# The influence of litter age, litter temperature and ventilation rate on ammonia emissions from a broiler rearing facility

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**ABSTRACT**: The research reported in this article attempts to address the ammonia problem by quantifying the effect of several variables on ammonia concentrations and emissions. These variables include litter temperature, litter age and ventilation rate. Data was collected in a commercial tunnel-ventilated grow-out facility with deep litter, designed for 25 000 broilers, during 6 consecutive flocks. Birds were housed from hatching to approximately 40 days of age. Litter temperature and litter age were positively correlated ($P < 0.0001$) with the production of ammonia gas. The amount of ammonia emissions increased with the litter age ($P < 0.0001$) as a consequence of both the increased ammonia concentration and the ventilation rate ($P < 0.0001$). The lowest concentrations of $NH_3$ were observed in a "summer" period, although ammonia emissions tended to be higher just in summer months because of a higher ventilation rate. The elevated levels of ammonia in winter were attributed to the lower ventilation rate during cold weather. After the evaluation of ammonia emissions it can be concluded that during the grow-out period of broilers kept on renewed litter there is an average loss of 6.18 g ammonia per bird and/or 0.043 kg of ammonia per bird yearly. The increase in litter temperature during grow-out periods is a process which could be controlled to prevent excessive ammonia volatilization from housing facilities.

**Keywords**: ammonia; litter; broiler chickens; grow-out period; ventilation rate

Broiler production is a prime example of high density animal production. Broilers are often grown in production houses containing 20 000 birds or more at densities of 0.06 $m^2$ per bird. Broiler litter typically contains 4 to 6 % nitrogen, much of which is in the $NH_3$ or $NH_4^+$ form. The mixture of litter and manure is effectively a nitrogen storehouse. Under the proper conditions, a considerable quantity of this nitrogen will be released as ammonia (Carr et al., 1990). Many factors, such as season of the year, ambient temperature and humidity, bird health, and management practices can influence ammonia volatilization from broiler rearing facilities (Coufal, 2005). Ammonia is formed from the breakdown of nitrogenous waste products in poultry manure (undigested proteins and uric acid) by exogenous enzymes produced by microorganisms. Factors that exhibit direct control over these processes have been identified as pH, temperature, and moisture (Elliot and Collins, 1982). Ammonia release is depressed at pH < 7 but is very high at pH > 8 (Parker et al., 2005). Therefore, in a commercial broiler grow-out facility, pH would seldom be a factor determining $NH_3$ volatilization since the pH of broiler litter is

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normally higher than pH 8 unless acidifying agents have been applied to the litter (Lacey et al., 2003). This fact leaves temperature and moisture as the second most important factors affecting the variability of $NH_3$ volatilization in a commercial setting (Coufal, 2005). During breeding periods, high indoor temperatures required for baby chicks tend to cause growers to conserve fuel by reducing ventilation rates, thereby elevating the $NH_3$ concentration (Brewer and Costello, 1999). It is also important to point out that also litter age significantly affects N retention in the litter and, consequently, influences the N loss (Coufal et al., 2006).

At present, the European Union permits to keep broiler chickens on littered floor only (Council Directive 2007/43/EC, 2007). The way of bird keeping directly influences the pollution with dangerous compounds, dust emissions and microbiological pollution on farms. Chemical pollutants are risk factors for the health of human beings and animals (Vaičionis et al., 2006). The piled up straw is gradually enriched with excrements, rests of feed, water and feathers. Thus poultry manure is and starts to be the main source of ammonia emissions. Environmental features, such as bulk and surface temperature of the manure, influence ammonia volatilization with higher temperature resulting in increased ammonia volatilization (Richard et al., 2005). Litter moisture, which is mainly influenced by the ventilation and drinking system management, may affect the conversion rate of uric acid to ammonium nitrogen (Liu et al., 2006). All the above-mentioned factors are strongly influenced by litter age, i.e. by bird age. It has been reported that the emission rate of $NH_3$ increases with the flock age from the nearly zero value at the beginning of flock cycle to maximum values at its end (Gates et al., 2008).

