonia emission mass flow was 29,22 $mg.s^{-1}$. The resultant specific production ammonia emission (SPE) was **2.835 kg·year^{-1}·animal^{-1}** in the reference hall.

The final agent efficiency was **24 %**. The average weight of a pig in the hall 10D was 82kg, the average weight of a pig was 78 kg in the hall 9A.

The agent applied in broiler housing:

Fig. 3 shows the curves of ammonia concentration of all sampling points during the measurement in the hall No. 1 with agent application and Fig. 4 shows the curves of ammonia concentration during the measurement in the reference hall No. 2.

The average ammonia concentrations, the air flow rates and calculated ammonia emission mass flows for each sampling point in the hall No. 1 with agent application are summarized in Table 3.

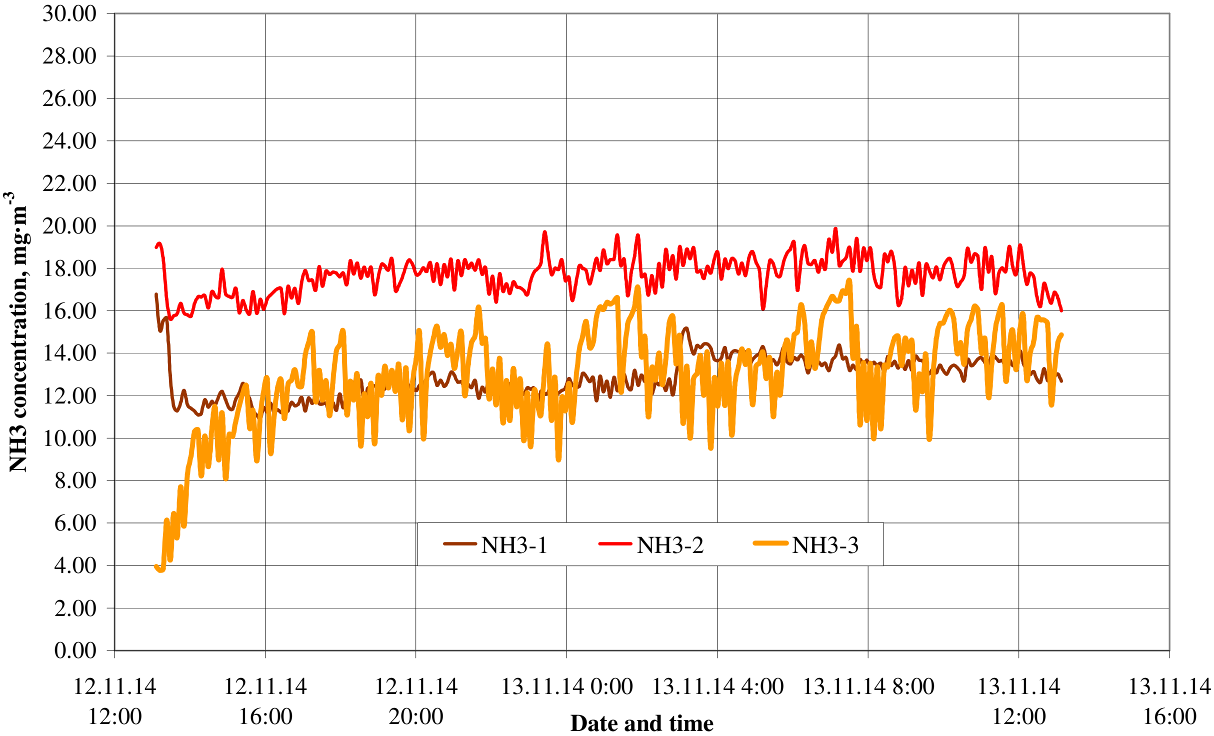

Fig. 3. **Ammonia concentration in the hall No. 1**

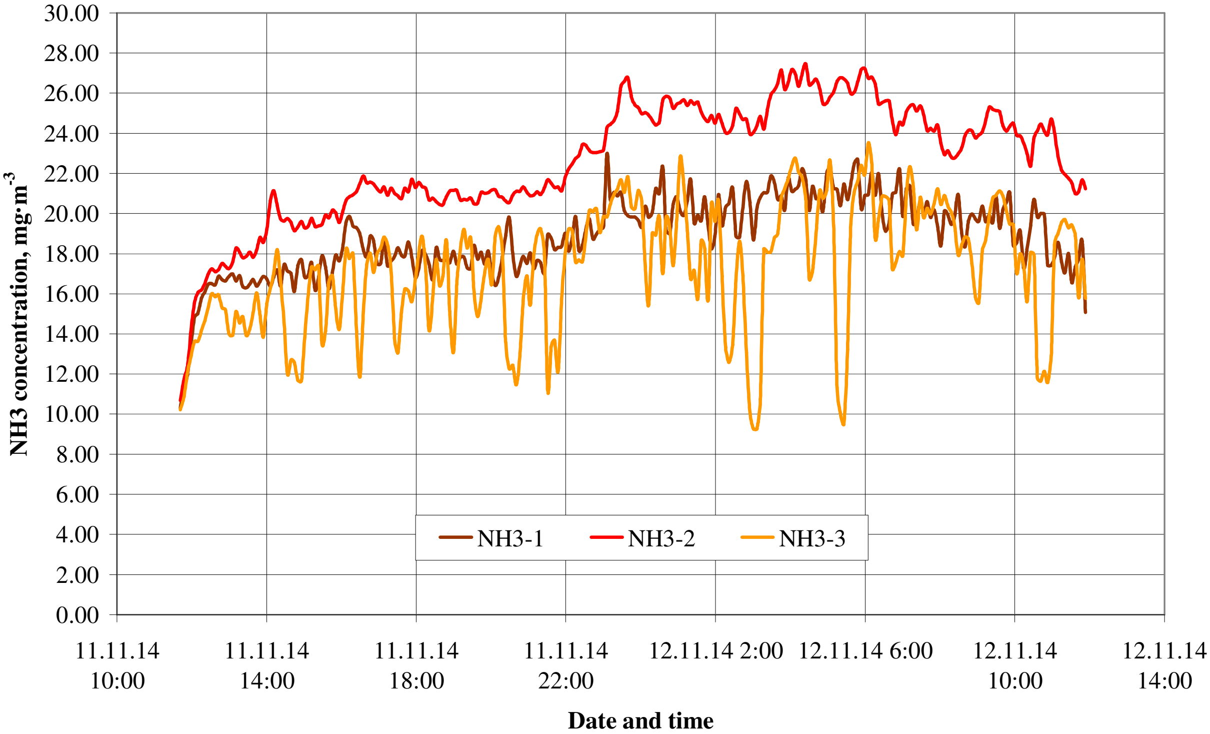

Fig. 4. **Ammonia concentration in the hall No. 2**

Table 3

Summarized data from ammonia emissions measurement in the hall No. 1

Fan No.	**3**	**6**	**9**
Sampling point	1	2	3
Average speed, $m \cdot s^{-1}$	2.73	2.57	2.62
Air flow, $m^3 \cdot s^{-1}$	2.14	2.02	2.05
