Slovak J. Anim. Sci., 45, 2012 (2): 53-59
© 2012 CVŽV
ISSN 1337-9984

EFFECT OF SEASON ON AMMONIA EMISSIONS IN PIG FATTENING

Z. PALKOVIČOVÁ*, J. BROUČEK, A. HANUS, P. TONGEĽ, M. UHRINČAŤ, A. STRMEŇOVÁ

Animal Production Research Centre Nitra, Slovak Republic

ABSTRACT

The aim of this study was to determine emissions and emission factors of ammonia from pig housing on the fully slated floor during four fattening batches. We tested the hypothesis that ammonia emissions show differences in their emission rates relative to season. During investigation we found that within all four batches 836 kg of NH_3 was produced. The highest daily emission rate of NH_3 was found in autumn-winter batch and the lowest in summer-autumn batch II. Differences in daily emission rates of NH_3 were significant among all batches except the batches: summer-autumn I and autumn-winter. Ammonia emissions of all batches increased with increase in their concentrations ($P<0.01$). Only in the autumn-winter batch they were in positive correlation with amount of emitted air ($P<0.01$). We also registered their negative correlation with outdoor temperature in all batches ($P<0.01$; $P<0.05$). Ammonia emission factors of individual batches recorded different values, and therefore the average NH_3 emission factor with the value 2.1 kg of NH_3 per animal and per year was calculated.

Key words: emission; emission factor; pig housing; ammonia

INTRODUCTION

One of the most important factors affecting the production of ammonia in housing area is microclimate. It is first of all based on temperature, humidity and air velocity in the housing area. Increase of this parameters results in increase of NH_3 production (Dolejš *et al*., 2004; Aarnink and Elzing, 1998; Pattey *et al*., 2005). The pH of manure solution is also an important factor affecting NH_3 release (Rotz and Oenema, 2006). Ammonia release is reduced when the pH drops below 7. Conversely, it is very intense at pH higher than 8. Another factor influencing the NH_3 production is the season. Coufal *et al.* (2006) found the higher NH_3 emissions in summer than in winter, which they associated with a higher temperature in summer time. The higher ammonia emissions during late spring and summer in comparison to rest of the year were also recorded by Liang *et al.* (2003). This fact was related with higher ventilation capacity in warm weather. The ammonia production can be influenced by feed too. Therefore it is necessary to balance accurately the feed ration to the species, category and efficiency of animals. Equally serious factors affecting ammonia emissions are age and weight of animals. The amount of excrements, which is a function of animal weight, and the concentration of urea and other crude protein, which is inversely proportional to the weight of animals, contribute to NH_3 production (Dolejš *et al*., 2004). Housing technology has significant impact on the amount of NH_3 emissions. The farms with daily removal of manure and slatted floor had significantly lower emissions than the farms with 14 daily removals of manure and concrete floor (Ivanova-Peneva *et al*., 2008). The state of litter is a significant factor, which can also affect NH_3 emissions. Temperature, humidity and pH of litter belong to the primary factors influencing ammonia release (Redwine *et al*., 2002; Richard *et al*., 2005).

In this research paper factors affecting ammonia production, the effect of seasons on emissions and emission factors of ammonia are investigated.

***Correspondence:** E-mail: palkovicova@cvzv.sk
Zuzana Palkovičova, Animal Production Research Centre Nitra,
Hlohovecká 2, 95141 Lužianky, Slovak Republic
Tel. +421 37 6546 227 Fax: +421 37 6546 483

Received: April 12, 2012
Accepted: May 28, 2012

MATERIAL AND METHODS

The investigation was carried out on fattening pigs (live weight 30 - 110 kg) reared on the fully slatted floor during four fattening batches: summer-autumn I (352 pigs, 87 fattening days); autumn-winter (352 pigs, 121 fattening days); spring (357 pigs, 99 fattening days) and summer-autumn II (a year later, 360 pigs, 105 fattening days). Animals were housed in 16 pens in one fattening section with 22 pigs per pen. Forced ventilation was provided by three suction ceiling fans and inlet flaps located along the sidewalls of the housing. Slurry was stored in deep pits under slatted floor.

