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EFFECT OF BEDDING MATERIAL ON DUST AND AMMONIA EMISSION FROM BROILER HOUSES

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ABSTRACT

Fine dust and ammonia are main pollutants emitted from broiler houses. The type of bedding material could influence these emissions. Therefore, in this study the effect of different bedding materials on fine dust and ammonia emissions from broiler houses was determined. The study was carried out in a mechanically ventilated broiler house with eight identical rooms for 2260 broilers each and compromised two production cycles (rounds) of 35 days. The broilers were raised on four different bedding materials: 1) white wood shavings; 2) chopped wheat straw; 3) ground rapeseed straw; 4) silage maize. In each of the two production cycles the bedding materials were randomly assigned to two of the eight rooms. PM10, PM2.5 and ammonia concentrations and ventilation rates were measured. Ammonia and ventilation rate were measured continuously, whereas dust concentrations were measured during 24 h at 16, 23, 30 and 33 days of age. The main results of the study were:

- Compared with wood shavings, silage maize as bedding had a 19% lower PM2.5 emission ($P<0.05$). PM2.5 emissions of silage maize were not different from wheat straw and rapeseed straw.
- Bedding material had no effect on PM10 emission.
- PM2.5 mass was on average 4.8% of PM10 mass. This percentage increased with the age of the animals.
- Silage maize had a 49, 58 and 53 percent lower ammonia emission compared to wood shavings, wheat straw and rapeseed straw, respectively.

KEYWORDS. Broilers, dust emission, ammonia emission, bedding material

INTRODUCTION

From different studies it is known that fine dust (PM10) in the ambient air could cause health problems and early death of humans (Buringh and Opperhuizen 2002). Problems are related to heart and respiratory disorders (Brunekreef and Holgate 2002). In animal houses, especially poultry and pig houses, high concentrations of dust can be found (Takai et al. 1998). This can cause health problems to people working in such an environment (Gustafsson 1997; Dosman et al. 1997; Preller et al. 1995)

The EU has set standards for maximum concentrations of fine dust in the ambient air. Standards were defined for dust particles smaller than 10 µm (PM10) and for particles smaller than 2.5 µm (PM2.5). In the Netherlands, especially some poultry farms are exceeding the defined threshold values. Therefore a research program was set up to study different measures to reduce fine dust emissions from poultry houses. Changing the type of bedding material might be one option to reduce fine dust emissions. From different studies it is known that use of bedding increases dust concentrations in pig houses (Aarnink *et al.* 2004; Banhazi and Cargill 1999). In laying hens considerable higher dust concentrations and emissions were found in floor housing systems then in cage systems (Takai et al. 1998). Poultry bedding is always a mixture of the initial bedding

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material and the manure deposited by the birds. Gustafsson and Von Wachenfelt (2004) showed that bedding material could influence dust emissions. In a layer house they found clear lower dust productions when using wood shavings or clay granules then when using chopped straw, heather or gravel.

Besides fine dust emissions, the emissions of ammonia from animal houses should be reduced, as well. In the year 2013 all livestock houses in The Netherlands should be implemented with a low ammonia emitting system. While bedding material might also influence ammonia emission, this effect was also studied in this research.

The objective of this study was to determine the effects of different bedding materials (wood shavings, chopped wheat straw, ground rapeseed straw, silage maize) on emissions of fine dust and ammonia from broiler houses and on the performance of the animals.

MATERIAL AND METHODS

Housing

The study was conducted in a mechanical ventilated broiler house of the experimental farm 'Het Spelderholt' in Lelystad. This house consisted of 8 identical climate separated rooms. Each room was subdivided in four pens of 4.1 x 6.8 m. Every pen had one feeding line with 7 feed hoppers (Minimax, Roxell, US) and 2 drinking lines with in total 45 drinkers (Ziggity, US). The rooms were heated with plate radiators along the sidewalls underneath the air inlet valve. The air inlet was controlled per room with 12 turning valves (Tulderhof, Belgium), 6 on each side of the room. Each room had 3 ventilators in the roof of which one was continuously working and the other two were working when needed.

During the first two days after the start of the growing period the rooms were continuously lighted. During the rest of the growing period an intermittent light scheme was given of 8 h light and 4 h dark (07:45 – 15:45 (light); 15:45 – 19:45 (dark); 19:45 – 03:45 (light); 03:45 – 07:45 (dark)). Light intensity was the same for all rooms (20 lux).

Animals

In each pen 565 one day old broilers (Ross 308) were placed, i.e. 2260 broilers per room. The broilers were delivered at 35 days of age, at approximately 2.0 kg live weight. Broilers had *ad libitum* access to feed and drinking water. Broilers got all necessary vaccinations. The first 10 days the broilers received crumb feed and during the rest of the growing period pellet feed.

