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SEASONAL DIFFERENCES IN LEVELS OF CARBON DIOXIDE AND AMMONIA IN BROILER HOUSING

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ABSTRACT

Air emission and air quality issues are the important topics of environment in concern to poultry houses. This study attempts to point out possible sources of carbon dioxide and ammonia inside a broiler house, as well as an influence of several variables (temperature, age of chickens, ventilation rate) on their production. Concentrations and emissions of both gases (CO_2, NH_3) were assessed over a total of six fattening periods from commercial tunel-ventilated grow-out facility designed for 25,000 broilers placed onto straw litter. CO_2 production from heaters (approx. 39 kg/h) and CO_2 production from bird respiration (approx. 147 kg/h) were compared with a total CO_2 emission from the building ranging between 120 and 459 kg/h. CO_2 emission was mostly affected by chickens towards the end of fattening period (P<0.001) taking dominance over natural gas burning process by heaters. Very high statistic reliability was found between age of chickens and NH_3 concentration as well as between age of chickens and NH_3 emissions (P<0.001). From seasonal point of view, there was not statistically significant difference in emissions of NH_3 or CO_2 between fattening periods (seasons). After the evalutation of carbon dioxide and ammonia emission, it can be concluded that there is an average releasing of 10.4 kg CO_2 and 6.18 g NH_3 per bird and period and/or 73.11 kg CO_2 and 0.043 kg NH_3 per bird yearly. Ammonia levels did not achieve critical values (≥20 ppm) many times during monitoring unlike carbon dioxide with peaks even tree times higher than it is allowed (≥3000 ppm). For that reason, not only the temperature but also the amount of air released from poultry buildings and the content of that air should be new variables in operating ventilation system.

Key words: broiler chickens; carbon dioxide; ammonia; litter; fattening period

INTRODUCTION

Modern poultry housing is designed and constructed to reduce heat loss and improve energy efficiency, however when coupled with reduced ventilation, can result in elevated levels of carbon dioxide, ammonia and other air contaminants, which may adversely affect the health and productivity of flocks (Olanrewaju et al., 2008). On the other hand, Lendelová and Botto (2009) documented that pre-warming of incoming air could decrease this negative influence of reduced ventilation.

Air quality is one of the most difficult aspects of broiler management to grasp. This is probably because it is not possible to "see". It is difficult to visually determine the volume and direction of fresh air being brought into a broiler house.

During cold weather the primary function of the ventilation system is to eliminate ammonia and moisture from the broiler house. Carr et al. (1990) relate higher concentrations of NH_3 in winter months with reduced ventilation rates to conserve as much heat as possible. Many producers underestimate the detrimental effect

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of ammonia. Ammonia levels of just 25 ppm have been found to depress growth and increase feed conversion in broilers (Miles et al., 2004). The housing environment, including factors like carbon dioxide levels and oxygen levels, is known to influence the incidence of ascites (broiler pulmonary hypertension syndrome) in broiler chickens. The problem arises from very high metabolic rate of rapidly growing broiler strains. Subsequently, in less well ventilated poultry house as well as at higher altitudes, oxygen becomes a limiting factor as far as their health, welfare and performance are concerned (Movassagh Ghazani et al., 2008). The quality of the in-house environment is highly dependent upon litter quality, but the quality of litter is seldom given sufficient emphasis. In most instances, excess ammonia in broiler house is due to wet litter and insufficient ventilation. Litter moisture may affect the conversion rate of uric acid to ammonium nitrogen (Liu et al., 2006). The transformation of organic material in litter is also accompanied by the release of carbon in the form of CO_2, methane (CH_4) and other organic gases (Nicks et al., 2003). However, the main sources of CO_2 within a poultry house include fuel combustion, bird respiration and ambient air content (typically 300-500 ppm) (Olanrewaju et al., 2008). Both, the gas furnaces and the broilers generate CO_2 and consume O_2. Oxygen consumed is equal to the volumetric CO_2 produced by the birds and is assumed double the carbon dioxide produced by open-flame natural gas furnaces (McGovern et al, 2001). This means, the combustion of one molecule of fuel (CH_4) generates one molecule of CO_2 and consumes two molecules of O_2.