According to the EU Regulation 2007/43/EC (2007), which shall enter into force in 2010, all chickens should have permanent access to litter which is dry and friable on the surface. However, it can be a problem to keep litter material in such quality. This is caused not only by high stocking density (33–42 kg/m$^2$) but also by other factors occurring in housing (ventilation intensity, spilled water from drinkers, condensation of water vapour, adding litter, diseases of animals, etc.). Litter condition and quality of air can be kept in bearable limits by proper regulation of ventilation. The seasonality and correlation of ammonia concentration and ventilation rate become apparent with lower ammonia concentration and higher ventilation rate during warm summer conditions, while ammonia concentration tended to be higher during cold weather when low ventilation rates provided less fresh air dilution of ammonia (Wheeler et al., 2006). The influence of season on the amount of produced emissions is in fact the influence of ventilation rate which depends on the need to cool the temperature in the interior environment. Litter condition and ventilation intensity will probably markedly influence the amount of produced emissions.

The research discussed in this paper was conducted with objectives in mind:

(1) to measure atmospheric ammonia concentrations;

(2) to examine the impact of litter temperature, litter age, and ventilation rate on $NH_3$ volatilization;

(3) to calculate $NH_3$ emission rates over 6 consecutive flocks and annual emission factor in a commercial broiler grow-out facility.

## MATERIAL AND METHODS

A common broiler rearing facility was monitored for $NH_3$ emissions. The study was carried out on a commercial farm and continuous measurements were done over 6 flocks in different seasons. Flow chart of the assessment is presented in Table 1. The impact of litter temperature, litter age, air temperature and ventilation rate on ammonia production was evaluated.

### Housing description and equipment

The house was concrete-floored with the breeding area of 1 128 m$^2$ (94 × 12 m), designed for 25 000 broilers yielding a stocking density of 18 to 22 birds/m$^2$. The number of birds in each flock is shown in Table 1.

One-day-old broiler chickens of "Ross 308" commercial hybrid were reared to 40 to 42 days of age and fed diets obtained from commercial broiler feed producers. Final weight of broilers (approx. 2 kg) corresponds to the breeding area load of 36 to 42 kg/m$^2$ at the end of the grow-out period.

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 and four frontal fans with maximum capacity 35 000 m$^3$/h were installed to ensure the air exchange in the chicken house. At a maximum

Table 1. Flow chart of the assessment

| Flock | Date | Number of days | Average number of chickens |
|---|---|---|---|
| Summer/autumn I | 30.07.–07.09. | 40 | 23 929 |
| Autumn | 23.09.–01.1 1. | 40 | 24 310 |
| Autumn/winter | 18.11.–27.12. | 40 | 24 502 |
| Spring/summer | 02.05.–10.06. | 40 | 24 287 |
| Summer | 16.06.–25.07. | 40 | 23 908 |
| Summer/autumn II | 10.08.–18.09. | 40 | 24 016 |

ventilation rate the ventilation system could exhaust 212 000 $m^3$/h. Fresh air inlets were placed on both side walls of the hall. Evaporative cooling pads were used in hot weather to cool the birds, and natural gas furnaces (70 and 120 kW) were used for supplemental heating in winter. A thermostat override controlled the fans to remove excess heat from the building if the maximum set point temperature was reached at any time. The override thermostat was set at approximately 32°C at chick placement and was reduced by approximately 2°C each week.

A breeding area was equipped with 4 nipple drinker lines and 3 tube-style pan feeder lines that were filled automatically. Feed and water were provided ad libitum. Diets were changed at the bird age directed by the farmer.

## Litter management

A chopped wheat straw (20–30 cm) was used for each subsequent flock with old litter removed between flocks. The age of litter corresponded with the age of birds. Fresh new straw was added to the breeding area to a depth of 5 to 10 cm (approx. 1.6 kg/$m^2$). No additional litter material or amendments were added to the litter at any time throughout the study.

## Data and sample collection

Fattening lasted approx. 40 days with a technological break between periods approx. 10 days. The beginning and ending dates are provided for each flock to document the time of the year when each flock was reared.

The concentrations of ammonia were determined on the device 1312 Photoacoustic Multi-gas Monitor, the principle of which is based on the photoacoustic infrared detection method. Air samples for $NH_3$ concentration analysis were taken from the air stream at two ceiling, two frontal fans and from outdoor surroundings.