Treatments

In this study the following bedding materials were investigated:

1. white wood shavings; 1.5 kg/m^2
2. chopped wheat straw (3 – 5 cm); 1.9 kg/m^2
3. ground rapeseed straw (0.5 – 5.0 cm); 1.5 kg/m^2
4. silage maize; 2.0 kg/m^2

The treatments were randomly assigned to the 8 rooms during two growing periods, so in total each treatment was tested in four rooms. The bedding was added to the rooms one day before the start, except for the silage maize, this was added three days before the start. Silage maize is a humid product (35 – 40% dry matter). Therefore, this product had to be dried in the heated rooms before the broilers were placed. At day 0 (day the birds were placed inside the rooms) dry matter contents of the bedding materials were 90.3, 90.8, 89.1, and 89.8 % for wood shavings, wheat straw, rapeseed straw, and silage maize, respectively. Bedding materials were replaced in between growing periods.

Climate

The rooms with wood shavings, chopped wheat straw and ground rapeseed straw were heated to 25°C two days before the start (day -2). At day -1 the bedding material was added to the rooms and the room was heated to 33°C. To dry the silage maize, this bedding material was added to the rooms at day -3. At day -4 until day -1 the room was heated to 30°C and an extra fan inside the room took care of extra circulation of the air inside the room. At day -1 the room was heated to 33°C, similar as the other rooms. The temperature scheme during the growing period of the broilers was the same for all the rooms. At day 0 the temperature of the rooms were controlled at 33°C. The desired temperature, as inserted in the climate control system, decreased gradually to 28°C at day 7, to 25°C at day 14, to 22°C at day 21, and to 20°C at day 35.

Measurements

PM10 and PM2.5 concentrations were measured from the incoming air (outside) and in each room from the exhaust air, at 0.5 m horizontal distance from and 0.1 m vertical distance underneath the inlet of the ventilation shaft. Dust was sampled gravimetrically during 24 h at days 16, 23, 30 and 33 of the growing period. Larger particles then the aimed ones were pre-separated with cyclones (URG corp., US). The air flow through the samplers was 1 m^3/h and was drawn with a constant flow pump (Charlie HV, Ravebo Supply, The Netherlands). For details on the sampling procedure see Zhao *et al.* (2009).

Ammonia concentrations were measured semi-continuous by continuously sampling air from each room and by sequentially measuring concentrations in each room for 5 min with an NOx-monitor (model ML8840, Monitor Labs, US). Aerial ammonia was first converted to NO by a converter at 775°C. Exhaust air was sampled inside the shaft with the ventilator that was continuously running. The monitor was calibrated weekly. Ventilation rate was measured with calibrated anemometers with the same diameter as the fan channel (Fancom, The Netherlands). Temperature and humidity outside and in each room, near the outlet shaft, were continuously measured with a temperature/humidity sensor (Rotronic Hygromer®). The accuracy of these sensors were ± 1,0°C and ± 2%. Hourly means were stored in a datalogging system.

Broilers were weighed per room at day 1 and day 35. The total amount of feed delivered to each room was determined by weighing.

Data analysis

Dust and ammonia emissions were calculated as follows:

$$Emission = (C_{exhaust} - C_{inlet}) \times Q$$

Where: Emission = dust or ammonia emission (g h^{-1});
$C_{exhaust}$ = concentration in exhaust air (g m^{-3});
C_{inlet} = concentration in the inlet air (g m^{-3});
Q = ventilation rate (m^3 h^{-1}).

From the hourly mean emissions, yearly emissions per broiler place were calculated by multiplication with 24 hours and 365 days, dividing this by the number of broilers that were initially placed inside the rooms and by correcting for an inoccupation of the rooms for 19% of the time.

Dust and ammonia emission data were statistically analyzed with a longitudinal model to determine effects of bedding material. A longitudinal model was used because of the repeated measurements in time in the same room. Treatment effects of bedding material was tested with an F-test using REML procedure of Genstat (Genstat Committee 2009).

Production results were analyzed with variance analysis with round as block and bedding material as explaining factor (ANOVA procedure, (Genstat Committee 2009)).

Results and Discussion

Dust concentrations and emissions

In Figure 1 the PM2.5 and PM10 concentrations are given on the different measurement days. Average PM2.5 and PM10 concentrations were 0.06 and 1.13 mg/m^3, respectively. PM2.5 and PM10 concentrations increased during the growing period. Average PM2.5 concentrations on days 16, 23, 30 and 33 were 0.03, 0.05, 0.06 and 0.08 mg/m^3, respectively; for PM10 this was 0.86, 1.06, 1.18 and 1.40 mg/m^3. On the different days, except for day 30, PM2.5 concentrations were lower in the rooms with silage maize than in the other rooms. For PM10 concentrations no effect of bedding material could be observed. On average PM2.5 concentration amounted 4.8% of the PM10 concentration. This ratio seemed to increase during the growing period, it was 3.3%, 4.4%, 5.4%, and 6.0% at day 16, 23, 30, and 33, respectively.