Management of the broiler house environment is a study in conflict between the need for temperature and humidity control for optimal bird performance, feed conversion, and energy conservation. Ventilation is used to remove noxious gases including ammonia, and carbon dioxide as well as dust and moisture. With the advent of modern nipple-type drinkers, most broiler operations are experiencing less difficulty with interior moisture but greather concentrations of dust, NH_3 and CO_2. Recent research suggests that current recommendations for minimum ventilation should be made based on minimum acceptable CO_2 and NH_3 concentrations, rather than moisture (Xin et al., 1996).

The objective of this study was to explain the potencial sources of CO_2 and to examine the effect of some litter variables on NH_3 volatilisation as well as to calculate emission rates of both problematic gases occuring at critical levels in broiler facilities.

MATERIAL AND METHODS

A common broiler rearing facility was monitored during 6 consecutive fattening periods specified below (Table 1). The begining and ending dates are provided for each flock to document the time of year when each flock was kept.

Housing description

Approximately 25,000 chicks yielding a stocking density of 18 – 22 birds per sq. m. were placed in a concrete-flored commercial broiler facility with a housing area of 1,128 m^2 (94 x 12 m) and/or interior volume of 4,455 cubic meters (0.178m^3/head).

The housing area was heated to nominal temperature of 31-33° C by two gas furnaces (Table 2). Ambient temperature was reduced as the birds progressed in age by approx. 2° C each week to ensure their comfort. The house was mechanically ventilated with combined tunnel and cross two-sided ventilation. Six ceiling axial fans, with maximum capacity of 12,000 m^3/h of each, and four frontal fans with maximum capacity of 35,000 m^3/h assured air exchange in chicken house. Fresh air inlets were placed on both side walls of the hall.

A breeding area was equipped with 4 nipple drinker lines and 3 tube-style pan feeder lines that were filled automatically. Birds (Ross 308) were fed *ad libitum* to a final market weight of around 2 kilograms. Each one of flock was kept for 40 days of fattening period.

New straw was used for each subsequent fattening period, littered to a depth of 5 to 10 cm (approx. 1.6 kg/m^2). The age of litter corresponded with age of birds. No additional litter material or amendments were added to the litter at any time throughout the study.

Table 1. Monitoring schedule

Fattening period	Season	Date	Duration (days)	Average number of chickens
1	summer / autumn I	30.07. - 07.09.	40	23,929
2	autumn	23.09. - 01.11.	40	24,310
3	autumn / winter	18.11. - 27.12.	40	24,502
4	spring / summer	02.05. - 10.06.	40	24,287
5	summer	16.06. - 25.07.	40	23,908
6	summer / autumn II	10.08. - 18.09.	40	24,016

Table 2.: Gas furnaces characteristic

Model	GP 70	GP 120
Power output (kW)	70	120
Natural gas consumption ($m^3.h^{-1}$)	7.5	12.5
Ventilation rate ($m^3.h^{-1}$)	5,000	7,000
Heating distance (m)	50	50
Weight (kg)	36	64

Sampling and calculation

Carbon dioxide and ammonia concentrations were measured by an infrared analyzer (1312 Photoacoustic Multi-gas Monitor). A self-contained pump draws air samples into the analyzer via sample tubes from five measuring points. Air samples were taken from air stream at two ceiling fans, two frontal fans and from outdoor environment. The sampling points were placed approx. 180 cm over the floor. Monitoring task operated continuously with one hour sampling interval.

At the same points, air temperature was measured by thermocouple probe. Two thermocouple probes were placed also into litter (30 mm deep), in the front part and opposite end of house.