Average concentration, $mg \cdot m^{-3}$	12.84	17.70	12.95
Emission mass flow, $mg \cdot s^{-1}$	27.47	35.75	26.65

The average air flow rate during the measurement in the hall No. 1 was 22356 $m^3 \cdot h^{-1}$. The resultant specific production ammonia emission (SPE) was **0.074 kg·year^{-1}·animal^{-1}**. The average ammonia concentrations, the air flow rates and calculated ammonia emission mass flows for each sampling point in the reference hall No. 2 are summarized in Table 4.

Table 4

Summarized data from ammonia emissions measurement in the hall No. 2

Fan No.	**3**	**6**	**9**
Sampling point	S1	S2	S3
Average speed, $m \cdot s^{-1}$	3.07	3.31	3.12
Air flow, $m^3 \cdot s^{-1}$	2.41	2.60	2.46
Average concentration, $mg \cdot m^{-3}$	17.64	22.84	18.18
Emission mass flow, $mg \cdot s^{-1}$	42.5	56.8	44.7

The average air flow rate during the measurement in the hall No. 2 was 26892 $m^3 \cdot h^{-1}$. The resultant specific production ammonia emission (SPE) was **0.099 kg·year^{-1}·animal^{-1}**. The final agent efficiency was **25 %.** The slaughter weight (1.8 kg) was got in 28 days with agent application and in 29 days in the reference hall.

