OPTIONS FOR DUST REDUCTION FROM POULTRY HOUSES

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ABSTRACT
Large poultry houses emit high amounts of fine dust (PM10) and in many cases they exceed the ambient air quality standard set by the EU. Technologies for PM10 reduction need to be developed on short term to minimize PM10 emissions from poultry houses. Studied options for dust reduction were: application of an oil film on the litter and application of an ionization system. Rapeseed oil was sprayed daily in a quantity of 8 to 24 ml/m^2 in broiler houses and 20 ml/m^2 in layer houses. The ionization system was applied in a broiler house and had a voltage difference of -30kV, with a current of approximately 0.7 mA. Daily emissions of PM10 particles were determined at regular intervals by measuring concentrations at the ventilation inlet and outlet and by measuring the airflow rate. For the oil system PM10 emission reductions were in the ranges of 55 – 85% in broilers and 25 – 40% in layers. The ionization system, applied in broilers, reduced PM10 emission on average by 36%.

Keywords: poultry, housing, dust emission, dust reduction, PM10

INTRODUCTION
Different publications report effects of ambient fine dust on human health (Buringh and Opperhuizen, 2002; Wathes et al., 2004; Weijers et al., 2003). For that reason the EU has set limits for concentrations of particles smaller than 10 μm (PM10) and of particles smaller than 2.5 μm (PM2.5) in ambient air. Calculations have shown that PM10 emitted from animal houses contributes to crossings of the European ambient air quality standard (Bleeker et al., 2007).

Livestock farmers, especially poultry and pig farmers, are exposed to dust concentrations inside their animal houses that are a lot higher than in the outside air. This leads to a much higher prevalence of respiratory problems in livestock farmers compared to other occupations (Bongers *et al.*, 1987). Also the animals themselves suffer from respiratory problems (Robertson et al., 1990). Therefore, measures that not only reduce dust emissions, but also improve inside air quality have a clear preference.

A literature study showed that spraying oil and air ionization in animal houses have high potential to reduce dust particle concentrations. Different studies show that dust can be reduced very effectively by spraying a mixture of oil and water (Nonnenmann et al., 1999; Takai et al., 1995). Little work has been done so far on testing oil spraying systems in animal houses with bedding. The principle of oil spraying is to apply an oil film on the floor so that dust particles are bound to the oil. For ionization systems an optimal design for use in livestock houses has not yet been fully developed (Rosentrater, 2004), although experimental results have shown good results of ionization to reduce dust concentration in livestock buildings (Chiumenti and Guercini, 1990; Tanaka and Zhang, 1996).

The objective of this study was to determine the effects of applying an oil film on the bedding material in houses for broilers (floor housing) and layers (aviary system) on dust concentrations and emissions. Furthermore, the effect of ionization on dust reduction in broilers was determined.

MATERIAL AND METHODS

Oil film in broilers

The study was conducted in 4 identical rooms during the first round and 5 identical rooms during the second to fifth round at the experimental station 'Het Spelderholt' in Lelystad. Within each room 2,675 one day old broilers of both sexes were placed. Each room measured 8.3 x 16.0 m (133.6 m^2). Broilers had *ad libitum* access to feed and drinking water. One day before placing the broilers 1 kg m^{-2} of wood shavings was spread over the floor as bedding material. All rooms were heated to 33°C three days before the broilers were placed in the rooms. The target temperature was gradually decreased to 19 °C in week 5. Minimum ventilation was controlled at 1.0 m^3 h^{-1} per kg live weight. The maximum ventilation rate in the room was 3.9 m^3 h^{-1} per kg live weight. The broilers were delivered to the slaughterhouse at 35 days of age, at approximately 2.0 kg live weight.

Pure rapeseed oil was sprayed by nozzles (Spraying Systems, The Netherlands) fitted on pipes. Two parallel pipes were placed across the width, in the centre of the room at approximately 2.5 m height. On both pipes 4 nozzles were fitted. Each pipe with nozzles had to cover an area of approximately 8 x 8 m^2. In round 5 extra oil tubes were placed, so the area to cover per oil tube was reduced to 8 x 4 m^2. In this way, we could reduce the pressure in the system in order to increase the droplet size of the oil. Oil was sprayed by injecting oil and air into the nozzles simultaneously.

