AMMONIA AND ODOUR EMISSION FROM A BROILER HOUSE WITH A LITTER DRYING VENTILATION SYSTEM

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Abstract

In order to reduce emissions of ammonia from poultry housing systems a litter drying system for broiler houses (broiler litter air mixing system - BLAMS) was designed and tested during four growing cycles at a practical farm (45.000 broilers). The aim was to prevent decomposition of uric acid into ammonia in the litter–manure mixture through enhancement of water evaporation from the litter. To achieve this, BLAMS enhanced internal air circulation. The BLAMS consisted of shafts with controllable fans inside, hanging vertically in the broiler house. Warmer air form the upper part of the house was redirected towards the litter in a horizontal circular plane. This way, BLAMS enhanced air turbulence over the broilers and litter at a height of approximately 1 meter above the animals. In this practical farm 16 shafts were installed. Slaughter weight of the broilers varied between 2255 and 2514 g, mean growth per day varied from 57 to 61 g/d. These figures were better than Dutch mean values, being a slaughter weight of 2050 g in 43 days with a growth rate of 48 g/d. Mean total ammonia emissions per growing cycle amounted respectively 78, 69, 266 and 214 g/h NH_3. This meant, accounting for a yearly stocking rate of 81%, an ammonia emission of respectively 12.4, 10.2, 41.8 and 31.7 g/y per broiler. The mean emission was 70% less then the Dutch emission factor for the traditional housing systems for broilers, being 80 g/y per broiler. The odour emission was 0.41 and 0.11 OU_E/s. With a geometric mean of 0.21 OU_E/s this was similar to the odour emissions from traditional broiler houses without litter drying.

Keywords: ammonia emission, broilers, housing, litter, drying

Introduction

The EU NEC-Directive sets an upper limit (National Emission Ceiling) for each Member State for the total emission of ammonia. Because agriculture is the main source of ammonia, the Dutch government, agricultural businesses and research organisations are, in a joint effort, developing new techniques and methods to reduce ammonia emissions from agriculture (Anonymous, 2001). This led up to low-emission application of slurry, statutory regulation concerning coverage of slurry storages and low-emission housing systems for cattle, pigs and poultry. Knowledge about emission processes in poultry houses and typical successful examples for reduction strategies are given by Groot Koerkamp (1998). Several strategies and methods to reduce ammonia from broiler houses were tested, like the application of belts underneath wire mesh floors and regular removal of manure from the house, prevention of water spilling into the litter (by means of cups underneath), decrease of stocking density, drying of litter by blowing air through the litter lying on a netting floor on wire mesh, feed adjustments, and cooling the litter (see e.g. Kroodsma *et al.*, 1989). However, none of these approaches were successfully implemented in practice, mainly due to higher costs, problems with hygiene, negative side-effects or public acceptance (welfare). Reduction of ammonia emissions from broiler houses needs a robust, effective though simple technique, economically compatible with current husbandry systems. Other important requirements are: possibility of implementation in existing broiler houses, ease of cleaning between cycles for hygiene aspects, limited additional costs or, preferably, improvement of production results and/or product quality (breast blisters, foot lesions), and no negative effect on welfare aspects.

A litter drying system for broiler houses (broiler litter air mixing system - BLAMS) was designed and developed in the period 1998 to 2001 and tested in a practical house during 2001-2005. The aim of the BLAMS is to prevent decomposition of uric acid in the litter – manure mixture into ammonia. This decomposition is a microbial process. Enhancement of the evaporation of water from the litter mixture by continuously drying the top layer will decrease the availability of water for microbes and by decreasing microbial activity the break down of uric acid is reduced. The BLAMS is commercially available from Fancom (ImagO®), Hotraco and ITB Boxmeer.

The goal of this study was to assess the effectiveness of the BLAMS on ammonia and odour emissions from a broiler house under practical circumstances. Detection of possible side-effects of the BLAMS on welfare and health of the animals were part of the study.

