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Concentration of harmful gases in poultry and pig houses*

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A common chicken broilers rearing house and fattening pig barn were monitored for harmful gases concentration (NH_3, CO_2, NO_2 and CH_4). In chickens the concentrations of NH_3 rose during fattening periods in all seasons of the year (from 0.23 to 10.77 $mg.m^{-3}$). They varied depending on the ventilation rate and were influenced by litter temperature. The daily mean concentrations of CO_2 were decreasing towards the end of the fattening period and were influenced by heating at the beginning and by birds breathing at the end of fattening periods. Mean daily concentrations of N_2O ranged from 0.92 to 8.24 $mg.m^{-3}$ and CH_4 from 46.59 to 134.12 $mg.m^{-3}$. In the pig house the NH_3 concentrations varied from 2.64 to 22.9 $mg.m^{-3}$, but not simultaneously to the growth of body weight as in chickens. They also varied depending on ventilation rate, but differences in that parameter between the colder and warmer periods were not found sinificant. The mean daily production of CO_2 ranged from 975.36 to 9948.78 $mg.m^{-3}$, N_2O from 1.08 to 6.39, and CH_4 from 33.51 to 189.63, without any significant differences between periods and with no relation to age and weight of animals. Significant positive correlations in chicken broilers were found between the production of ammonia and litter temperature and in cold periods also with ventilation rate. In fattening pigs higher correlations related to methane production were found only.

KEY WORDS: broilers /chickens / fattening pigs / harmful gases / litter

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Production of gases in the conventional livestock industry affects the environment and climate. In animal husbandry, there are produced mainly ammonia (NH_3), carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Ammonia is a toxic gas with a direct negative effect on the environment. Methane is a classic greenhouse gas that along with carbon dioxide (CO_2) and nitrous oxide (N_2O) causes warming of the atmosphere [Weiske and Petersen 2006, Knížatová *et al*. 2010]. Greenhouse gas emissions from animal production and agricultural land are the highest in countries with a high density of livestock [Freibauer 2003]. Given the growing world population it is expected that the intensity of agricultural production will increase, including increased numbers of animals [FAO 2006].

The urine of animals is the main source of ammonia. It is generated during bacterial decomposition of protein and urea in housing areas and during storage and application of excreta under aerobic and anaerobic conditions [Richard *et al*. 2005, Misselbrook *et al*. 2010]. It creates odours, contributes to the acidification of soils, formation of acid rain, eutrophication of surface waters and nitrate contamination of groundwater, adversely affects the quality of air and water, as well as animal and human health [Becker and Graves 2004].

The main source of carbon dioxide in livestock is animal respiration, combustion of natural gas for heating and cooking, and decomposition of organic matter [Knížatová *et al*. 2010b]. There is also a link between metabolism and animal production of CO_2 [Nicks *et al*. 2003].

Nitrous oxide is generated by the microbial conversion of nitrates in excreta during their storage and applications [Oenema *et al*. 2005]. However, it is formed mainly during fuel and biomass combustion. N_2O in the atmosphere has a long life and contributes significantly to global warming. It is converted to NO, which decomposes stratospheric ozone that protects Earth from harmful ultraviolet radiation [Hardy 2003, Schulze *et al*. 2009].

Methane is created during intestinal processes in ruminants, while in pigs and poultry it comes from decomposition of excrements [Monteny *et al*. 2006, Chase 2008]. A major source of methane is the stored manure with high concentrations of easily degradable organic matter [Petersen *et al*. 2005]. Methane is 23 times more active radiation gas than carbon dioxide and its concentration in the atmosphere increases by about 1% per year [Baylis *et al*. 2010].

In animal housing there are several factors that affect the production and release of harmful gaseous compounds. These are primarily the number and live weight of housed animals, floor surface covered with their excrements, manure storage time in housing area, performance of ventilation, air temperature, year season, air movement above the litter surface or not bedded barn floor, air permeation through the litter, litter temperature, its moisture, pH, the ratio C:N and feed composition [Gustafsson 1997, Knowlton 2000, Wheeler *et al*. 2003, Richard *et al*. 2005, Coufal 2006].