In the rooms different quantities of oil were sprayed. In Table 1 the spraying time of oil is given for the different rounds and rooms. Oil was sprayed once every day or once every two days (at 08:00 h) during 10 to 80 s. The quantity of oil sprayed was linearly related to the spraying time. During 60 s of spraying 24 ml of oil was applied per m^2 floor area.

Table 1. Spraying time of oil, starting day of spraying and oil and air pressure in the different rooms and rounds.

Round	Start oil spraying (day)	Oil and air pressure (kPa)	Room[a)]					
			1	2	3	4	5	6
1	12	350	-[b)]	-	60 (1)	40 (1)	20 (1)	0
2	5	350	0	-	60 (1)	15 (1)	45 (1)	30 (1)
3	12	350	-	0	20 (1)	60 (1)	40 (1)	40 (1)[c)]
4	21	300	0	0	80 (2)	20 (1)	40 (1)	40 (2)
5	21	300	0	0	40 (2)	80 (2)	20 (1)	40 (1)

a) (1) oil applied once a day and (2) once every two days
b) -: room not available for the study
c) Start oil spraying: day 21

In Table 2 a summary of the methods for the different measurements are given.

Table 2. Measured parameters, frequency, and methods used in broilers.

Parameter	Measuring days	Method
PM10, PM2.5 concentration incoming, outgoing air	Round 1: 20, 33 Round 2: 8, 22, 26, 33 Round 3: 15, 22, 29, 32[a)] Round 4, 5: 23, 30, 33	Gravimetrically; pre-separation of larger particles with cyclones (URG corp., VS); constant flow pumps (Charlie HV, Ravebo Supply, The Netherlands)
Personal dust load	Round 2: 26, 34 Round 3: 17, 31 Round 4: 25, 32, 33 Round 5: 25, 32	Continuous measurement with DustTrak (TSI, USA)
Ventilation rate	Continuous	Anemometer (Fancom, The Netherlands)

[a)] In round 3 PM10 and PM2.5 were also measured at days 1 and 8, before the oil spraying started.

Oil film in Layers

The experiment was done in four climate separated rooms of a natural ventilated house for organic layers. Two rooms were equipped with Natura Nova aviary systems of Big Dutchman (Germany), two others with BLA aviary systems of Meller (Farmtec, The Netherlands). In one room of each aviary system an oil film was daily applied on top of the bedding material; the other rooms served as control. The oil film was applied by spraying the rapeseed oil manually with a spraying gun (Spraying Systems, The Netherlands) at a dose of 20 ml/m^2 per day. In the Natura Nova system there were approximately 970 layers per room, while this was 870 in the rooms with the Meller system, at densities of approximately 17 and 15 birds per m^2 floor surface, respectively.

PM10 and PM2.5 concentrations were measured for a period of 24 h three times at one week intervals, with standard measuring equipment based on the gravimetrical measuring principle, similar as in broilers. Carbon dioxide concentrations were measured for determining ventilation rates by the CO_2 mass balance method (Pedersen et al., 2008). In this way fine dust emissions could be calculated.

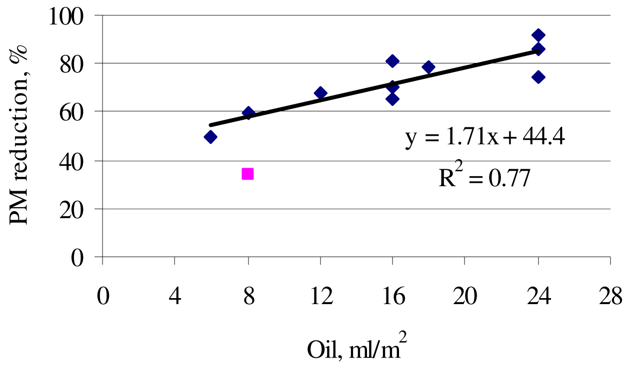
Ionization in broilers

The experiment was conducted in 4 similar rooms as the oil film experiment. As ionization system the “Electrostatic Particle Ionization” (EPI) system (Baumgartner Environics, Inc. USDA Patent number 6,126,722 U.S.A.) was used. The EPI system consisted of two rows of negative DC ionization units running along the length of the rooms, composed of discharge electrodes (ion generator) and a grounded collection plate. These units were installed by the manufacturing company at a height of approximately 2.5 m above the litter. The discharge electrodes were connected to a high voltage power supply to create a high density electron array (-30 kV DC), limited to a current of below 0.9 mA to assure safety. The emitted electrons generate negatively charged ions. These ions charge circulating airborne particles, which are directed towards the grounded plates and are collected by electrostatic attraction on room surfaces or collector plates. The ionization system was randomly assigned to 2 of the 4 rooms, while the other two rooms served as control. The experiment was done during two rearing cycles (rounds). The following parameters were measured or determined: ionization performance, ion concentrations, ozone concentration, ultra fine particle concentration, ventilation rates, PM10 and PM2.5 concentrations and emissions, and personal dust exposure. This study has been reported in more detail in Cambra-López et al. (2009).