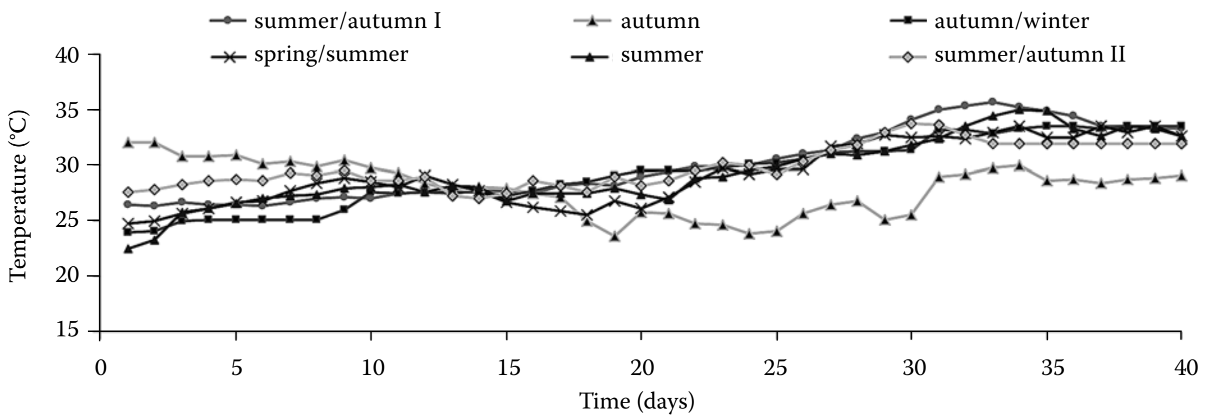


Figure 1. Course of changes in the internal temperature of litter during individual periods

Table 2. Litter and air temperature variations during individual grow-out periods

| Days of grow-out period | | 1. to 10. | | | 11. to 20. | | | 21. to 30. | | | 31. to 40. | | | 1. to 40. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | flock | $n$ | $x$ | $s$ | $n$ | $x$ | $s$ | $n$ | $x$ | $s$ | $n$ | $x$ | $s$ | $n$ | $x$ | $s$ |
| Litter temperature (°C) | summer/autumn 1 | 480 | 26.7 | 0.49 | 480 | 27.9 | 0.89 | 480 | 31.1 | 1.56 | 480 | 34.4 | 0.97 | 1 920 | 30.0 | 3.19 |
| | autumn | 480 | 30.7 | 1.52 | 480 | 27.1 | 1.96 | 480 | 25.3 | 1.58 | 480 | 29.0 | 0.89 | 1 920 | 28.0 | 2.56 |
| | autumn/winter | 480 | 25.2 | 1.26 | 480 | 28.1 | 1.04 | 480 | 30.5 | 0.85 | 480 | 33.3 | 0.72 | 1 920 | 29.3 | 3.15 |
| | spring/summer | 480 | 26.9 | 1.76 | 480 | 27.1 | 1.76 | 480 | 30.3 | 2.12 | 480 | 32.9 | 1.05 | 1 920 | 29.3 | 3.03 |
| | summer | 480 | 26.2 | 2.09 | 480 | 27.7 | 1.42 | 480 | 30.0 | 1.76 | 480 | 33.5 | 1.35 | 1 920 | 29.3 | 3.24 |
| | summer/autumn II | 480 | 28.7 | 1.04 | 480 | 28.1 | 1.78 | 480 | 30.8 | 2.12 | 480 | 32.2 | 1.01 | 1 920 | 29.9 | 2.27 |
| Air temperature (°C) | summer/autumn 1 | 960 | 29.2 | 1.60 | 960 | 26.5 | 2.00 | 960 | 25.1 | 1.80 | 960 | 24.7 | 1.80 | 3 840 | 26.4 | 2.50 |
| | autumn | 960 | 29.7 | 1.80 | 960 | 26.1 | 2.10 | 960 | 21.3 | 1.60 | 960 | 23.7 | 2.50 | 3 840 | 25.2 | 3.70 |
| | autumn/winter | 960 | 32.5 | 3.90 | 960 | 24.7 | 1.60 | 960 | 21.7 | 1.40 | 960 | 19.7 | 1.40 | 3 840 | 24.7 | 5.40 |
| | spring/summer | 960 | 29.3 | 2.20 | 960 | 23.5 | 2.30 | 960 | 24.3 | 2.70 | 960 | 22.8 | 2.30 | 3 840 | 25.0 | 3.50 |
| | summer | 960 | 29.2 | 3.80 | 960 | 25.2 | 2.10 | 960 | 23.7 | 1.80 | 960 | 23.8 | 1.80 | 3 840 | 25.5 | 3.40 |
| | summer/autumn II | 960 | 28.6 | 2.30 | 960 | 24.9 | 1.70 | 960 | 24.4 | 2.70 | 960 | 23.3 | 2.50 | 3 840 | 25.3 | 3.10 |