Emission factors were determined using the average concentration near the house exhaust fans reduced by outdoor concentrations of monitored gases and multiplied by the volume of air that has passed through the building. The ventilation rate of exhausted air was based on current ventilation capacity (%) and known rate of air flow at 100 % efficiency (212,000 m^3/h).

Statistical evaluation

A statistical analysis software (SAS ver. 9.1) and descriptive statistics were used for a data processing. Spearman correlation was calculated for the evaluation of relationships between gas production and observed variables of indoor environment. The differences were declared as significant when their probability levels were below 0.05. Tukey HSD comparison test was chosen from multiple comparison procedures performed by Statistix 9.0 analytical software to test significant differences between means.

RESULTS AND DISCUSSION

It is generally recommended that CO_2 concentrations should be kept below 3,000 ppm in broiler housing environment (Council Directive 2007/43/EC, 2007). The critical values of CO_2 were reached in all observed periods and the CO_2 level was sometimes even three-fold higher than it is allowed. Particularly, during the first and the fourth quarter of period chickens were exposed to very high levels of carbon dioxide (Table 3). However, it is important to point out, that the concentrations were not measured at the level of chickens‘ heads.

Table 3: CO_2 and NH_3 concentration range in individual quarters of fattening periods

Days of fattening period	1. to 10.			11. to 20.			21. to 30.			31. to 40.			1. to 40.		
	$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max
CO_2 (ppm)	(n = 960)			(n = 960)			(n = 960)			(n = 960)			(n = 3840)		
summer/autumn I	4,123	939	9,427	2,323	993	5,272	2,459	986	5,050	2,651	1,092	5,161	2,889	939	9,427
autumn	5,767	1,395	10,067	4,394	1,172	7,141	3,694	959	7,643	3,273	1,069	5,693	4,282	959	10,067
autumn/winter	6,242	1,129	8,889	4,940	2,261	7,419	5,759	2,686	9,157	5,425	1,698	8,471	5,592	1,129	9,157
spring/summer	6,108	977	9,828	3,449	1,224	6,296	2,922	1,324	6,732	2,889	1,564	6,112	3,842	977	9,828
summer	4,035	887	10,489	2,209	994	4,363	2,783	1,283	5,418	2,856	1,461	5,554	2,971	887	10,489
summer/autumn II	3,960	1,043	10,236	2,630	1,289	4,913	3,091	1,601	6,313	2,943	1,515	5,375	3,156	1,043	10,236
NH_3 (ppm)	(n = 960)			(n = 960)			(n = 960)			(n = 960)			(n = 3840)		
summer/autumn I	2,8	0,7	5,1	2,2	0,8	6,1	4,2	0,8	13,3	4,7	1,1	13,3	3,5	0,7	13,3
autumn	4,0	1,6	6,6	3,8	1,2	7,6	4,8	1,4	12,3	5,8	2,0	11,6	4,6	1,2	12,3
autumn/winter	2,3	1,1	4,2	2,6	1,1	10,5	10,2	4,0	26,0	13,7	4,6	29,1	7,2	1,1	29,1
spring/summer	1,8	0,4	4,1	1,0	0,1	2,6	3,4	0,6	14,0	4,2	1,4	14,0	2,6	0,1	14,0
summer	1,2	0,0	11,1	0,5	0,0	2,1	3,7	0,4	14,1	5,0	1,9	14,0	2,6	0,0	14,1
summer/autumn II	1,2	0,1	3,4	1,7	0,2	6,2	5,8	1,6	19,6	4,7	2,2	11,1	3,3	0,1	19,6