Production of mentioned gases which are one of sources of global problems and significantly deteriorate the standard of local life, can be reduced by various organization and technological interventions [Metz 2002, Gay and Knowlton 2005, Pratt *et al*. 2006]. The aim of this paper was to publish the results of measurements of concentrations of harmful gases in buildings for chicken broilers and fattening pigs.

Material and methods

A common chicken broilers rearing house and fattening pig barns were monitored for harmful gases concentrations (NH_3, CO_2, NO_2 and CH_4). The study was carried out at commercial farms. Measurings were done in both species over 4 fattening periods in 4 consecutive seasons of the year. Duration of each raising period in chicken's house was 40 days. Measurements were done during September and October (autumn period), November and December (winter period), May and June (spring period) and June and July (summer period).

In pig fattening barn measurements were done from August to October (97 days – autumn period) , from November to February (106 days – winter period), from March to June (99 days – spring period) and from July to October (105 days – summer period).

Table 1. Gas furnaces characteristic

Model	GP70	GP 120
Power output (kW)	70	120
Natural gas consumption (m^3h^{-1})	7.5	12.5
Ventilation rate (m^3h^{-1})	5000	7000
Heating distance (m)	50	50

The commonly used chicken house designed for 25,000 broilers had concrete-floor bedded with chopped straw. Manure was removed at the end of each period. No additional litter material or amendments were added to the litter at any time throughout the studied periods. Final body weight of broilers was approximately 2 kg. The hall was mechanically ventilated with combined tunnel and cross two-sided ventilation. Maximum total ventilation rate of fans was 212000 $m^3.h^{-1}$. Fans were automatically controlled according to the inner temperature. Real exchange of air during particular fattening periods is shown on Figure 1. The housing area was heated to nominal temperature of 31-33° C by two gas furnaces (Tab. 1). Ambient temperature was reduced as the birds progressed in age by approx. 2°C each week.

The pig fattening insulated barn with fully slatted floor was designed for 360 heads. Final weight of pigs was approximately 130 kg. Each barn was mechanically ventilated by three vacuum fans placed in the ceiling. Maximum total ventilation rate of fans was 21,000 $m^3.h^{-1}$. Fans were automatically controlled according to the air temperature. Real exchange of air during particular fattening periods is shown on Figure 2.