At the same points, air temperature was measured by a thermocouple probe. Two thermocouple probes were placed also in litter (approx. 30 mm under the surface), in the front and back part of the breeding area to evaluate temperature variations of litter.

Concentrations of $NH_3$ and temperature values were recorded continuously at one-hour intervals during the whole rearing period.

## Emission rate determination

Emissions were calculated from the one-hour concentration of gases in interior and exterior environments and air flow through measuring fans by means of the equation:

$$E = Q \times (c_i - c_e) \text{ (mg/h)}$$

where:

$E$ = emission of gas

$Q$ = air flow through the fans

$(c_i - c_e)$ = difference between concentrations of gas in the interior and exterior environment

The determination of air flow through the ventilation system was based on current ventilation capacity (%) and known rate of air flow at 100% efficiency (212 000 $m^3$/h) and was used for the calculation of total emissions.

The research data was processed by Spearman's correlation coefficient method using the SAS ver. 9.1 computer programme. The results are accepted as reliable when $P < 0.05$.

## RESULTS AND DISCUSSION

From the data in Table 2 and Figure 1 it can be concluded that the temperature of litter increased ($P < 0.001$) with the age of litter and the difference between the first and the fourth quarter of rearing period was 6.5°C on average. The "autumn" flock did not follow this trend and it cannot be fully explained.

The warmth in litter is produced by bacterial fermentation and partly by contact with chickens. Results obtained by Reiter and Bessei (2000) confirmed it. They found different temperatures of litter at different stocking densities of broilers. Higher temperatures also stimulate the microbial activity in litter, thereby increasing the potential for the enzymatic degradation of uric acid and proteins to $NH_3$ (Coufal et al., 2006).

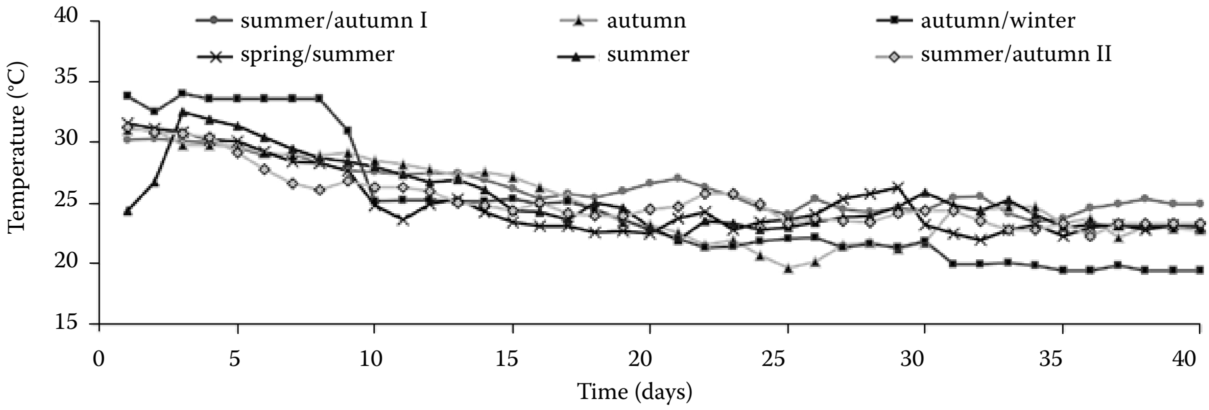


Figure 2. Course of changes in air temperature in the housing area

The temperature of air was decreasing (Figure 2). Both the temperature of litter and the temperature of air were in antagonistic relation ($P < 0.001$) in four observed flocks (Table 3).