RESULTS

Oil film in broilers

In the first three rounds PM10 and PM2.5 concentrations during the measuring days varied between 0.72 and 5.45 mg/m^3, and between 0.03 and 0.24 mg/m^3, respectively. Emissions varied for PM10 between 0.09 and 10.7 mg/h per bird and for PM2.5 between 0.01 and 0.82 mg/h per bird. Effects of oil dose on reductions of PM10 and PM2.5 emissions are given in Figure 1. Reductions for PM10 ranged from 55 to 85% for oil doses in the range of 6 to 24 ml/m^2 per day. Reductions of PM2.5 were independent of the oil dose and were approximately 80%.



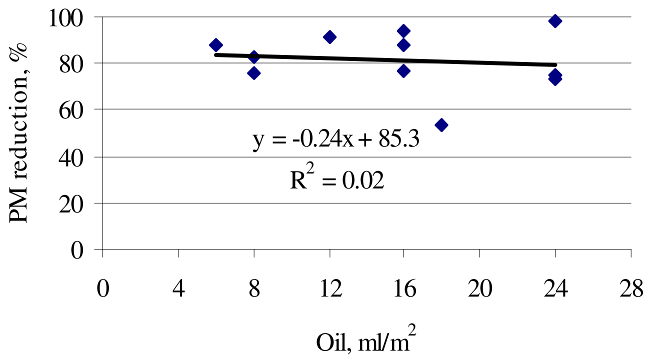


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Figure 1. Effect of spraying oil on reduction of dust emission from broilers; Left: PM10; Right: PM2.5. The square dot in the left figure was an outlier and was not included in the regression analysis.

Results of the fourth and fifth round with daily application of the oil were similar with respect to reduction efficiencies as in the first three rounds. Analysis of the data in the last two rounds showed that daily application of oil was 23% more effective in reducing PM10 than application every other day (P=0.05); for PM2.5 no difference was found.

In Figure 2 the pattern of PM10 emission during the third round is given. Dust emission increased exponentially during the growing period of the birds. From this curve the cumulative PM10 emission was calculated. This curve shows that most dust emitted during the last two weeks of the growing period: 88% of the total PM10 emission; for PM2.5 this was even 95% of the total emission. Figure 3 shows the effect of oil dose on the personal PM10 load of the poultry farmer during the first three rounds. This graph shows that dust load can be reduced by more than 60% at an oil dose of 6 ml/m^2 per day; this reduction increased to approximately 80% at a dose of 24 ml/m^2 per day.

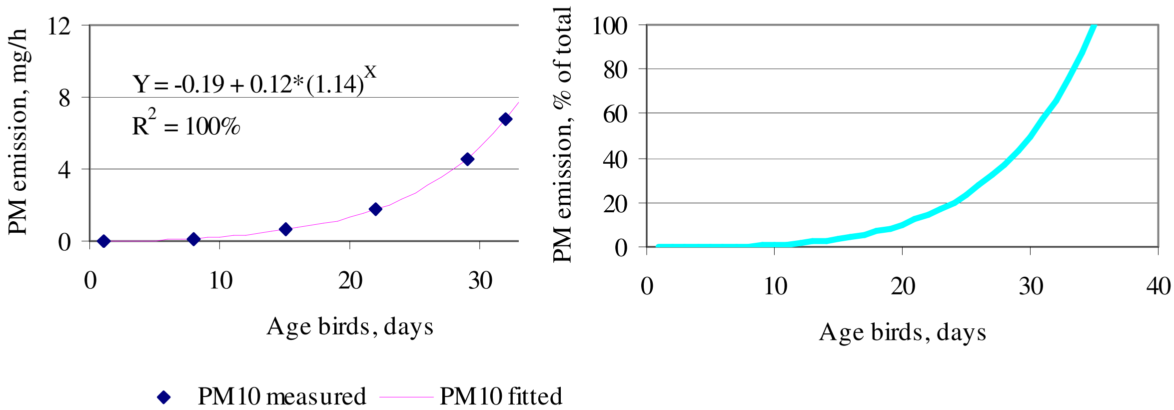

Figure 2. PM10 emission during the third round in the control room. Left: measured PM10 emission in mg/h per broiler; Right: cumulative PM10 emission as percentage of total emission in the whole round.