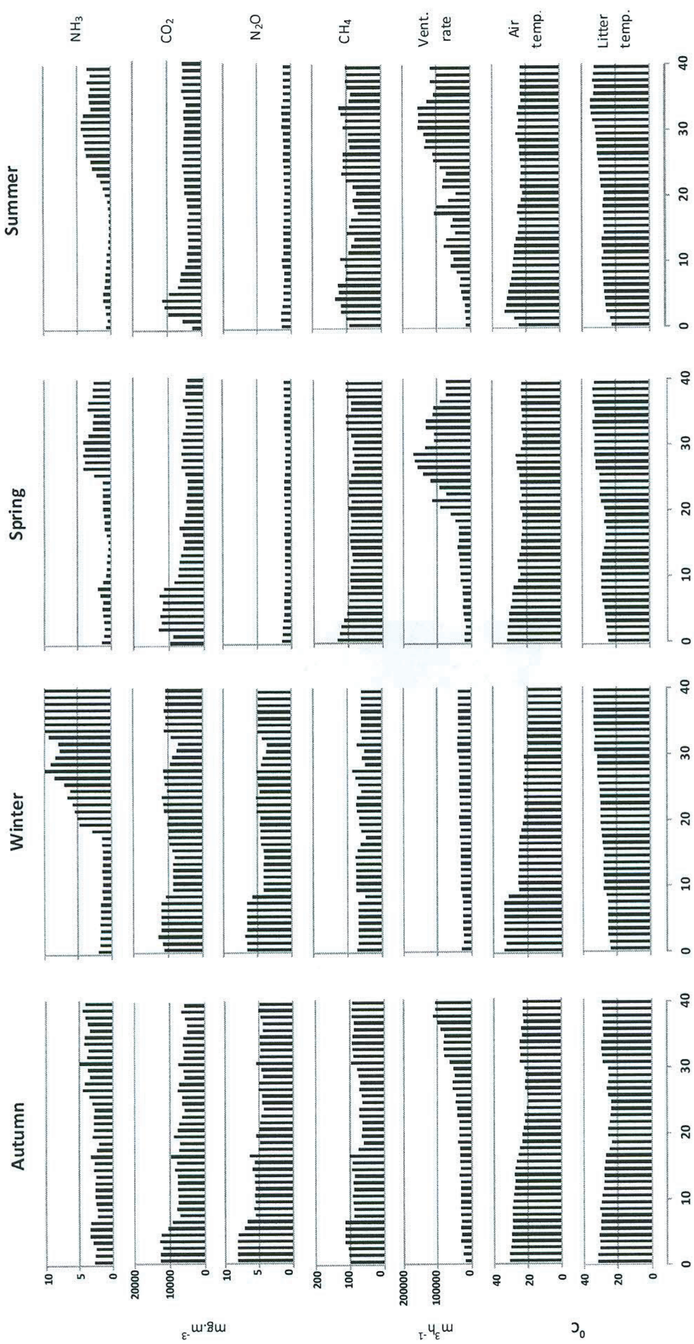

Fig. 1. Average concentrations of harmful gases, ventilation rate and air temperature in chicken barn during whole fattening periods

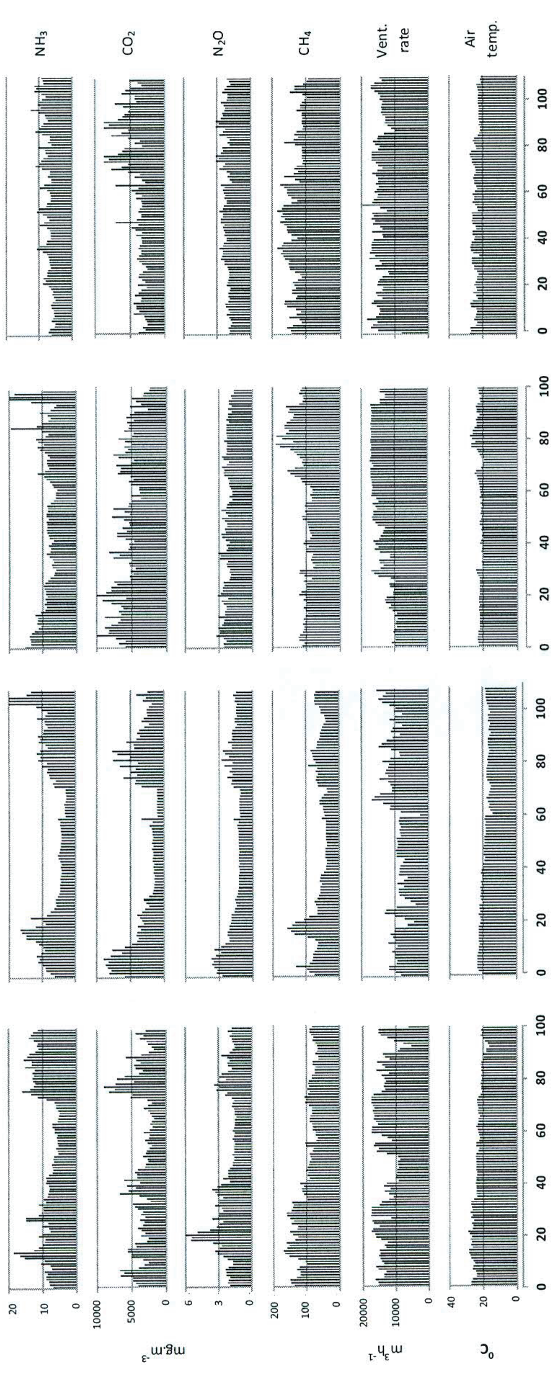

Fig. 2. Average concentrations of harmful gases, ventilation rate and air temperature in pig barn during whole fattening periods

The concentration of gases was measured by the device 1312 Photoacoustic Multi-gas Monitor (INNOVA), which principle is based on the photoacoustic infrared detection method. Air samples were taken during each entire period every 5 min in chickens and every 45 min in pigs by tubes with openings installed at the level of animals. Air temperature at animal level in both species and temperature inside chicken's litter were recorded by thermocouple probes. Ventilation rate was measured by measuring fans.