To calculate the ammonia emissions and emission factors it was needed to determine their concentrations ($mg.m^{-3}$) in the housing and outdoor areas, and to quantify the amount of exhausted air (m^3). For this purpose the gas concentrations were measured using gas analyzer Innova (Innova Air Tech Instruments, Denmark) based on photo acoustic analysis of absorption of infrared radiation, and the airflow rate using measuring fans. At the same time the housing and outdoor temperatures were recorded using thermocouple probes. The observations of gas concentrations and temperatures were made in housing (animal zone, ventilation zone) and outdoor areas, and the observations of emitted airflow rate were performed under three ceiling fans. The measured data were registered in a database at 12 min intervals (gas concentration) or three times per hour (temperature, airflow rate). For statistical analysis each batch was divided into three equally long time fattening phases (FPs).

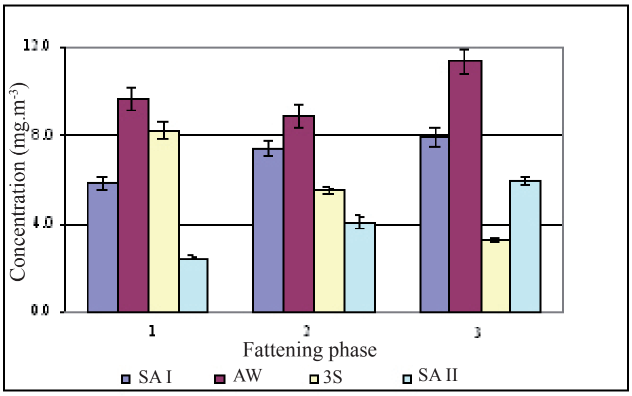
Statistical analysis

The data were analyzed with a statistical package STATISTIX 9. The normal distribution of data was evaluated by Wilk-Shapiro/Rankin Plot procedure. All the data conformed to a normal distribution. Comparisons among the groups were analyzed using a general linear model ANOVA (General AOV/AOCV). To determine the relationship between NH_3 production and observed parameters a Spearman‘s rank correlation was used (SPSS v.19). The differences were declared significant when their probability levels were below 0.05.

RESULTS AND DISCUSSION

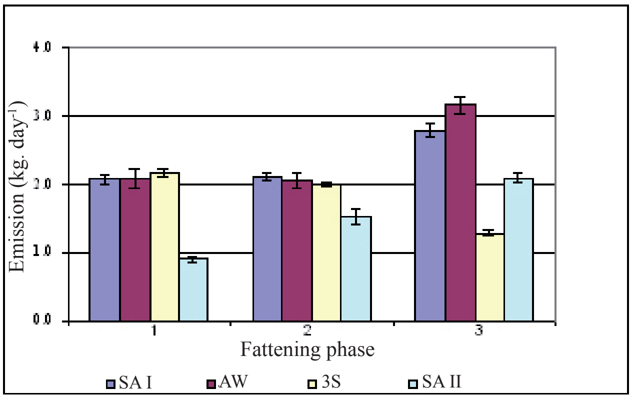
During both summer-autumn batches the increase of ammonia concentrations from 1st to 3rd FP was noted. The same was detected for ammonia emissions in summer-autumn batch II. In summer-autumn batch I the stable course of NH_3 emissions in 1st and 2nd FP and subsequently their increase from 2nd to 3rd FP was recorded. In autumn-winter batch the ammonia concentrations and daily emissions decreased or registered stable course from 1st to 2nd FP, respectively. Conversely, in 3rd FP an increase was recorded. In spring batch we observed decrease of ammonia concentrations and daily emissions from 1st to 3rd FP. Differences in NH_3 concentrations, emissions and probability of differences are given in table 1, and figures 1, 2.

In summer-autumn batch I the temperature in animal zone decreased from 1st to 3rd FP. The maximum temperature difference among FPs registered was 1.9 °C. In summer-autumn batch II the temperature in animal zone recorded approximately balanced course (increase by 1 °C from 1st to 2nd FP, decrease by 1 °C from 2nd to 3rd FP). In autumn-winter and spring batches the



SA I - summer-autumn I, AW - autumn-winter, S - spring,
SA II - summer-autumn II

Fig. 1: NH_3 concentrations during three fattening phases of four batches



SA I - summer-autumn I, AW - autumn-winter, S - spring,
SA II - summer-autumn II

Fig. 2: NH_3 emissions during three fattening phases of four batches

Table 1: Course of NH_3 concentrations and emissions during three fattening phases of four batches