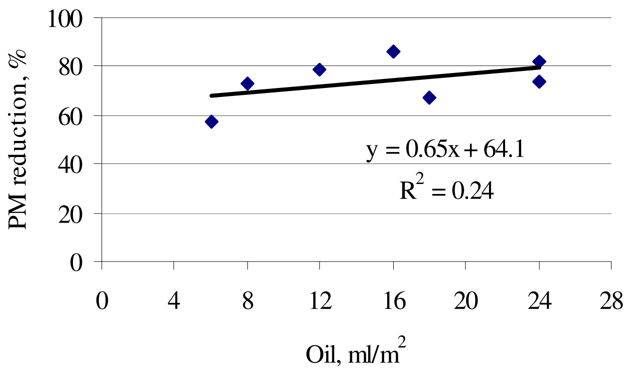

Figure 3. Effect of oil dose on reduction of PM10 concentration during occupation of the farmer inside the broiler rooms.

Oil film in Layers

Mean dust concentrations in the different rooms varied between 0.80 and 1.41 mg/m^3 for PM10 and between 0.037 and 0.078 mg/m^3 for PM2.5. In Table 3 mean fine dust emissions for the two aviary systems with and without oil spraying are given in mg/h per bird. This table shows that oil spraying gave significant reductions of PM10 and PM2.5 emissions. No significant interaction effect was found between aviary system and dust reduction. The reduction efficiency seemed to be related to the emission level of the control room. We did not find any effect on egg production between control and oil rooms.

Table 3: Mean fine dust emission for two aviary systems with and without oil spraying (in mg/h per layer).

Dust fraction	Aviary system	Oil spraying		Reduction
		no	yes	
PM10	Meller	7.47	5.36	25 (12-51) %
	Big Dutchman	10.73	6.40	40 (25-48) %
PM2.5	Meller	0.76	0.28	59 (49-75) %
	Big Dutchman	0.46	0.27	38 (31-50) %

Ionization in broilers

The installed ionization system worked correctly over the whole experiment. Voltage set to -30 kV did not vary along time, over the rearing cycle. Amperage readings showed some variation over the rearing cycle. For round 1, amperage showed a linear decrease in time. Amperage was set to 0.7 mA at the start of the experiment, and it gradually decreased along the rearing cycle, showing a minimum of about 0.4 mA at the end of the growing period. The cleaning of the plates in round 1, showed a slight effect on amperage, which tended to increase after cleaning.

Mean ion concentrations, measured in round 2, were approximately 1,800 ions/cm^3, ranging from 220 to 6,400 ions/cm^3. Ion concentrations remained more or less constant along the whole experiment. Ion concentrations, however, were not uniformly distributed. As distance from the negative electrode increased, ion concentrations decreased, as also did the range of variation. Measured ozone concentrations were all below the detection limit of 0.01 ppm. Ultra fine particle counts, in the range from 5 to 1100 nm, were on average 45% lower in rooms with ionization compared with control rooms.

Overall mean (SD) PM10 and PM2.5 concentrations were 1.01 (0.60) and 0.07 (0.05) mg/m^3, respectively. On average PM10 emissions for the control and ionization rooms were 33.4 and 20.1 g/year per bird in the first round and 16.1 and 11.7 g/year per bird in the second round. The overall measured mass reduction for PM10 emission was 36% ($P<0.001$). The reduction was not influenced by the age of the birds. PM2.5 emissions for the control and ionization rooms were the same in the first round, on average 1.42 g/year per bird and 0.80 and 0.58 g/year per bird in the second round. The overall measured mass reduction in PM2.5 emission was only 10% ($P<0.05$). There was a tendency ($P<0.10$) for an effect of day number on PM2.5 reduction by the ionization system. Calculated reductions were 64, 23, 28, and 1% for day 16, 23, 30, and 33, respectively.

Continuous PM10 measurements showed a similar daily PM10 concentration pattern over the experiment. Concentrations of PM10 increased when lights were on, and decreased when lights were off. The cleaning of grounded collectors showed no statistically significant difference in PM10 concentrations in ionization rooms before and after cleaning. Personal sampling at human's breathing height showed that ionization rooms had a mean reduction of PM10 exposure of about 30%.