These tests in real big production halls confirmed the laboratory results of agent efficiency [9; 10] and measurement in other production pig halls [11]. The results of the measurement in broiler halls could be influenced by the low number of running fans, because of non-uniform ventilation in all volume of the halls. The decreasing of ammonia emissions got 24 % for pigs and 25 % for broilers.

Conclusions

1. The phytase enzyme agent decreased the ammonia emission in the pig house for 24 % and in the broiler house for 25 %.
2. Other effects of the used agent were proved: decreasing the feeding period of broilers to the slaughter weight for 1 day and increasing the slaughter weight of the pigs in average for 4 kg in comparison with the reference group without agent.

Farmers in the EU states have to decrease the ammonia emissions by strict rules. Adjustment of current technologies [12] in old livestock housing is usually very expensive. In these cases using of verified biotechnological agents is one of the best ways how to fulfill the rules and get some economic benefits like better feeding conversion or better consistence of pig manure.

Lower ammonia concentration inside the livestock housing improves the health of the animals, too. This is asset especially in poultry breeding, where decreasing of the ammonia concentration reduces an occurrence of lung disease noticeably.

Decreasing of the ammonia concentration improves the work condition inside the housing for farmers and lower ammonia emissions, too.

Acknowledgment

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References

1. Czech Hydrometeorological Institute “Yearbook 2013” [online]. Available at: http://portal.chmi.cz/files/portal/docs/uoco/isko/grafroc/13groc/gr13e/Obsah_GB.html
2. Czech Statistical Office ”Statistical Yarbook of the Czech Republic 2013” [online]. Available at: http://www.czso.cz/csu/2013edicniplan.nsf/engt/0E002419D2/$File/0001131316.xls
3. Becker J.G., Graves R.E.. Ammonia emissions and animal agriculture. In Proceedings Mid-Atlantic Agricultural Ammonia Forum. Woodstock, Va. March 16, 2004.
4. Botermans J., Gustafsson G., Jeppsson K., Brown N., Rodhe L. Measures to reduce ammonia emissions in pig production – Review, Swedish University of Agricultural Sciences, Faculty of Landscape Planning, Horticulture and Agricultural Science, Report 2010:12, ISSN 1654-5427, ISBN 978-91-86373-19-1
5. Al-jBar A., Ishmail P.R., Nakue H.S. Effect of dietary Yucca schidigera extract of environmental ammonia and growth performance of chicken and rabbits. 1993, J. Animal Sci. 71(1), p. 114.
6. Dawkins M. S., Donnelly C. A., Jones T. A. Chicken welfare is influenced more by housingconditions than by stocking density. Nature 427(1), 2004, pp. 342-344.
7. LumaSense Technologies, Inc.,”INNOVA 1312_User_Manual” [online] [5.02.2012]. Available at: http://innova.lumasenseinc.com/uploads/media/1312_User_Manual_be6002-11_01.pdf
8. LumaSense Technologies, Inc., “INNOVA-1309-Multipoint-Sampler_Datasheet” [online] [10.03.2012]. Available at:http://www.lumasenseinc.com/uploads/Products/Gas_Monitoring_Products/Gas_Monitoring_Instruments/pdf/Datasheets/INNOVA-1309-Multipoint-Sampler_Datasheet.pdf
9. Toufar O., Dolejš J. Produkce amoniaku u nejčastějších chovů hospodářských zvířat. In Ochrana zvířat a welfare. Brno: Veterinární a farmaceutická univerzita, 2004, s. 168-172. (in Czech)
10. Jelínek A., Dedina M., Pliva P., Soucek J. Research of biological agents effects on reduction of ammonia concentration in stables of intensive farm animals breeding. Research in Agricultural Engineering, 50, 2004, pp. 43-53.
11. Kavolelis B. Impact of Animal Housing Systems on Ammonia Emission Rates, Lithuanian University of Agriculture, Polish Journal of Environ. Stud. Vol. 15, No. 5, 2006, pp. 739-745
12. Philippe F., Nicks B. Emissions of ammonia, nitrous oxide and methane from pig houses: Influencing factors and mitigation techniques, University of Liège, Belgium, in European Workshop: Reconciling the environment with livestock management, 19. - 20. 3. 2013.