Fattening phase		1st phase			2nd phase			3rd phase			P between fattening			1st - 3rd phase			P between
Parameter	Batch	N	Mean	SE	n	Mean	SE	N	Mean	SE		phases		n	Mean	SE	batches
NH_3 concentration (mg/m^3)	summer-autumn I	29	5.8	0.3108	29	7.4	0.3747	29	7.9	0.4301	0.0005	1:3 ***	1:2**	87	7.0	0.2344	0.0000
	autumn-winter	40	9.6	0.5031	40	8.9	0.4747	41	11.4	0.540	0.0024	2:3**	1:3*	121	10.0	0.3055	1:2,3,4***
	spring	33	8.2	0.3567	33	5.5	0.1615	33	3.3	0.0825	0.0000	1:2,3***	2:3***	99	5.7	0.2435	2:3,4***
	summer-autumn II	35	2.5	0.0923	35	4.1	0.2662	35	5.9	0.2013	0.0000	1:2,3***	2:3***	105	4.2	0.1806	3:4***
NH_3 emission (kg/day)	summer-autumn I	29	2.1	0.0762	29	2.1	0.0548	29	2.8	0.0988	0.0000	3:1,2***		87	2.3	0.0575	0.0000
	autumn-winter	40	2.1	0.1414	40	2.1	0.0973	41	3.2	0.124	0.0000	3:1,2***		121	2.4	0.0845	1:3,4***
	spring	33	2.2	0.056	33	2.0	0.035	33	1.3	0.0338	0.0000	3:1,2***	1:2**	99	1.8	0.0461	2:3,4***
	summer-autumn II	35	0.9	0.0384	35	1.5	0.1032	35	2.1	0.0659	0.0000	1:2,3***	2:3***	105	1.5	0.0638	3:4**

*** P<0.001; ** P<0.01; * P<0.05

Table 2: Course of housing and outdoor temperature during three fattening phases of four batches

Fattening phase		1st phase			2nd phase			3rd phase			P between fattening			1st - 3rd phase			P between
Parameter	Batch	N	Mean	SE	n	Mean	SE	N	Mean	SE		phases		n	Mean	SE	batches
Outdoor temperature (°C)	summer-autumn I	29	20.9	0.4544	29	14.4	0.6552	29	10.7	0.7632	0.0000	1:2,3***	2:3***	87	15.3	0.582	0.0000
	autumn-winter	40	2.2	0.4399	40	0.1	0.7583	41	3.2	0.604	0.0018	2:3***	1:2*	121	1.8	0.3713	1:2***
	spring	33	7.0	0.6739	33	13.2	0.5416	33	18.2	0.6411	0.0000	1:2,3***	2:3***	99	12.8	0.5844	2:3,4***
	summer-autumn II	35	20.3	0.5384	35	19.7	0.4377	35	11.3	0.5305	0.0000	3:1,2***		105	17.1	0.4955	3:4***
Housing temperature (°C)	summer-autumn I	29	28.9	0.2762	29	28.1	0.1456	29	27.0	0.2686	0.0000	1:3***	2:3**	87	28.0	0.1596	0.0000
	autumn-winter	40	25.7	0.1568	40	20.9	0.5948	41	22.5	0.162	0.0000	1:2,3***	2:3**	121	23.0	0.2776	1:2,3***
	spring	33	26.7	0.2983	33	23.9	0.2553	33	26.0	0.3174	0.0000	2:1,3***		99	25.5	0.2039	2:3,4***
	summer-autumn II	35	27.3	0.2321	35	28.3	0.1871	35	27.3	0.1491	0.0004	2:3***	1:2**	105	27.6	0.1189	3:4***

*** P<0.001; ** P<0.01; * P<0.05

Table 3: Course of differences in volume of exhausted air during three fattening phases of four batches