Ammonia concentrations were measured between 0.0 and 29.1 ppm and increased with bird age. Ammonia concentration had a rising tendency in all periods (Figure 3). Vučemilo et al. (2007) associated the increase in the air concentration of ammonia with the increase in animal age and air humidity. He reported the almost seven times higher level of $NH_3$ concentration between the first and the fifth week of age (litter – mixture of wooden sawdust and shavings). In our measurements we found an approximately triple increase in ammonia concentration between the first and the last quarter of grow-out period. Very high statistic reliability was found between the age of litter and ammonia concentration as well as between the age of litter and ammonia emissions ($P < 0.001$). Wheeler et al. (2003, 2006) came to the same conclusion.

We did not notice any marked differences in temperatures of litter when comparing the summer and winter period (Table 2). Since the temperature of litter was quite stable during the whole year, lower concentrations of ammonia during the summer periods must have been caused by other factors (intensive ventilation, drier litter and crust on its surface). The increase in litter temperature with ammonia concentrations as well as with ammonia emissions was significant ($P < 0.001$) in five flocks.

Ammonia emission rates were higher in "summer/autumn II" (187.5 kg) than in "autumn" and "spring/summer" (125.6 and 127.2, resp.), although $NH_3$ concentrations were lower in "summer/au-tumn II". On the other hand, we found no significant differences in ammonia emissions between the cold period "autumn/winter" (156.5 kg and 6.39 g per head) and warm period "summer/autumn I" (154.8 kg and 6.47 g/head). Liang et al. (2003) reported generally higher emission rates in summer than in winter because of the highest ventilation capacity, even though