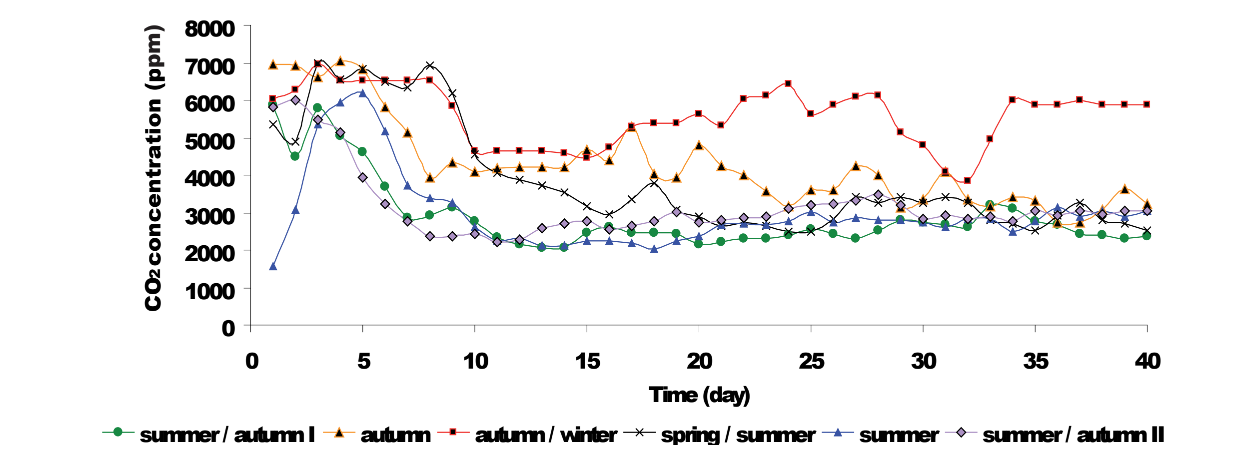

Fig. 1: The course of carbon dioxide concentrations during individual fattening periods

Table 4: Parameters of indoor environment during individual fattening periods

Days of fattening period	1. to 10.		11. to 20.		21. to 30.		31. to 40.	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Ventilation rate (m³/h)	(n = 240)		(n = 240)		(n = 240)		(n = 240)	
summer / autumn I	39,079	27,921	73,361	49,373	114,772	49,642	130,725	58,893
autumn	28,284	7,503	34,159	4,173	46,349	10,328	90,524	18,899
autumn / winter	25,581	5,029	32,330	2,525	35,060	2,227	39,406	2,287
spring / summer	22,711	7,580	39,061	14,191	126,458	58,806	102,387	41,257
summer	27,322	19,426	68,105	44,233	98,819	55,572	128,764	47,680
summer / autumn II	30,873	13,656	66,877	41,550	124,594	64,793	145,785	55,652
Air temperature (°C)	(n = 960)		(n = 960)		(n = 960)		(n = 960)	
summer / autumn I	29.2	1.6	26.5	2.0	25.1	1.8	24.7	1.8
autumn	29.7	1.8	26.1	2.1	21.3	1.6	23.7	2.5
autumn / winter	32.5	3.9	24.7	1.6	21.7	1.4	19.7	1.4
spring / summer	29.3	2.2	23.5	2.3	24.3	2.7	22.8	2.3
summer	29.2	3.8	25.2	2.1	23.7	1.8	23.8	1.8
summer / autumn II	28.6	2.3	24.9	1.7	24.4	2.7	23.3	2.5
Litter temperature (°C)	(n = 480)		(n = 480)		(n = 480)		(n = 480)	
summer / autumn I	26.7	0.49	27.9	0.89	31.1	1.56	34.4	0.97
autumn	30.7	1.52	27.1	1.96	25.3	1.58	29.0	0.89
autumn / winter	25.2	1.26	28.1	1.04	30.5	0.85	33.3	0.72
spring / summer	26.9	1.76	27.1	1.76	30.3	2.12	32.9	1.05
summer	26.2	2.09	27.7	1.42	30.0	1.76	33.5	1.35
summer / autumn II	28.7	1.04	28.1	1.78	30.8	2.12	32.2	1.01

sd = standard deviation

CO_2 accumulation can occur when additional CO_2 is produced by direct heating systems (where the exhaust gases remain inside the broiler house) and when the ventilation rate is operated at extremely low level (EC, 2000). There are two main sources of CO_2 in general. The first one is supposed to be heaters, however, as the birds approached marked age, the CO_2 source is primarily from the bird's respiration (McGovern et al., 2001).