Fattening phase		1st phase			2nd phase			3rd phase			P between fattening phases		1st - 3rd phase			P between batches
Parameter	Batch	N	Mean	SE	n	Mean	SE	N	Mean	SE			n	Mean	SE	
Ventilation rate (m^3/h)	summer-autumn I	29	15196	312.11	29	12498	510.92	29	15162	345.75	0.0000	2:1,3***	87	14285	265.41	0.0000
	autumn-winter	40	9008	329.4	40	10030	500.63	41	11928	359.570	0.0000	1:3*** 2:3**	121	10335	255.86	1:2***
	spring	33	11380	373.24	33	15493	289.68	33	16259	258.9	0.0000	1:2,3***	99	14377	280.05	2:3,4***
	summer-autumn II	35	15465	263.31	35	15720	234.77	35	14859	299.42	0.069		105	15348	156.8	1:4*

*** $P<0.001$; ** $P<0.01$; * $P<0.05$

temperature in animal zone decreased from 1st to 2nd FP and then increased from 2nd to 3rd FP. The maximum temperature difference among FPs in autumn-winter and spring batches noted were 4.8 °C and 2.8 °C, respectively. Temperature differences in housing, outdoor areas and probability of differences is given in table 2.

In summer-autumn batch I the amount of exhausted air decreased from 1st to 2nd FP and consecutively increased from 2nd to 3rd FP. The trend was opposite in summer-autumn batch II. In autumn-winter and spring batches the airflow rate increased from 1st to 3rd FP. Airflow rate differences among FPs of individual batches and probability of differences are in table 3.

Ammonia concentrations and emissions were in positive correlation in all batches ($P<0.01$). It means that increase of ammonia concentrations caused the increase of ammonia emissions too. In all batches the ammonia concentrations were in negative correlation with amount of emitted air ($P < 0.01$, $P <0.05$) except autumn-winter batch and with outdoor temperature ($P <0.01$). It means that decrease of outdoor temperature and amount of emitted air caused increase of ammonia concentrations. Positive correlation between housing temperature and ammonia concentrations was only confirmed in summer-autumn batch I ($P <0.01$). In case of ammonia emissions these were in positive correlation with amount of emitted air in autumn-winter batch ($P <0.01$) and in negative correlation in summer-autumn batch I ($P <0.05$) and spring batch ($P <0.01$). Negative correlation between ammonia emissions and outdoor temperature was also confirmed in all batches ($P <0.01$, $P <0.05$). Correlation between ammonia emissions and housing temperature was noted only in summer-autumn batch I (negative correlation, $P < 0.01$), as shown in table 4.

In all batches the emission rate of ammonia was mainly dependent on its concentration. These had origin in animal excreta, which were stored in deep pits and occurred also on the slatted floor.

In summer-autumn batches NH_3 emissions increased from 1st to 3rd FP (except summer-autumn batch I with stable course in 1st and 2nd FP). It could be due to the gradual filling of deep pits with slurry, amount of which increased with fattening time. Detected facts were in accordance with those of Osada *et al.* (1998), who found that more manure has more possibility of NH_3 production. Distance of slurry surface from slatted floor could also play specific role (Osada *et al.*, 1998). In addition to increase of slurry in deep pits almost the whole floor area was polluted with excreta due to the increase of animal density and the inability to use natural behaviour. The greater floor area polluted with animal excreta provided the opportunity for the release of greater ammonia amount, as confirmed by several studies (Amon *et al.*, 2008; Aarnink and Elzing, 1998; Aarnink *et al.*, 1996; Gustafsson, 1997). Dependence of

Table 4: Correlations among observed parameters and ammonia production

	Parameter	NH_3 emission	Airflow rate	Outdoor temperature	Indoor temperature
	Batch				
NH_3 concentration	summer-autumn I	0.756**	-0.763**	-0.734**	0.614**
	autumn-winter	0.777**	-0.174^{NS}	-0.523**	0.077 ^{NS}
	spring	0.903**	-0.826**	-0.931**	0.028 ^{NS}
	summer-autumn II	0.958**	- 0.209*	-0.581**	0.007 ^{NS}
NH_3 emission	summer-autumn I		-0.216*	-0.635**	-0.554**
	autumn-winter		0.417**	-0.189*	-0.119 ^{NS}
	spring		-0.586**	-0.799**	-0.070 ^{NS}
	summer-autumn II		0.046 ^{NS}	-0.456**	0.172 ^{NS}
Airflow rate	summer-autumn I			0.462**	0.414**
	autumn-winter			0.448**	-0.280**
	spring			0.827**	-0.040 ^{NS}
	summer-autumn II			0.517**	0.635**
Outdoor temperature	summer-autumn I				0.803**
	autumn-winter				-0.118 ^{NS}
	spring				0.086 ^{NS}
	summer-autumn II				0.686**