Materials and Methods

Broiler house

The field test was carried out on a practical farm in the Netherlands (Dutch reports by Scheer *et al.*, 2003; Bleeker & van den Bulk, 2005a en b). Two identical houses were equipped with the BLAMS, and one of them was used for this study. The floor, ceiling and walls of the house were insulated. The house was 90.0 m long and 22.6 m wide (indoor sizes). At the beginning of each growing cycle the whole floor was littered with 2 cm of wood shavings. The broilers were fed automatically with five lines with feeding pans. Three types of feed were used during each growing cycle. Water was ad libitum available at six lines with nipple drinkers with spill trays during the first 14 day and restricted to 4 blocks of 3 hours per day thereafter. Four gas heaters heated the air in the house up to 34 ºC at the start of the growing cycle. The set-point temperature declined the first four days with one degree Celsius per day, after that, the decline was 0.5 degree Celsius per day, until the set-point temperature was approximately 20 ºC. The floor was heated with warm water in tubes during the first 10 days of the growing cycle with a water temperature of 32 ºC at day 1 declining to 25 ºC at day 10. The house was equipped with a so called tunnel ventilation system: outside air entered through adjustable inlet valves in the side walls at a height of 1.50 m and was exhausted by means of fans in the back wall of the house. The exhaust fans varied in diameter from 0.8 to 1.4 m and had a total ventilation capacity of 195.000 m^3/h during the first three growing cycles and was expanded to 240.000 m^3/h in the fourth cycle. A mist sprayer system was installed to reduce heat stress on hot summer days.

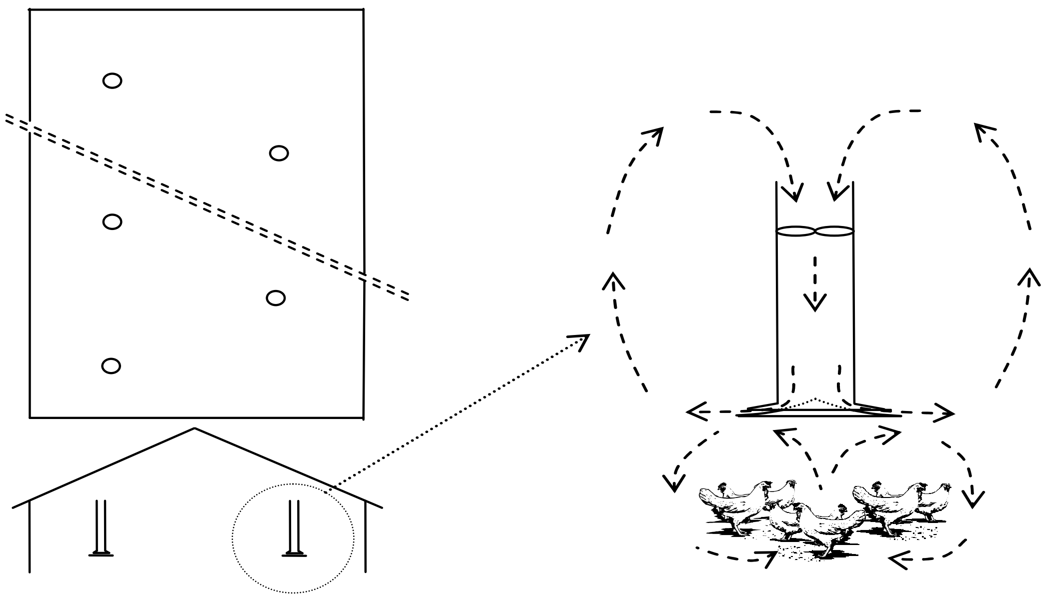

Figure 1. Schematic plan view and cross section of one air circulation unit and the air flow pattern.