A speculation can be accomplished if is assumed that natural gas consists of 97.6 % methane, 1.5 % ethane, propane, butane, 0.1 % CO_2, and 0.8 % nitrogen. The gas furnaces used for heating in chicken house (Table 2) had natural gas consumption of 7.5 and 12.5 m^3/h and the power output of 70 and 120 kW. If we burn completely 20 m^3 of natural gas and assume that it is pure methane (CH_4), it is in agreement with the following equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.

Since 1 mole of a gas occupies 22.4 liters at STP (standard temperature and pressure, i.e., temperature of 0° C and pressure of 101.325 kPa), 20,000 liters of CH_4 contain 20,000/22.4 = 892.86 moles of CH_4.

Since for each mole of methane we get one mole of carbon dioxide (see equation above) and one mole of CO_2 has a mass of approx. 44 g, then 892.86 mole of CO_2 has a mass of approx. 892.86 x 44 or 39.3 kg of CO_2. Therefore, the complete combustion of 20 m^3/h at STP of natural gas results in the production of about 39.3 kg/h of CO_2. However, both heating units were not running continuously. Thus, we can not state this amount of CO_2 was produced every hour.

Carbon dioxide levels in the broiler house atmosphere tend to increase upon time with bird growth and respiration (Miles et al., 2006). Due to intensive heating at the begining, CO_2 concentration decreased from placement to mid-fattening and then increased slightly towards the end of periods (Figure 1). It means, one source of CO_2 (gas burning) was replaced with other one (birds respiration). This effect is not very obvious, since more intensive ventilation (Table 4) entered this process and CO_2 was diluted in fresh air from outdoor environment.

The amount of CO_2 produced by respiration of chickens can be explained in a similar manner as a fuel combustion mentioned before. The amount of CO_2 produced by birds is proportional to the heat production of the animal (1 liter CO_2 for every 24.6 kJ of total heat produced). This corresponds approximately to 1.5 l/h/kg liveweight (EC, 2000). The production of carbon dioxide in the experiment carried out by Para et al. (2003) decreased with increasing weight of broilers from the mean weight of 0.25 kg/head always up to the final weight of 1.5-2.0 kg/head; the initial value reaching 1.85 l/h/kg and the final one 1.23 l/h/kg, resp. Since 1.5 liter of CO_2 corresponds to 0.06696 moles (1 mole CO_2 = 22.4 liters at STP) and one mole of CO_2 has a mass of 44 g, then chicken exhales approx. 0.06696 x 44 or 2.946 g CO_2 /h/kg. At market age of 2 kg and the capacity of 25,000 chickens kept in this broiler house, 50,000 x 2.946 g or 147.3 kg of CO_2 is emitted per hour, as a consequence of birds respiration. If we take into consideration the first day of just hatched chicks with liveweight of 40 g, 2.9 kg of CO_2/h is produced by their respiraton. However, it is also important to point out, that the breathing frequency changes by age markedly.

Values of NH_3 were recorded in concentration range between 0.0 and 29.1 ppm. Ammonia concentration had rising tendency in all periods (Figure 2). Correlation with the bird (litter) age was very highly significant (P<0.001) (Table 5). Vučemilo et al. (2007) associate the increasing of air concentration of ammonia with the increase in animal age and air humidity. He reported almost septuple higher level of NH_3 concentration between the first and the fifth weeks of age (litter – mixture of wooden sawdust and shavings). In our measurement we found approximately triple increase in the ammonia concentration between the first and last quarter of fattening period (Table 3). Since the temperature of litter was quite stable during the whole year (Table 4) and the tested differences among fattening