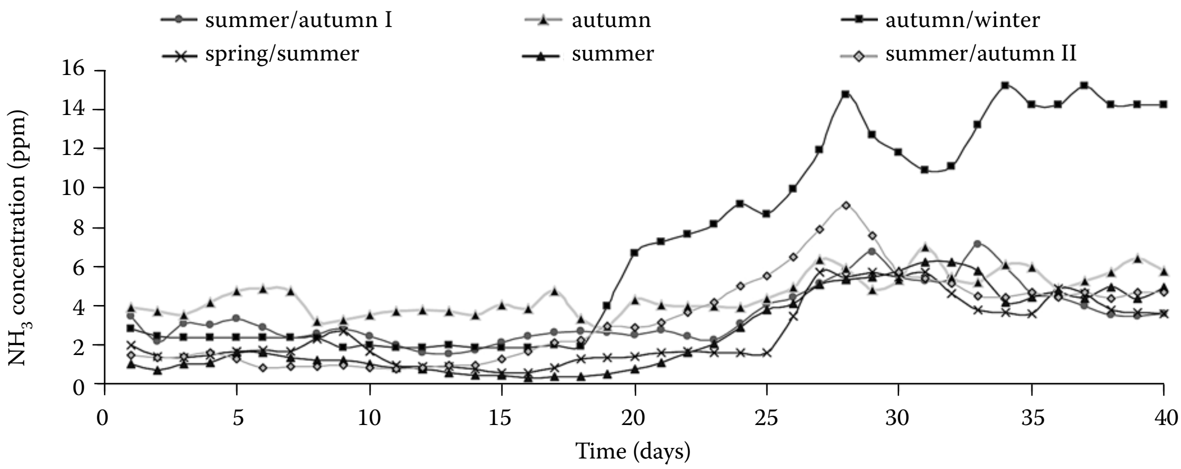


Figure 3. Course of changes in ammonia concentrations

Table 3. Correlations among the studied factors influencing ammonia production

| Parameter | Period | $NH_3$ missions | Air temperature | Litter temperature | Age of chickens | Amount of exhausted air |
|---|---|---|---|---|---|---|
| $NH_3$ concentration | summer/autumn I | 0.85159*** | –0.65235*** | 0.69925*** | 0.64015*** | 0.49261** |
| | autumn | 0.90844*** | –0.44897** | 0.00281$^{NS}$ | 0.72289*** | 0.69803 |
| | autumn/winter | 0.86885*** | –0.80878*** | 0.82104*** | 0.92368 *** | 0.75421*** |
| | spring/summer | 0.90300*** | –0.09191$^{NS}$ | 0.75779*** | 0.62293*** | 0.60674 |
| | summer | 0.88028*** | –0.28434$^{NS}$ | 0.74765*** | 0.70269*** | 0.68581*** |
| | summer/autumn II | 0.90459*** | –0.71000*** | 0.71508*** | 0.78864*** | 0.74108*** |
| $NH_3$ emissions | summer/autumn I | | –0.82158*** | 0.89268*** | 0.85685*** | 0.77386*** |
| | autumn | | –0.64653*** | –0.22852$^{NS}$ | 0.90882*** | 0.89853*** |
| | autumn/winter | | –0.93315*** | 0.95023*** | 0.94125*** | 0.92988*** |
| | spring/summer | | 0.32531* | 0.80460*** | 0.79231*** | 0.85386*** |
| | summer | | –0.44328** | 0.88914*** | 0.86049*** | 0.89205*** |
| | summer/autumn II | | –0.81206*** | 0.80210*** | 0.89319*** | 0.89504*** |
| Air temperature | summer/autumn I | | | –0.86998*** | –0.87167*** | –0.66992*** |
| | autumn | | | 0.81707*** | –0.76191*** | –0.73378*** |
| | autumn/winter | | | –0.97895*** | –0.91712 *** | –0.92599*** |
| | spring/summer | | | –0.36237* | –0.68543*** | –0.47424** |
| | summer | | | –0.57309*** | –0.70232*** | –0.44555** |
| | summer/autumn II | | | –0.61222*** | –0.92488*** | –0.79356*** |
| Litter temperature | summer/autumn I | | | | 0.95722*** | 0.84422*** |
| | autumn | | | | –0.41689** | –0.38101* |
| | autumn/winter | | | | 0.98815*** | 0.94918 *** |
| | spring/summer | | | | 0.85264 *** | 0.72238*** |
| | summer | | | | 0.90984*** | 0.89885*** |
| | summer/autumn II | | | | 0.78967 *** | 0.80858*** |
| Age of chickens | summer/autumn I | | | | | 0.90220*** |
| | autumn | | | | | 0.98213*** |
| | autumn/winter | | | | | 0.93074*** |
| | spring/summer | | | | | 0.83932*** |
| | summer | | | | | 0.87958*** |
| | summer/autumn 11 | | | | | 0.92446*** |

***very highly significant $P < 0.001$; **highly significant $P < 0.01$; *significant $P < 0.05$; NS – nonsignificant

the concentrations were lower. A number of authors (Redwine et al., 2002; Coufal et al., 2006) recorded similar seasonal changes in emissions. The highest concentrations of ammonia were in "autumn" and "autumn/winter" flocks, the lowest in "spring/summer" and "summer" ones (Table 4).

The ventilation rate showed a rise in all periods (Figure 4). The ventilation system operated at a much higher capacity during summer (average of 34 to 43%) but at a much reduced capacity during cold weather (average of 16 to 24%) to maintain the inside temperature (Table 5). Carr et al. (1990) observed decreasing

Table 4. Parameters of environment in the hall during the particular grow-out periods