Means for charts drawing were calculated from all data obtain in each day and for statistical comparison from all data in each quarter (in chicken) and in each third (in pigs) of fattening periods.

Results and discussion

Chicken broiler house

The mean daily **concentration of NH_3** in chicken house ranged from 0.23 to 10.77 $mg.m^{-3}$ (Fig. 1). The highest values were in the final quarter of winter fattening period. In spring and summer maxima were approximately comparable to a half of a winter records and in the autumn were slightly higher than in the spring and summer. Differences in concentrations between periods corresponded to differences in the intensity of ventilation. While in the spring and summer the intensity of ventilation in the second half of the fattening period ranged from 74 to 169 thousand $m^3.h^{-1}$, in winter it ranged only from 32 to 42 thousand $m^3.h^{-1}$. The concentrations of NH_3, however, rose towards the end of fattening periods in all periods. Of course it varied depending on the ventilation rate. Vučemilo *et al*. [2007] explain the increase of ammonia concentration during the fattening period by growth of chickens' age and humidity. They reported nearly 7-fold increase in concentration of NH_3 between the first and fifth week of fattening. In the present study, in summer, about 2.5-fold and in winter more than 4-fold differences were found between the first and the last fattening quarter (Tab. 2).

The daily mean **concentration of CO_2** decreased towards the end of all fattening periods. – from 12831 to 2881 $mg.m^{-3}$ (Fig. 1). In winter it was higher than in other periods. High values in the first quarter of fattening periods resulted from the use of gas heater [Olanrewaju *et al*. 2008, Knížatová 2010b]. In the later quarters of fattening periods carbon dioxide is produced primarily by birds breathing [Nicks *et al*. 2003]. Similarly to ammonia, its concentration is reduced by ventilation. However, in winter, significance of differences between quarters of fattening periods were not found, although mean values decreased (Tab. 2). In summer, in spring and to some extent in the autumn there was a conclusive reduction in CO_2 air concentration immediately after the first quarter of fattening periods, *i.e*. after the reduction of heating.

The daily mean **concentrations of N_2O** shown on Figure 1 were found in winter and autumn (from 3.57 to 8.24 $mg.m^{-3}$), being much higher than in spring or summer (0.92 to 1.48 $mg.m^{-3}$). This was reflected also by significance of differences between

Table 2. Concentration of harmful gases in chicken broilers facility in different seasons and phases of fattening

Gas	Days of fattening	Autumn (n=2690)		Winter (n=1443)		Spring (n=1781)		Summer (n=2433)	
		mean	SD	mean	SD	mean	SD	mean	SD
NH_3 ($mg.m^{-3}$)	1-10	2.94^a	0.52	1.56^a	0.32	1.19^a	0.30	0.99^a	0.57
	11-20	2.87^a	0.49	4.65^b	1.06	1.11^a	0.53	0.48^a	0.23
	21-30	3.48^a	1.07	6.11^{bC}	1.12	1.69^a	0.63	2.03^b	1.18
	31-40	3.34^a	0.85	6.65^{bC}	2.92	1.69^a	0.63	2.62^B	0.96
CO_2 ($mg.m^{-3}$)	1-10	10765.00^a	2964.90	10652.00^a	2083.90	11399.00^a	3485.20	7887.80^a	4563.60
	11-20	8613.40^a	1697.40	10717.00^a	1384.60	9066.30^a	2698.10	4382.60^a	1356.90
	21-30	7026.30^b	164.40	9894.60^{ab}	2255.20	4959.10^B	1756.70	5217.70^a	1276.60
	31-40	5355.80^{bC}	1262.20	7648.30^b	2764.50	4959.10^B	1756.70	4603.00^a	1085.50
N_2O ($mg.m^{-3}$)	1-10	7.23^a	1.48	5.52^a	1.32	1.11^a	0.21	1.09^a	0.24
	11-20	5.80^b	0.78	4.84^a	0.51	0.89^a	0.14	1.06^a	0.22
	21-30	4.89^b	0.67	4.55^a	0.78	1.05^a	0.16	1.00^a	0.17
	31-40	4.63^b	0.52	0.98^B	0.03	1.05^a	0.16	1.23^a	0.18
CH_4 ($mg.m^{-3}$)	1-10	111.60^a	13.50	66.70^a	10.41	113.58^a	14.34	118.09^a	27.41
	11-20	86.92^b	14.50	73.75^a	22.17	89.86^a	2673	94.30^a	18.34
	21-30	73.08^b	8.84	74.36^a	27.88	80.30^a	16.96	100.67^a	15.18
	31-40	93.51^a	7.29	56.42^b	14.11	80.30^a	16.96	104.61^a	16.89