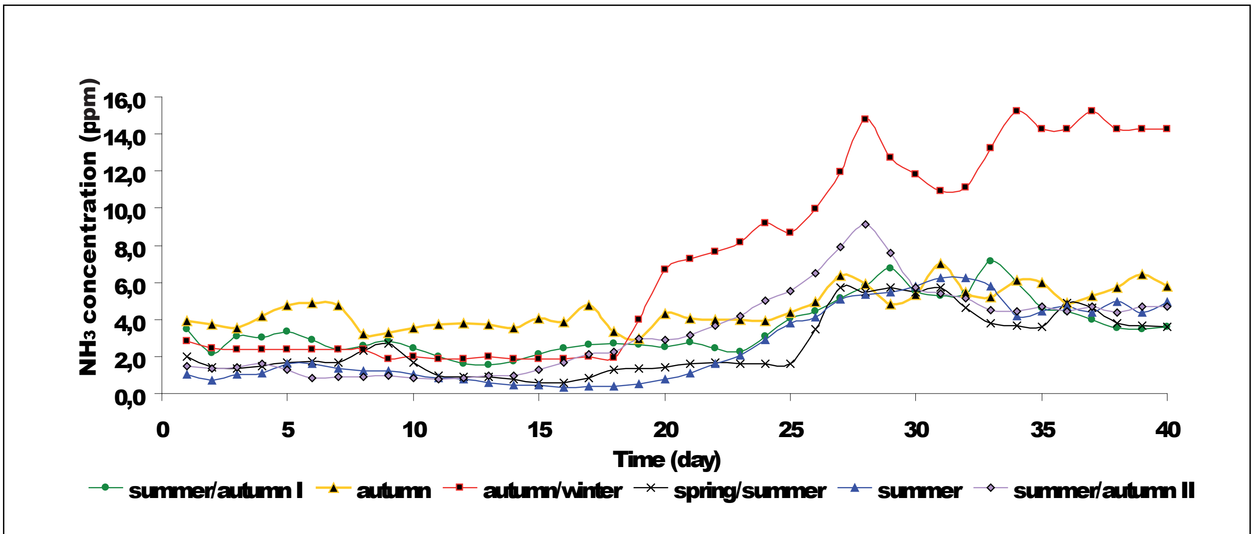

Fig. 2: The course of changes in ammonia concentrations

Table 5: Correlations between studied variables and production of gases

Variables	Air temperature	Litter temperature	Chicken (litter) age	Ventilation rate
CO_2 conc.				
summer/autumn I	0.23227 -	0.26454 -	-0.35066 +	-0.51503 +++
autumn	0.68612 +++	0.41463 ++	-0.84578 +++	-0.84712 +++
autumn/winter	0.23450 -	-0.24237 -	-0.19743 +	-0.37745 +
spring/summer	0.64880 +++	-0.51859 +++	-0.76916 +++	-0.70775 +++
summer	0.19248 -	0.02576 -	0.00563 -	-0.14816 -
summer/autumn II	-0.02198 -	0.18901 -	0.06354 -	-0.04149 -
NH_3 conc.				
summer/autumn I	-0.65235 +++	0.69925 +++	0.64015 +++	0.49261 ++
autumn	-0.44897 ++	0.00281 -	0.72289 +++	0.69803 +++
autumn/winter	-0.80878 +++	0.82104 +++	0.92368 +++	0.75421 +++
spring/summer	-0.09191 -	0.75779 +++	0.62293 +++	0.60674 +++
summer	-0.28434 -	0.74765 +++	0.70269 +++	0.68581 +++
summer/autumn II	-0.71000 +++	0.71508 +++	0.78864 +++	0.74108 +++

+ P<0.05; ++ P<0.01; +++ P<0.001; - non-significant

periods were also not significant (Table 6), lower NH_3 concentrations during summer periods must have been caused by other factors (intensive ventilation, drier litter, and crust on its surface). Moreover, we did not notice marked differences in temperatures of air when comparing the summer and winter period as well (Table 6).