| Days of grow-out period | | 1. to 10. | | | 11. to 20. | | | 21. to 30. | | | 31. to 40 | | | 1. to 40. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | flock | *n* | *x* | *s* | *n* | *x* | *s* | *n* | *x* | *s* | *n* | *x* | *s* | *n* | *x* | *s* |
| $NH_3$ concentration (ppm) | summer/autumn 1 | 960 | 2.8 | 0.96 | 960 | 2.2 | 0.71 | 960 | 4.2 | 1.96 | 960 | 4.7 | 1.85 | 3840 | 3.5 | 1.80 |
| | autumn | 960 | 4.0 | 0.79 | 960 | 3.8 | 0.75 | 960 | 4.8 | 1.33 | 960 | 5.8 | 0.93 | 3840 | 4.6 | 1.25 |
| | autumn/winter | 960 | 2.3 | 5.27 | 960 | 2.6 | 1.58 | 960 | 10.2 | 2.48 | 960 | 13.7 | 2.42 | 3840 | 7.2 | 5.27 |
| | spring/summer | 960 | 1.8 | 0.55 | 960 | 1.0 | 0.32 | 960 | 3.4 | 2.20 | 960 | 4.2 | 1.37 | 3840 | 2.6 | 1.84 |
| | summer | 960 | 1.2 | 0.82 | 960 | 0.5 | 0.23 | 960 | 3.7 | 2.05 | 960 | 5.0 | 1.57 | 3840 | 2.6 | 2.27 |
| | summer/autumn II | 960 | 1.2 | 0.39 | 960 | 1.7 | 0.89 | 960 | 5.8 | 2.71 | 960 | 4.7 | 0.91 | 3840 | 3.3 | 2.49 |
| Ventilation rate ($m^3/h$) | summer/autumn 1 | 240 | 39 079 | 27 921 | 240 | 73 361 | 49 373 | 240 | 114 772 | 49 642 | 240 | 130 725 | 58 893 | 960 | 89 484 | 59 724 |
| | autumn | 240 | 28 284 | 7 503 | 240 | 34 159 | 4 173 | 240 | 46 349 | 10 328 | 240 | 90 524 | 18 899 | 960 | 49 829 | 27 001 |
| | autumn/winter | 240 | 25 581 | 5 029 | 240 | 32 330 | 2 525 | 240 | 35 060 | 2 227 | 240 | 39 406 | 2 287 | 960 | 33 094 | 5 970 |
| | spring/summer | 240 | 22 711 | 7 580 | 240 | 39 061 | 14 191 | 240 | 126 458 | 58 806 | 240 | 102 387 | 41 257 | 960 | 72 654 | 56 594 |
| | summer | 240 | 27 322 | 19 426 | 240 | 68 105 | 44 233 | 240 | 98 819 | 55 572 | 240 | 128 764 | 47 680 | 960 | 80 752 | 57 714 |
| | summer/autumn II | 240 | 30 873 | 13 656 | 240 | 66 877 | 41 550 | 240 | 124 594 | 64 793 | 240 | 145 785 | 55 652 | 960 | 92 032 | 66165 |

ammonia concentrations with increasing ventilation rate. How he explained, the increased ventilation rate diluted the released ammonia, thus producing lower concentrations. The ammonia concentration and the amount of air exhausted through the ventilation system were in positive correlation ($P < 0.001$). It means that in spite of the rising ventilation rate towards the end of the grow-out period, the ammonia concentration did not decrease in individual periods but it had an even slightly increasing tendency.

The trend of emission rates closely followed that of ventilation rates during warm weather but it followed the $NH_3$ concentration pattern during the minimum ventilation periods. Carr et al. (1990) related higher concentrations of $NH_3$ in winter months with reduced ventilation rates to conserve as much heat as possible.

The starting mechanism of ventilation was the temperature of the environment, not the content of harmful gases. Therefore, a situation occurred when the maximum permitted $NH_3$ concentration 20 ppm (EU Regulation 2007/43/EC (2007)) was exceeded for a short time in the third (26.9 ppm) and fourth (29.1 ppm) quarter of the “autumn/winter” period. Ammonia did not reach the critical values during the other studied periods.

The $NH_3$ emission rates averaged 6.18 g $NH_3$ per bird over the particular grow-out periods (emission factor ranged from 5.17 g/bird to 7.81 g/bird). Gates et al. (2008) reported almost three times higher ammonia emissions (17.4 g/bird for one period in fattening to live weight 2.1 kg housed on sawdust litter). Lacey et al. (2002) emphasized that different values of emission factors published by American and European authors are caused by different climatic conditions and differences in the average live weight of animals. He reported the emission factor 19.8 g $NH_3$/bird for a 49-day fattening cycle (average live weight of chickens 1.03 kg).

## CONCLUSION

It is possible to attain precise results only if data are collected over a long period of time (seasonal influence). Therefore, an experiment was conducted for 6 consecutive flocks. Quality of litter and quality of air related with intensity of ventilation and production of ammonia emissions were the main parameters observed in this study.