Broiler litter air mixing system

Besides the tunnel ventilation system for air exchange with the outdoor environment, an additional internal air circulation system was installed. A schematic overview of the house with the circulation units is given in Figure 1, together with a detailed cross-section of the circulation units and the air flow. This so called broiler litter air mixing system (BLAMS) consisted of two rows of 8 units (16 total) equally distributed over the floor area, hanging vertically inside the broiler house (see Figure 2). Each unit consisted of a shaft with a diameter of 45 cm and was equipped with a ventilator with a controllable rotation frequency. The length of the shaft was typically between 2 and 3 meters, so that the warmer air from the upper part of the house was redirected downwards through the shaft. At the bottom of each shaft, at an adjustable distance, a convex plate was mounted to distribute the air in a horizontal circular plane around the shaft. Turbulence and mixing of the air enhanced the air exchange between the broilers and above the litter. The height of the convex plate, being the outlet of the shaft, was fixed at about 1.1 m. Each circulation unit covered a floor area of about 125 m^2, being a circle with a radius of about 6.3 m. The rotation frequency of the fans inside the shafts was set at the minimum (0%) at the start of the growing cycle and increased with regular intervals up to the maximum (100%) at the end of the growing cycle. The ventilation capacity of the circulation units without the convex bottom plate was 2.0 m^3/h per broiler.

Figure 2. Photograph of the experimental broiler house with an air circulation unit in the front.

Measurements and experimental set-up

During four growing cycles (Table 1), 2 cycles in 2002 and 2 cycles in 2005, production results were recorded, emissions of ammonia and odour and climate measurements were taken and during the cycles in 2002 litter composition was assessed.

Table 1. Characteristics of the four growing cycles, and the Dutch mean for relevant parameters (KWIN, 2002).

Growing cycle (no.)	1	2	3	4	Dutch mean
Start (day-month-year)	25-6-2002	1-10-2002	22-3-2005	30-6-2005	-
End (day-month-year)	4-8-2002	7-11-2002	3-5-2005	11-8-2005	-
Length of growing cycle (d)	41	38	41	40	43
Number of broilers (-)	44500	48000	45000	48000	-
Ventilation capacity (m^3/h p. broiler)	4.2	4.2	4.2		7.0
Stocking density (broilers / m^{-2})	22.1	23.8	22.3	23.8	-
Intermediate removal (broilers / day)	8164 / 30	10598 / 31	5100 / 32	4372 / 32 4158 / 38	-

Productions results

The following standard production figures were recorded: number of one-day old birds, mortality (number of dead birds removed per day), weight of the birds at moment of intermediate removal of birds and at the end of the growing cycle (kg), food supply per day and total (kg) and length of the growing cycle (days). The amount of food supplied was supposed to be the intake by the birds. The growth per day was calculated from the end weight divided by the length of the growing cycle (g/d). The Feed Conversion Ratio was calculated from the total feed intake divided by the total live weight of all birds and corrected for two standard live weights, being 1500 and 2050 g (according to Dutch standards as given in KWIN, 2002).

Climate

The indoor and outdoor temperature and relative humidity were measured with combined sensors (Rotronic®. Proces & Milieu BV, IJzendoorn). The indoor temperature was measured at 4 places evenly distributed over the house 0.5 m above the floor, and at the inlet or outlet of the circulation units. Mean values per growing cycle were calculated based on hourly recorded values.

Concentrations and emissions

Ammonia (NH_3) concentration (mg/m^3), ventilation rate of exhaust fans and, during cycle 3 and 4 also of four circulation units (m^3/h) were measured semi-continuously. Means were recorded every hour. The concentration of ammonia was measured at the inlet and in the exhaust air in the ventilation shaft with a NO_x analyser. With this method (Mosquera, 2002) an air sample was transported to a thermal ammonia converter where NH_3 was converted into NO. The air sample with the less adsorptive gas NO was then transported from the converter to the NO_x analyser (Advanced Pollution Instrumentation Inc., model 200A) where the NO concentration was measured on the basis of the principle of chemi-luminescence. The conversion efficiency of the ammonia converters was determined before and after the measurements of each growing cycle, and the mean efficiency was used to correct measured concentrations. On average 92% of the NH_3 was converted into NO. The net contribution of the broiler system to the ammonia concentration was determined as the difference between the concentration of ammonia in the exhaust air and the inlet air.