** P<0.01; * P<0.05; NS - nonsignificant

NH_3 emissions on airflow rate was registered as negative correlation only in summer-autumn batch I (-0.216, *P*<0.05). It meant if amount of exhausted air increased then ammonia emissions decreased. This was opposite to the study by Redwine *et al.* (2002), who found increase of ammonia emissions in relation to high ventilation capacity during the summer. Positive correlation between housing temperature and ammonia emissions was not confirmed. This was not in accordance with the study by Arogo *et al.* (2001) and Pattey *et al.* (2005) indicating that the higher housing temperature causes the higher ammonia release. In our study dependence of NH_3 concentrations on housing temperature was only confirmed in summer-autumn batch I (0.614, *P* <0.01), in contrast to NH_3 emissions (-0.554, *P* <0.01).

Different course of NH_3 emissions was observed in autumn-winter and spring batches. In these batches the deep pits were full before starting of fattening. Stored slurry was removed during 2nd FP in both batches. The high NH_3 concentrations in 1st FP of both batches as observed in the present study can be influenced by amount of slurry in deep pits (Osada *et al.*, 1998). After removal of slurry from deep pits NH_3 concentrations decreased in both batches. Decrease of NH_3 emissions was observed only in spring batch. In autumn-winter batch NH_3 emissions did not decrease although its concentrations declined. Only in this batch the positive correlation between airflow rate and ammonia emissions was detected. As the airflow rate increased, NH_3 emissions registered the same amount as in 1st FP though NH_3 concentrations decreased. Difference was registered in 3rd FP of these batches. In spring batch the ammonia concentrations and emissions decreased although deep pits started to fill again and polluted floor area magnified. To contrast, in autumn-winter batch the ammonia concentrations and emissions increased in 3rd FP. It could be caused by gradual filling of deep pits and pollution of almost all slatted floor in housing area. In both batches the correlation between amount of exhausted air and ammonia emissions was confirmed (autumn-winter batch 0.417, *P* <0.01; spring batch -0.586, *P*<0.01). Positive correlation between ammonia emissions and amount of exhausted air in winter batch was in accordance with the study by Liang *et al*. (2003), who detected that ammonia emissions increased with increase of amount of exhausted air, but in summer period. These findings were not in line with the spring batch. In this batch negative correlation between airflow rate and ammonia emissions was confirmed. The correlation between housing temperature and ammonia emissions was not observed in both batches.

The highest daily emission rate of NH_3 was recorded in autumn-winter batch and the lowest in summer-autumn batch II. This was not in accordance with the study by Redwine *et al.* (2002) and Coufal *et* *al.* (2006), who found the greatest amount of ammonia emissions during the summer, which they associated with warm weather in relation to high ventilation capacity. Effect of season on the amount of ammonia emissions was confirmed in all batches ($P<0.001$, $P<0.01$), except summer-autumn batch I and autumn-winter batch. Observed fact was not detected in the study by Knížatová *et al*. (2010), who did not find statistically significant differences of ammonia emissions among individual fattening periods in broiler housing during the year.

CONCLUSION

Amount of ammonia emissions depend mainly on ammonia concentrations. Their height was associated with amount of slurry in deep pits and size of polluted floor in housing area. With the time of fattening the amount of slurry increased in summer-autumn batches and size of polluted floor magnified in all batches.

During summer-autumn I, autumn-winter, spring and summer-autumn II batches 202 kg, 295 kg, 180 kg and 159 kg of NH_3 were produced, respectively. Within all batches the exhausted air contained 836 kg of ammonia.

Calculated ammonia emission factors showed different values in all batches (summer-autumn I, autumn-winter, spring, summer-autumn II - 2.4 kg, 2.5 kg, 1.9 kg and 1.5 kg of NH_3 per animal and year, respectively). It was necessary to calculate the average ammonia emission factor, the value of which was 2.1 kg ammonia per animal and year.

AKNOWLEDGMENT

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0632-10.