DISCUSSION

Oil film

The oil spraying system in broilers has functioned properly during the whole study. Plugging of the nozzles caused by coagulated oil was not observed in this study, unlike in other studies where a mixture of oil and water was sprayed (Takai, 2007). This might be caused by the fact that we used pure oil or by the type of nozzles we used. A mixture of oil and water can be sprayed with liquid pressure only, while spraying oil needs air pressure, as well. Within this study reductions of PM10 dust could be achieved in the range of approximately 55 to 85%, depending on the amount of oil sprayed. This is similar to the range mentioned by (Takai, 2007), based on an extensive literature review on oil spraying.

Measurements in the control rooms showed that the contribution of PM2.5 mass to PM10 mass was on average 5 to 6%, in broilers as in layers. This is far lower than measured in the outside air in The Netherlands (60 to 80%) (Matthijsen and Ten Brink, 2007).

It is remarkable that we did not find a relationship between the amount of oil sprayed and PM2.5 reduction in our study. It seems that already a small amount of oil is sufficient to decrease PM2.5 emission to a considerable level (80%). That extra oil did not give an extra reduction of PM2.5 emission seems to be caused by the generation of small oil particles. Because production of PM2.5 particles is relatively low in broiler rooms the effect of the small oil particles on PM2.5 concentration is higher than for PM10 concentration. By decreasing the air and oil pressure the number of small particles can be reduced, but then more nozzles are needed to cover the whole area.

The results show an exponential increase of dust emission during the growing period of the broilers. The dust emission during the first 3 weeks is relatively low. Therefore, starting oil application at a birds' age of 3 weeks still gives a considerable dust reduction.

The effects of oil on personal dust load were similar as on dust emissions. This is a clear advantage of the oil system when compared to end of pipe solutions like air scrubbers. Results from the control broiler rooms show that PM10 concentrations can be as high as 5.5 mg/m^3. This is 110 times higher than the maximum allowed daily mean concentration in the outdoor air (0.05 mg/m^3). A disadvantage of the oil film system is the extra time needed for cleaning the rooms.

Application of an oil film in layer housing with aviary systems had much less effect on dust concentrations and emissions than in broiler housing. The main reason seems to be that in aviary housing, contrary to broiler housing, a lot of dust is coming from other places than the bedding on the floor. Layers only spend a part of the time on floor level, while broilers have no other levels available. The oil spraying system in this study only applied oil on the bedding material on the floor.

Ionization

Some of the drawbacks reported for ionization systems such as ozone formation and ultra fine particle generations were investigated in the experiment. It was shown that the ionization system did not produce a lot of ozone, nor was there an increase of ultra fine particle formation observed. Ozone concentrations could not be detected with gas tubes with a detection limit of 0.01 ppm. Other studies have reported ozone concentrations in the range from 0.01 to 0.165 ppm (Britigan et al., 2006). Ultra fine particle concentrations were lower in ionization rooms compared with the control rooms. Results suggest a low rate of ultra fine particle formation in ionization rooms, at least below the rate of ultra fine particle formation in control rooms.

The effect of ionization on dust, in this experiment, was in agreement with the lower part of reduction ranges reported in other studies. Higher reductions of dust, 43% in a broiler house (Ritz et al., 2006), and 61% in a broiler breeder house (Mitchell et al., 2004) have been observed. These higher reduction percentages are probably expressed as total dust, whereas in our study differential dust fractions were measured. Dust measurements in these studies were furthermore done using light scattering devices which could be affected by particle charges, as they have a plastic sampling inlet, usually positively charged, which could cause attraction of negatively charged particles, and thus loss of particle mass measurement in the treated houses (Lyngtveit and Eduard, 1997). When using gravimetric analysis to measure dust mass, this effect is less probable, because the electrical charge is smaller (Lyngtveit and Eduard, 1997).

CONCLUSIONS

From this study the following can be concluded:

- Application of an oil film on bedding material in broiler housing and aviary housing for layers is very effective in reducing PM10 and PM2.5 concentrations and emissions.
- Daily application in broiler houses of an oil film ranging between 8 and 16 ml/m^2, starting at day 21, seems to be optimal with respect to dust reduction.
- Ionization can reduce PM10 and PM2.5 concentrations and emissions in broiler houses by approximately 36% and 10%, respectively.

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