Ventilation rate was determined with anemometers with the same diameter as the ventilation shafts they were placed in. The anemometers were calibrated in a wind tunnel before the experiment. The rate of ammonia emission from the house (g/h) was calculated as the product of the corrected, net NH_3 concentration and the ventilation rate. The emission rate per animal per year was calculated based on the number of birds at the start of the growing cycle and an occupation rate in time of 81%. Nitrogen emission of ammonia was calculated based on the measured emission rates per growing cycle relative to the estimated excreted nitrogen for broilers for 2002 (cycle 1 and 2) and 2005 (cycle 3 and 4) (Jongbloed en Kemme, 2005).

The ventilation capacity of the circulation units without the convex bottom plate was 2.0 m^3/h per broiler. However, due to the extra resistance by the convex plate at the bottom of the shaft the capacity was reduced to 0.5-0.7 m^3/h per broiler.

Odour samples were collected during cycle 1 and 2 in teflon odour bags (60 l) over a two hours cycle between 10 and 12 h in the morning once a week. The odour bags were placed in airtight containers with the inlet connected to the sampling tube. The bags were filled by evacuating the surrounding air from the container by a pump. The evacuation rate was controlled by a critical orifice. The inlet of the sampling tube was located in the ventilation shaft below the fan. At the inlet of the tube a dust filter (1-2 µm) was placed to prevent intake of dust that could contaminate the olfactometer. Sampling tubes were heated to avoid condensation. The odour bags remained in the container until analysis in the odour lab within 30 hours after collection. Odour concentrations were determined complying with the European olfactometric standard method EN 13725. The odour threshold of the panel was calculated taking the geometric mean of the individual thresholds. The odour concentrations were expressed in European Odour Units per m^3 air (OU_E/m^3). Odour emissions were calculated as the product of the odour concentrations and the mean ventilation rate during the sampling period.

Litter composition

Litter samples were taken during growing cycle 1 and 2 every week at approximately 10 spots evenly distributed over the house. Concentrations of dry matter, ammoniacal (NH_3 plus NH_4^+) nitrogen, total nitrogen and pH were determined in the mixture of sawdust and manure.

Results

Productions results

Table 2 shows the production results of the four growing cycles. The slaughter weight varied between 2255 and 2514 g whereas the growing cycle amounted 38 to 41 days. This resulted in mean growing rates of 57 to 61 g/d per bird. The feed conversion ratio at 2050 g varied between 1.50 and 1.69, and the mortality ranged between 2.4 and 5.9%. The mean growing rate of the broilers during the four growing cycles (59.5 g/d) was 24% higher compared to the Dutch mean (48 g/d). The mean FCR at 2050 g (1.58) was 0.17 lower than the Dutch mean (1.75). The mean mortality rate (4.1%) was similar to the Dutch mean, with a relatively high value for cycle 2, probably due to an e-coli infection - several medications were administered then.

Table 2. Production results of the four growing cycles, and the Dutch mean for relevant parameters (KWIN, 2002).

Growing cycle (no.)	1	2	3	4	Dutch mean
Slaughter weight (kg)	2.514	2.255	2.329	2.443	2.050
Mortality (%)	2.4	5.9	4.8	3.4	
Growth rate (g/d) (final weight)	61.3	59.3	56.8	61.0	48
FCR – 1500 g (kg/kg) [1]	1.28	1.33	1.36	1.47	1.53
FCR – 2050 g (kg/kg) [2]	1.50	1.55	1.58	1.69	1.75
Mortality (%)	2.4	5.9	4.8	3.4	4.2
Water to feed ratio	1.73	1.65	1.78	1.89	-

1: Feed conversion ratio - kg of feed / kg of growth, corrected to a broiler weight of 1500 g.