In Figure 2 emissions of PM2.5 and PM10 are given for the different bedding materials on the different measurements days, calculated on a yearly basis. These figures show a strong increase of PM2.5 and PM10 emissions during the growing period of the broilers. On day 16 PM10 emission was significantly lower for the rooms with silage maize as bedding material. For the other days no differences in PM10 emission between bedding materials were found. PM2.5 emissions were significantly lower in the rooms with silage maize as bedding for all the measurement days compared to the rooms with wood shavings. PM2.5 emissions from the rooms with wheat straw or rapeseed straw did not differ significantly from the rooms with wood shavings or from the rooms with silage maize.

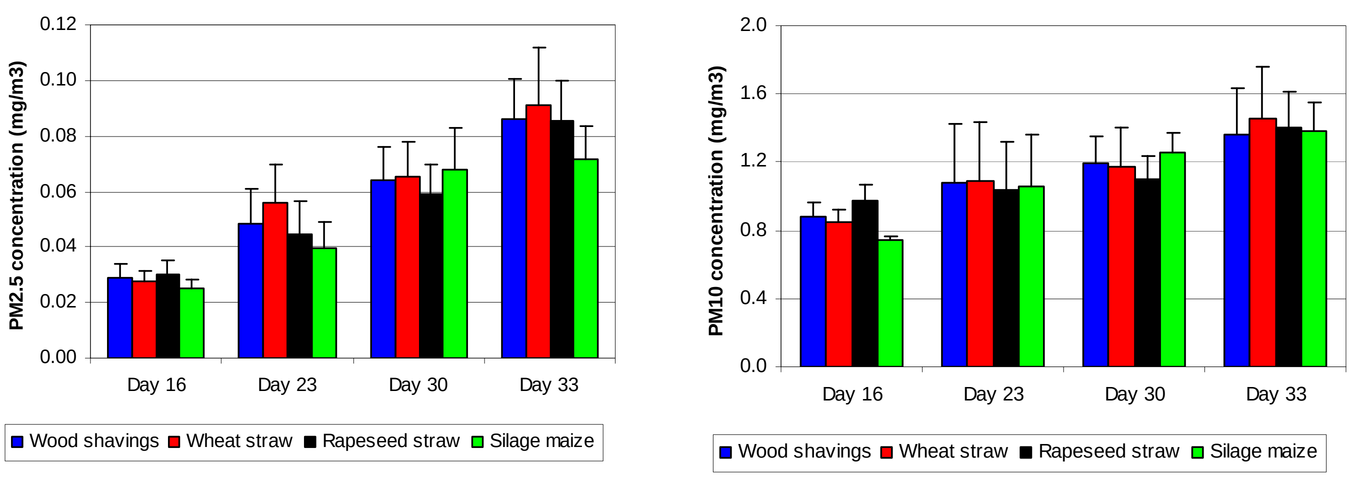

Figure 1. Mean (n=4) PM2.5 (left) and PM10 (right) concentrations at the different measurements days for the different bedding materials