Very high statistic reliability was found between the age of litter and ammonia concentration as well

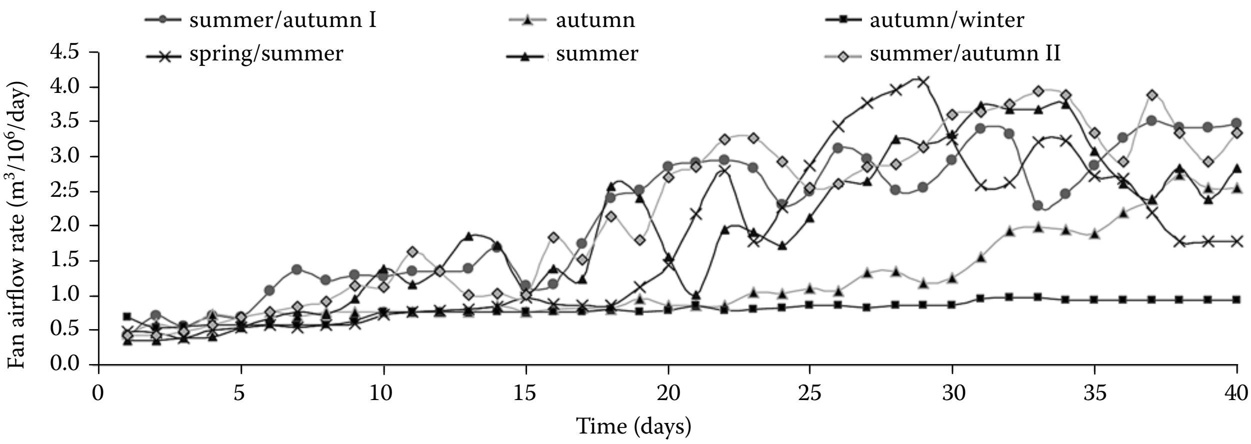


Figure 4. Performance curves of ventilation for the particular grow-out periods

as between the age of litter and ammonia emissions ($P < 0.001$). Summertime was associated with higher $NH_3$ emission rates than wintertime, even though the concentrations were lower. This was mainly attributed to the increased ventilation rates of the building. In the particular grow-out periods the emission factor for $NH_3$ was determined out of the average number of animals: 6.47, 5.17, 6.39, 5.24, 6.00 and 7.81 g/bird, respectively. The resulting annual emission factor 0.043 kg/bird was calculated for 7 periods, i.e. one production year.

On the basis of obtained results it can be concluded that about 1 000 kg of ammonia is emitted yearly from a poultry house with the capacity of

Table 5. Amount of ammonia contained in exhausted air

| Parameter | Period | Days of period | | | | |
|---|---|---|---|---|---|---|
| | | 1. to 10. | 11. to 20. | 21. to 30 | 31. to 40. | 1. to 40. |
| Ventilation intensity (°C) | summer/autumn I | 18 | 35 | 54 | 62 | 42 |
| | autumn | 13 | 16 | 22 | 43 | 24 |
| | autumn/winter | 12 | 15 | 17 | 19 | 16 |
| | spring/summer | 11 | 18 | 60 | 48 | 34 |
| | summer | 13 | 32 | 45 | 61 | 38 |
| | summer/autumn II | 15 | 32 | 59 | 69 | 43 |
| Amount of exhausted air ($m^3 \times 10^6$) | summer/autumn 1 | 9.379 | 17.607 | 27.545 | 31.374 | 85.905 |
| | autumn | 6.788 | 8.198 | 11.124 | 21.726 | 47.836 |
| | autumn/winter | 6.140 | 7.759 | 8.414 | 9.457 | 31.770 |
| | spring/summer | 5.451 | 9.375 | 30.350 | 24.573 | 39.748 |
| | summer | 6.557 | 16.345 | 23.716 | 30.903 | 77.522 |
| | summer/autumn II | 7.409 | 16.051 | 29.903 | 34.988 | 88.351 |
| $NH_3$ emission (kg) | summer/autumn 1 | 9.46 | 14.02 | 58.81 | 72.51 | 154.80 |
| | autumn | 14.35 | 16.64 | 29.56 | 65.03 | 125.58 |
| | autumn/winter | 7.72 | 12.14 | 54.31 | 82.33 | 156.50 |
| | spring/summer | 5.89 | 5.04 | 62.64 | 53.58 | 127.15 |
| | summer | 4.38 | 4.91 | 51.18 | 82.94 | 143.41 |
| | summer/autumn 11 | 4.121 | 15.15 | 82.49 | 85.78 | 187.54 |

25 000 broiler chickens housed on litter. The design of the current research was focused on real commercial conditions. In this manner, the obtained data are relatively precise and applicable to other similar broiler rearing facilities.

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