$^{aA...}$Within individual gases means in rows bearing different superscripts differ significantly at: small letters – $P \leq 0.05$; capitals – $P \leq 0.05$.

means (Tab, 2). Nitrous oxide is generated by the microbial conversion of nitrates in excreta [Oenema *et al*. 2005].

The daily mean c**oncentrations of CH4** were only slightly lower in in autumn (60.52 to 114.79 $mg.m^{-3}$) and winter (46.59 to 85.62 $mg.m^{-3}$) than in spring (up to 81.063 131.57 $mg.m^{-3}$) and summer (66.84 to 134.12 $mg.m^{-3}$), which was probably due to higher external temperatures (Fig. 1 and Tab. 2). According to Pattee *et al*. [2005] methanogenesis is affected by temperature.

Production of pollutants in fattening chickens can be influenced is litter status. As litter gets older it is more polluted by accumulating droppings and the amount of metabolic heat produced by the chickens is increased, too. Then, higher temperature of litter stimulates microbial activity resulting in the formation of ammonia as indicated bv Coufal *et al*. [2006]. In this study the temperature was rising in every period, while the differences were not high. At the beginning of fattening periods the temperature ranged from 22.5 to 24.7°C and at the end from 32 to 35°C (Fig. 1). To the same conclusions came Wheeler *et al*. [2003, 2006].

Although the measurements were conducted in different seasons and at different ambient temperatures, the courses of mean values of inside air temperature were very similar (Fig. 1). At the beginning of fattening periods they ranged from 31.1 to 33.8°C and at the end from 19.5 to 23.2°C. This was caused by heating at an early age and by regulating the intensity of ventilation during the season. However, despite the very low ventilation rate, in the housing hall in winter the lowest temperatures were recorded. There is a direct relation between ammonia production and temperature and humidity in housing area [Dolejš *et al*. 2004] and as it was already mentioned between the temperature and methane production [Pattey *et al*. 2005].

Pig fattening building

In the pig house the concentrations of noxious gases did not grow depending on the growth of body weight as in chickens (Fig. 2). In most cases, the average daily concentrations in the intermediate phase of fattening periods were the lowest, often statistically significant (Tab. 3).

The mean daily of NH_3 concentrations ranged from 2.64 to 22.9 mg.m^{-3}, while the smallest peaks (up to 12.47 mg.m^{-3}) were achieved in the summer, when the ventilation rate was the highest. The differences between colder and warmer periods in pigs were less pronounced than in broilers. This emerges from the fact that weaned pigs were compared to the small chickens less sensitive to cold and thus farmers intensively ventilate also during colder seasons reducing the production of harmful gases. However, Coufal *et al*. [2006], Redwine *et al*. [2002] and Liang *et al*. [2003] observed a more abundant NH_3 emission in summer than in winter, which they associated with a higher temperature in warmer season.

Daily mean of CO_2 concentrations ranged from 975.36 to 9948.78 mg.m^{-3}, without any significant differences between periods and with no relation to age and weight of animals. Our results in this did not confirm those of Nicks *et al*. [2003], Olanrewaju *et al*. [2008] and Pattee *et al*. [2005].

Increased mean N_2O concentrations were found in autumn and early winter (3.62 to 6.39 mg.m^{-3}). Values of N_2O were below 3 mg.m^{-3} in the second half of winter fattening period and during the spring and summer.

Lower CH_4 concentrations were produced in winter (daily mean of 33.51 to 157.52 mg.m^{-3}), although, during other periods its production was only slightly higher, but with a larger proportion of higher values (64.01 to 189.63 mg.m^{-3}).