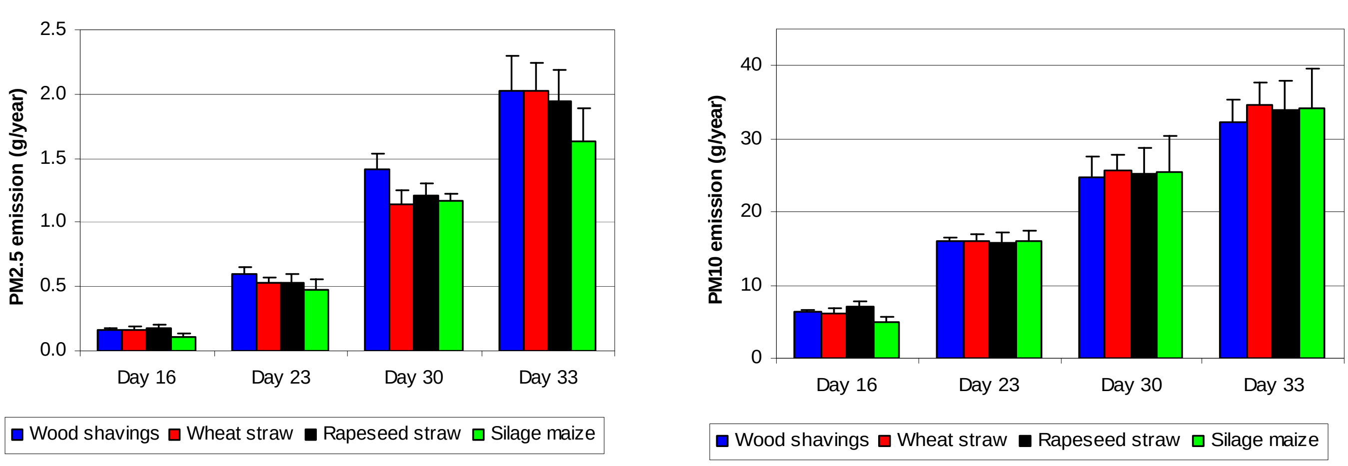

Figure 2. Mean (n=4) PM2.5 (left) and PM10 (right) emissions at the different measurements days for the different bedding materials (in g/year per animal place)

In Table 1 the average PM2.5 and PM10 emissions are shown. This table shows that PM2.5 emissions were significantly lower in rooms with silage maize than in the other rooms. Differences between other bedding materials were not significant. For PM10 no difference in emissions between the different bedding materials were found.

Table 1. Fine dust emissions (PM2.5 and PM10) for the different bedding materials in broilers[1,2]

	Wood shavings	Wheat straw	Rapeseed straw	Silage maize
PM2.5 [g $year^{-1}$ ap^{-1}]	1.05^{a} (100)	0.98^{ab} (93)	0.97^{ab} (92)	0.85^{b} (81)
PM10 [g $year^{-1}$ ap^{-1}]	20.3^{a} (100)	20.6^{a} (102)	20.5^{a} (101)	21.0^{a} (104)

[1] Superscripts in a row containing a same superscript letter are not significantly different (P>0.05)
[2] Between brackets PM2.5 and PM10 emissions are given as percentage from wood shavings
[3] ap = animal place (inoccupation = 19%)

Ammonia concentrations and emissions

Table 2 shows the mean ventilation rates, ammonia concentrations and ammonia emissions for the rooms with the different bedding materials. Ventilation rates were very comparable between treatments. Ammonia concentrations and emissions were significantly lower in the silage maize rooms than in the other rooms (P<0.05). Ammonia emissions from the rooms with wood shavings, wheat straw or rapeseed straw did not significantly differ (P>0.05).

Table 2. Mean ventilation rate, ammonia concentration (inside) and ammonia emission for the different bedding materials[1,2]

	Wood shavings	Wheat straw	Rapeseed straw	Silage maize
Ventilation rate [m^3 h^{-1} $broiler^{-1}$]	1.81^{a}	1.80^{a}	1.77^{a}	1.78^{a}
NH_3 concentration [mg m^{-3}]	3.98^{a}	3.97^{a}	4.00^{a}	1.88^{b}
NH_3 emission [g h^{-1}]	12.3^{a}	13.6^{a}	12.0^{a}	7.8^{b}
NH_3 emission [g $year^{-1}$ ap^{-1}][3]	38.6^{a} (100)	42.9^{a} (111)	37.9^{a} (98)	24.6^{b} (64)

[1] Superscripts in a row containing a same superscript letter are not significantly different (P>0.05)
[2] Between brackets ammonia emissions are given as percentage from wood shavings
[3] ap = animal place (inoccupation = 19%)

Production results

Table 3 shows the production results of the broilers. Statistical analyses showed no significant differences in production results between the different bedding materials.

Table 3. Mean production results of the broilers during the growing period

	Wood shavings	Wheat straw	Rapeseed straw	Silage maize
Final weight (g)	2078	2069	2074	2058
Daily weight gain (g d^{-1} $broiler^{-1}$)	58.3	58.0	58.2	57.7
Died (%)	2.6	2.8	2.6	2.4
Feed conversion (g feed/g growth)	1.604	1.598	1.597	1.598
Feed intake (g)	3270	3244	3249	3227
Water/feed (g water/g feed)	1.80	1.77	1.81	1.79

CONCLUSIONS

From this study the following was concluded:

1. The use of silage maize as bedding material for broilers resulted in a significant lower PM2.5 emission (19%) than when using wood shavings. PM2.5 emission when using silage maize was not significantly different from using wheat or rapeseed straw as bedding.
2. The studied bedding material had no significant effect on PM10 emissions.
3. PM2.5 concentration was on average 4.8% of the PM10 concentration. This percentage increased during the growing period of the broilers.

4. The use of silage maize as bedding material for broilers resulted in a significant lower ammonia emissions compared with wood shavings (-36%), wheat straw (-47%, and rapeseed straw (-34%). There were no differences in ammonia emissions between wood shavings, wheat straw, and rapeseed straw.
5. The production results (growth rate, feed conversion rate, and %dead birds) were not influenced by the used bedding material.

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