2: Feed conversion ratio - kg of feed/ kg of growth, corrected to broiler weight of 2050 g.

Climate and ventilation

Table 3 shows that the mean indoor temperature was about 24.8 ℃ for growing cycles 2 and 3 with lower outside temperature, and increased up to 25.7 and 26.8 for cycle 4 and 1 respectively when outdoor temperature was substantially higher (19.7 and 21.6 ℃). The mean ventilation rate per broiler increased with the outdoor temperature: in increasing order cycle 2, 3, 4 and 1. During cycle 1 and 2 the temperature of the circulated air was about 1 tot 2 degrees lower than the mean air temperature at animal level, while this was the opposite during cycle 3 and 4 (0.5 ℃ or less). The ventilat ion rate of the circulation units was higher during cycle 4 than during cycle 3 (0.62 and 0.45 m^3/h respectively). This was mainly due to the fact that the first 9 days of measurements, with relatively low rates, were missing in cycle 4.

Table 3. Mean temperature and relative humidity of the outdoor and the indoor air and floor, and the ventilation rate per mean present animal per growing cycle.

Growing cycle		1	2	3	4
Temperature (℃)	Outdoor air	21.6	11.6	13.2	19.7
	Indoor air	26.8	24.9	24.7	25.7
	Floor	33.7	29.6	-	-
	Circulated air	25.0 [1)]	24.0 [1)]	25.2 [2)]	25.9 [2)]
Relative Humidity (%)	Outdoor air	77	89	76	88
	Indoor air	69	65	58	65
	Circulated air	71 [1)]	65 [1)]	58 [2)]	66 [2)]
Ventilation rate (m^3/h per animal)	Exhaust fans	2.8	1.1	1.3	1.9
	Circulation units	-	-	0.45	0.62 [3)]

1) Air going into the circulation unit;

2) Air coming out of the circulation unit;

3) Measurements of the first 9 days were missing

Emission of ammonia and nitrogen

Table 4 shows the results of the ammonia emission measurements. Outdoor ammonia concentrations were low (<0.10 mg/m^3) and mean concentrations of the outgoing air varied between 0.93 and 3.28 mg/m^3. The ammonia emission rates during cycle 1 and 2 (12.4 and 10.2 g/y per animal) were considerable lower than during cycle 3 and 4 (41.8 and 31.7 g/y per animal).

Table 4. Mean ammonia concentration of inlet and outlet air, and mean ammonia emission per growing cycle per h and per year per animal with a yearly stocking rate of 81%.

Growing cycle and overall mean	1	2	3	4	1-4
NH_3 concentration incoming air (mg/m^3)	0.08	0.08	0.03	0.08	0.07
NH_3 concentration outgoing air (mg/m^3)	0.93	1.47	3.28	1.83	1.88
NH_3 emission from the house (g/h)	78	69	266	214	157
NH_3 emission (g/y per animal)	12.4	10.2	41.8	31.7	24.0
NH_3-N emission (g/y per animal)	10.2	8.4	34.4	26.1	19.8

Table 5 presents the emissions of NH_3-N relative to the excreted N. The excreted N depends on the amount of N consumed and on the efficiency of the metabolism, which is expressed in the Feed Conversion Ratio (FCR), meaning the amount of feed (kg) needed per kg growth.

The relative nitrogen emission during the 4 growing cycles varied between 1.6% and 7.7%, and was considerably lower as compared to the nitrogen emission from a traditional housing system for broilers (12.4% to 14.7%). Table 5 also shows that with decreasing FCR the relative N-loss increases, mounting up to 2.3% (14.7 minus 12.4) for the reference house with an ammonia emission of 80 g/y per broiler. Litter from a traditional broiler house contained about 10% less nitrogen that litter from a house with the BLAMS.