The comparison of concentration and emission rate according to the fattening period (season) is given in Table 6. The highest NH_3 concentrations were recorded in fattening period 3 (autumn/winter) and 2 (autumn), and the lowest in period 4 (spring/summer). The differences were significant (P<0.001 and P<0.05 respectively). CO_2 concentrations reached also the highest values in period 3 (autumn/winter). The lowest ones were recorded in period 1 (summer/autumn I) (P<0.001). The seasonal differences in case of NH_3 and CO_2 emissions were not significant. Liang et al. (2003) reported higher emission rates in summer than in winter because of highest ventilation capacity, even though the lower concentrations. A number of authors (Coufal et al., 2006; Redwine et al., 2002) published similar seasonal changes in emissions.

The ventilation rate showed a rise in all periods. The ventilation system operated at the highest capacity during period 6 (summer/autumn II) and at the most reduced capacity during period 3 (autumn/winter) to maintain proper indoor temperature. The difference was significant (P<0.001) (Table 6). Ammonia concentration and amount of air exhausted through the ventilation system were in positive correlation (P<0.001), unlike carbon dioxide (Table 5). It means, that in spite of rising ventilation rate towards the end of the fattening period, the ammonia concentration did not decrease but it had even slightly increasing tendency.

From a seasonal point of view, CO_2 emissions reached the highest values (280 t) in flock “summer/autumn II“ (Table 7). This was attributed to increasing ventilation rate of the building (P<0.001). Relatively high emission rates were also determined in flocks “autumn/winter“ (269 t) and “spring/summer“ (276 t). This was significantly affected not only by ventilation rate, but also by increasing CO_2 concentrations (P<0.01, P<0.001). There was also a moderate correlation between ventilation rate and CO_2 concentration - the higher the ventilation rate, the lower the concentration of CO_2. Moreover, there was also no statistically significant correlation between CO_2 concentration and CO_2 emission in three flocks (Table 5).

The NH_3 emission factor ranged from 5.17 g/head to 7.81 g/head per period. Gates et al. (2008) reported almost 3-times higher ammonia emission (17.4 g/head for one period in fattening to life weight 2.1 kg housed on sawdust litter). Lacey et al. (2002) emphasize that different values of emission factors published by American and European authors are caused by different climatic conditions and differences in average live weight of animals. He reports emission factor 19.8 g NH_3/head for 49 days fattening cycle (average life weight of chickens 1.03 kg).

Table 6: A seasonal comparison of observed variables

Fattening period	$\bar{x}$	sd	Significance
NH_3 conc. (ppm) (n = 3840)			
1	3.5	1.8	
2	4.6	1.2	F = 17.17
3	7.2	5.3	P = 0.0000
4	2.6	1.8	3:2,1,6,5,4 +++
5	2.6	2.3	2:5,4 +
6	3.3	2.5	
NH_3 emission (kg/h) (n = 3840)			
1	0.16	0.14	
2	0.13	0.10	
3	0.16	0.14	F = 1.13
4	0.13	0.16	P = 0.3454
5	0.15	0.17	
6	0.20	0.18	
Litter temperature (°C) (n = 1920)			
1	30.0	3.2	
2	28.0	2.6	
3	29.3	3.2	F = 2.69
4	29.3	3.0	P = 0.0219
5	29.3	3.2	
6	29.9	2.3	
Ventilation rate (m^3/h) (n = 960)			
1	89.484	59.724	F = 14.76
2	49.828	27.001	P = 0.0000
3	33.094	5.970	6:2,3 +++
4	72.654	56.594	1:2,3 +++
5	80.752	57.714	5,4:3 +++
6	92.032	66.165	5:2 +
CO_2 conc. (ppm) (n = 3840)			
1	2889	1430	F = 37.89
2	4282	1456	P = 0.0000
3	5592	979	3:2,4,6,5,1 +++
4	3842	1761	2:6,5,1 +++
5	2971	1535	4:1 +++
6	3156	1311	5:4 ++ 4:6 +
CO_2 emission (kg/h) (n = 3840)			
1	225.6	119.1	
2	258.4	110.0	
3	280.5	66.2	F = 2.48
4	288.0	199.7	P = 0.0325
5	233.4	151.5	
6	291.8	186.3	
Air temperature (°C) (n = 3840)			
1	26.4	2.5	
2	25.2	3.7	
3	24.7	5.4	F = 1.32
4	25.0	3.5	P = 0.2582
5	25.5	3.4	
6	25.3	3.1	