Table 3. Concentration of N_2O and CH_4 in fattening pig barnin different seasons and phases of fattening

Gas	Phase of fattening	Autumn (n=753)		Winter (n=840)		Spring (n=784)		Summer (n=613)	
		mean	SD	mean	SD	mean	SD	mean	SD
NH_3	1st	10.61^{b}	3.17	8.64^{Ba}	3.58	10.04^{a}	2.88	6.53^{a}	1.17
($mg.m^{-3}$)	2nd	7.02^{a}	1.01	4.44^{a}	1.81	7.43^{a}	1.97	7.59^{a}	1.54
	3rd	11.77^{b}	3.06	11.98^{B}	4.77	11.24^{a}	7.67	9.38^{b}	2.43
CO_2	1st	4193.50^{a}	4048.40	4333.10^{a}	3131.70	6985.00^{a}	5029.60	3355.50^{a}	2386.70
($mg.m^{-3}$)	2nd	3396.70^{a}	2863.20	2034.30^{a}	1703.20	5732.30^{a}	3594.00	4368.80^{a}	2976.30
	3rd	4261.80^{a}	3695.30	3713.40^{a}	2905.50	4929.90^{a}	3560.90	5063.60^{a}	3004.90
N_2O	1st	3.11^{a}	1.57	2.41^{a}	1.01	2.80^{a}	1.12	1.46^{a}	0.39
($mg.m^{-3}$)	2nd	2.03_{a}	0.88	1.10^{b}	0.39	2.69^{a}	0.85	2.78^{b}	0.71
	3rd	2.19^{a}	1.06	1.98^{ab}	0.68	2.82^{a}	0.66	2.58^{b}	0.69
CH_4	1st	14.02^{B}	26.57	84.53^{a}	46.79	103.25^{a}	22.85	136.19^{a}	21.26
($mg.m^{-3}$)	2nd	91.88^{b}	16.66	46.45^{b}	13.28	99.68^{a}	24.97	148.94^{a}	28.12
	3rd	83.66^{b}	16.25	64.55^{a}	17.85	138.78^{a}	32.38	113.74^{a}	28.91

Within each gas means in rows bearing different superscripts differ significantly at $P \le 0.05$, particular gas in column with different letters "a" differs at $P \le 0.05$.

Maximum concentrations of NH_3 and CH_4 per one kg of final live weight of fattening pigs were higher than in chicken broilers (1.84 times and 1.22 times, respectively). The concentrations of CO_2 and N_2O were conversely lower in the pig fattening building (reaching about 70% of concentrations obtained in chicken house).

Correlation coefficients of gas concentrations with air temperature, ventilation rate and litter temperature are given in Tables 4. Significant positive coefficients for broilers were found between the production of ammonia and litter temperature and in

Table 4. Correlation of gas concentrations with air, litter temperature and ventilation rate in chicken barn

Parameter		NH_3	CO_2	N_2O	CH_4	Ventilation rate	Litter temperature
Air temperature	autumn	-0.2785	0.559	0.6565	0.6227	-0.4246	0.7463
	winter	-0.7159[a]	0.3193	0.6442	0.1690	-0.7983*	-0.8676**
	spring	-0.5054	0.5448	0.4026	0.4935	-0.3462	-0.5743
	summer	-0.3335	0.4010	0.3872	0.4076	-0.1632	-0.2635
Litter temperature	autumn	0.1069	0.4009	0.5410	0.7334	0.0198	
	winter	0.8716[a]	-0.227	-0.5188	-0.2679	0.8280*	
	spring	0.6781	-0.4313	-0.2651	-0.4497	0.6346*	
	summer	0.7139[a]	-0.1162	0.0716	0.0994	0.6888*	
Ventilation rate	autumn	0.5643	-0.4949	-0.4326	0.0049		
	winter	0.6877[a]	-0.3109	-0.5625	-0.1675		
	spring	0.4763	-0.5117	-0.1840	-0.4716		
	summer	0.3972	-0.3405	0.2162	-0.0538		

*$P \leq 0.05$; **$P \leq 0.01$.

cold periods also with the ventilation rate. Correlations were also found between the ventilation rates and litter temperature. However, we cannot talk about interrelationhip as both ventilation rates and litter temperature increased with animal age and thus of their weight. In fattening pigs, higher correlations were recorded only related to methane production. It will require further research.

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