Table 5. Relative nitrogen emission (%) of emitted ammonia for the 4 growing cycles as part of the excreted N. The amount of excreted N was calculated for three levels of the Feed Conversion Ratio (FCR). The reference refers to a traditional broiler system with an ammonia emission of 80 g/yr per animal (Anonymous, 2007),

Growing cycle		1	2	3	4	1-4	Reference
	1.65	2.3	1.9	7.7	5.8	4.4	14.7
FCR[1]	1.75	2.1	1.7	7.0	5.3	4.0	13.4
	1.85	1.9	1.6	6.5	4.9	3.7	12.4

1: With FCR of 1.65, 1.75 and 1.85 N excretions are respectively 448, 492 and 533 g/y per animal (Jongbloed & Kemme, 2005)

Odour emission

Table 6 shows the odour concentrations and emissions, being 0.41 and 0.11 OU_E/s respectively for cycle 1 and 2. The geometric mean of the measurements was 0.21 OU_E/s.

Table 6. Geometric mean of the odour concentrations and emission per growing cycle per h, per yr per animal with a yearly stocking rate of 81%.

Growing cycle	1	2
Nr of measurements (-)	3	5
Odour concentration (OU_E/m^3)	468	416
Average ventilation rate (m^3/h)	161 680	56 642
Odour emission (OU_E/s)	18 218	5 259
Odour emission per animal (OU_E/s)	0.41	0.11

Litter composition

According to Table 7, 11% of the nitrogen was present as NH_4^+ during cycle 1 and 2. The dry matter decreased gradually during the growing cycles (not shown) and the mean dry matter content was around 600 g/kg.

Table 7. Mean dry matter content, ammonium nitrogen (NH_4-N), total nitrogen (total-N) and pH of the litter during the two growing cycles.

Growing cycle	1	2
Dry matter, g/kg	586	617
NH4-N, g/kg	3.7	3.5
Total-N, g/kg	32.9	31.8
pH	6.4	6.5

Discussion and conclusion

The large variation in time (in this study: four growing cycles in various seasons) and place (between farms but also within animal houses) of emission of ammonia are typical for broiler houses, as was also found in data from literature (Groot Koerkamp *et al*.; 1998; Groot Koerkamp et al., 2000a and b). However, this variation could not straightforward be explained by factors most important for the volatilisation of ammonia from litter, being the ammonia concentration and pH, as was found by Groot Koerkamp & Elzing (1996) for litter in aviary houses for laying hens. From the many studies in broiler houses it is suggested that the history during a growing cycle, the structure (related to friability), cakyness (wet and closed top surface of the litter) and stratification of the litter are also important quality parameters of the litter. The breakdown of uric acid is reduced by a lower water content (higher dry matter content), but also by a lack of oxygen (that results from a lower dry matter content). So, decomposition and volatilisation processes are interlinked and interdependent and emission of ammonia from broiler houses is not only reduced by a higher dry matter content of the litter.

The BLAMS had a large reducing effect on the emission of ammonia, though the exact pathway could not be traced in detail. The BLAMS presumably had a large effect on the evaporation of water from the litter. The BLAMS did not have a perceptible negative effect on the welfare and health of the broiler, e.g. the thermal micro climate of the broilers. From the daily observations by the farmer and researchers it was concluded that broilers behaved normally and distributed evenly over the floor area as in other farm houses. The temperature data (Table 3) showed that the temperature differences between the air at broiler level and air in / from the circulation units were small – the air in the house was mixed well and a high air temperature close to the ceiling, as often found during the first weeks of a growing cycle, was prevented.

Reduction of ammonia resulted in a substantial higher amount of nitrogen in the litter. This might have consequences for the application of such manure on arable land, because the European Nitrate Directive limits nitrogen application to 170 kg/ha.

It was concluded that the emission of ammonia from a broiler house with a litter drying system was reduced to 24 g/y per broiler, which was 70% lower as compared to traditional broiler houses in the Netherlands, being 80 g/y per broiler (Anonymous, 2007). The odour emission was not reduced. The litter drying system had a positive effect on growth rate and feed conversion which might indicate that the living environment of the broilers (micro climate, litter and air quality) was improved.

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