+ P<0.05; ++ P<0.01; +++ P<0.001; sd = standard deviation

CONCLUSION

From calculations performed in this study it can be concluded, that a natural gas burning process is responsible for a substantial part of CO_2 emissions during first days of periods, and later, the respiration of animals takes dominance. The major part of CO_2 seemed to have it´s origin in a bird respiration with assumed production of approx. 147 kg of CO_2/h. The heaters could be theoretically a possible source of approx. 39 kg each hour, if they would work continuously. This evaluation of CO_2 emission sources could be complete if also CO_2 releasing from litter decomposition would be taken ito the consideration. The temperature of litter and the temperture of air related with chicken age and ventilation rate were main parameters observed during this experiment, to assess their influence on carbon dioxide and ammonia production. There was a great influence of chicken age on CO_2 emissions (P<0.001), but ventilation rate could markedly affect this correlation. The amount of ammonia emissions was increasing by chicken (litter) age (P<0.001) probably as a consequence of both, increasing NH_3 concentration and ventilation rate (P<0.001). However, there was no statistically significant difference in emissions of both gases from individual fattening periods.

Resulting annual emission factors for CO_2 (73.11 kg/head) and for NH_3 (0.043 kg/head) were calculated for 7 periods, i.e. one production year. On the basis of obtained results it can be concluded that from poultry facility with capacity of 25,000 broiler chickens placed onto litter, about $1,828.10^3$ kg CO_2 and 1,000 kg NH_3 is emitted yearly.

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Table 7: Summaries of CO_2 and NH_3 emission data (kg/h)

Days of fattening period	1. to 10.	11. to 20.	21. to 30.	31. to 40.	Total emission (kg)	EF [1] (kg/head)	EF [2] (kg/head)
CO_2							
summer/autumn I	155.75	137.91	270.09	338.60	216,563	9.05	73.11
autumn	240.21	212.57	232.31	348.55	248,075	10.20	
autumn/winter	247.02	238.70	311.21	325.07	269,280	10.99	
spring/summer	198.11	169.18	445.82	338.93	276,497	11.39	
summer	120.29	130.72	284.22	398.31	224,050	9.37	
summer/autumn II	131.96	177.71	398.38	459.27	280,156	11.67	
NH_3							
summer/autumn I	9.46	14.02	58.81	72.51	154.8	$6.47 . 10^{-3}$	0.043
autumn	14.35	16.64	29.56	65.03	125.58	$5.17 . 10^{-3}$	
autumn/winter	7.72	12.14	54.31	82.33	156.5	$6.39 . 10^{-3}$	
spring/summer	5.89	5.04	62.64	53.58	127.15	$5.24 . 10^{-3}$	
summer	4.38	4.91	51.18	82.94	143.41	$6.00 . 10^{-3}$	
summer/autumn II	4.121	15.15	82.49	85.78	187.54	$7.81 . 10^{-3}$	

[1] Partial emission factor calculated from average number of chickens in individual periods, represents emission of CO_2 or NH_3 per head and 40 days of fattening period; [2] Annual emission factor, i.e. emission converted into seven fattening periods in one productive year

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