REFERENCES

AARNINK, A. J. A. – VAN DEN BERG, A. J. – KEEN, A. – HOEKSMA, P. – VERSTEGEN, M. W. A. 1996. Effect of slatted floor area on ammonia emission and on the excretory and lying behaviour of growing pigs. *Journal of Agricultural Engineering Research*, vol. 64, 1996, p. 299-310.

AARNINK, A. J. A. – ELZING, A. 1998. Dynamic model for ammonia volatilization in housing with partially slatted floors for fattening pigs. *Livestock Production* Science, vol. 53, 1998, p. 153-169.

AMON, B. – PÖLINGER, A. – KRYVORUCHKO, V. – MÖSENBACHER, I. – HAUSLEITNER, A. – FRÖHLICH, M. – AMON, TH. 2008. Ammonia and greenhouse gas emissions from a straw flow system for fattening pigs. *Agriculture*, *Ecosystems and Environment*, vol. 124, 2008, p. 237–244.

AROGO, J. – ESTERMAN, P. W. – HEBER, A. J. – ROBARAGE, W. P. – CLASSEN., J. J. 2001. Ammonia in animal production: A review. *ASAE 2001, Paper No. 014089*, St. Joseph, Mich.: ASAE.

COUFAL, C. D. – CHAVEZ, C. – NIEMEYER, P. R. – CAREY, J. B. 2006. Nitrogen emissions from broiler measured by mass balance over eighteen consecutive flocks. *Poultry Science*, vol. 85, 2006, p. 384-391.

DOLEJŠ J. – TOUFAR, O. – MAŠATA, O. – ADAMEC, T. 2004. Emissions of ammonia and odour from pig farms and their elimination. *Pig farming - Good Manufacturing Practices - Technology - Housing environment*. Praha Uhříněves: Institute of Animal Science, 2004, p. 26-36.

GUSTAFSSON, G. 1997. Investigations of factors affecting air pollutants in animal houses. *Agric. Environ. Med.*, vol. 4, 1997, p. 203-215.

IVANOVA-PENEVA, S. G. – AARNINK, A. J. A. – VERSTEGEN, M. W. A. 2008. Ammonia emissions from organic housing systems with fattening pigs. *Biosystems engineering*, vol. 99, 2008, p. 412-422.

KNÍŽATOVÁ, M. – BROUČEK, J. – MIHINA, Š. 2010. Seasonal differences in levels of carbon dioxide and ammonia in broiler housing. *Slovak Journal of Animal Science*, vol. 43, 2010, 2, p. 105-112.

LIANG, Y. – XIN, H. – TANAKA, A. – LEE, S. H. – LI, H. – WHEELER, E. F. – GATES, R. S. – ZAJACZKOESKI, J. S. –TOPPER, P. – CASEY, K. D. 2003. Ammonia emissions from U.S. poultry houses: part II – layer houses. *Proc. 3rd International Conference on Air Pollution from Agricultural Operations*, Research Triangle Park, NC. October 2003. American Society of Agricultural Engineers, St Joseph, MI: ASAE, p. 147-158.

OSADA, T. – ROM, H. B. – DAHL, P. 1998. Continuous measurement of nitrous oxide and methane emission in pig units by infrared photoacoustic detection. T*ransactions of the ASAE*, vol. 41, 1998, 4, p. 1109-1114.

PATTEY, E. – TRZCINSKI, M. K. – DESJARDINS, R. L. 2005. Quantifying the reduction of greenhouse gas emissions as a result of composting dairy and beef cattle manure. *Nutrient Cycling in Agroecosystems*, vol. 72, 2005, p. 73-187.

REDWINE, J. S. – LACEY, R. E. – MUKHTAR, S. – CAREY, J. B. 2002. Concentration and Emissions of Ammonia and Particulate Matter in Tunnel Ventilated

Broiler Houses Under Summer Conditions in Texas. *Transactions of the ASAE*, vol. 45, 2002, 4, p. 1101-1109.

RICHARD, T. L. – WHEELER, E. – VARGA, G. – KAYE, J. – BRUNS, M. A. 2005. Strategies for reducing gas emissions from dairy farms. *Penn State Dairy Cattle Nutrition Workshop*, 2005, p. 91-96.

ROTZ, C. A. – OENEMA J. 2006. Predicting management effects on ammonia emissions from dairy and beef farms. *Transactions of the ASABE*, vol. 49, 2006, 4, 1139−1149.