Airborne Dust Control Measures for Floor Housing System for Laying Hens

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ABSTRACT

Floor housing systems for laying hens are being re-established in Sweden. Compared to traditional cage systems, the air in floor housing systems may be more polluted with dust.

Investigations about how different factors affect concentration and generation of dust in a floor housing system for laying hens have therefore been carried out at JBT:s research station Alnarp Södergård. A climate chamber was equipped with a floor housing system. How age of hens, storage time of manure, ventilation rate and bedding materials affected concentration and release of dust were investigated during two production cycles.

The concentration and generation of dust as well as the efficiency of different dust reducing measures were investigated and analysed in order to improve the understanding of how different factors influence dust conditions in these housing systems.

Settling of dust was a more important mechanism in the mass balance of dust than ventilation rate which reduced the influence of ventilation rate as a dust reducing measure. A major part of the generated dust settled on different surfaces inside the building. The settling rate of dust was affected by the concentration of dust in the air. The settled amount of dust also stood in relation to the floor area of the stable. An increased ventilation rate had a limited effect on the concentration of total dust due to the importance of the settling of the dust.

Dust release was also investigated when using six different bedding materials, namely; gravel, clay pellets, peat, wood shavings, chopped straw and chopped paper. Clay pellets and peat resulted in lowest concentrations of dust.

Automatic spraying of small droplets of water reduced the dust concentration in four trials whith different bedding materials (chopped paper, clay pellets, peat and wood shavings). Spraying a mixture of rape seed oil in water was also effective with an automatic spraying system.

From our findings from the investigations we will recommend using clay pellets as bedding material and using a sprinkler system spraying water droplets frequently in floor housing systems for laying hens.

Keywords: Laying hens, dust, climate, ventilation, bedding

1. INTRODUCTION

Hartung (1998) states that poultry house air has much higher dust concentrations than for other animals. Seedorf (2000) demonstrated that particle emission in fowl keeping was 22 times higher (3165 mg h^{-1} per livestock unit) than for cattle keeping and four times higher than for pig keeping.

Regarding laying hens, floor housing systems are being re-established in Sweden since animal welfare legislation stipulates that systems for laying hens must include laying nests and perches and provide access to litter. Compared to traditional cage systems, the air in floor housing systems may be more polluted with dust because of high activity and more bedding material (Gustafsson & Mårtensson, 1990; Hauser, 1990; Lyngtveit, 1992; Drost & van den Drift, 1992, 1993; Groot Koerkamp & Drost, 1993; Larsson *et al.*1999). The hygienic threshold limit value for dust for occupational safety and health (Swedish National Board of Occupational Safety and Health, 2000) of 5 mg m^{-3} is often exceeded during work operations in floor housing systems for laying hens. Whyte *et al.* (1993) reported that the average inspirable fraction breathed by poultry stockmen ranged from 2.1 to 28.5 mg m^{-3} for a complete working day.

In investigations about concentrations and emissions of airborne dust in Northern Europe (Takai *et al*, 1998) was it concluded that both inhalable and respirable dust concentrations were higher in percheries than in houses for caged layers. Ellen *et al.* (2000) reported that dust concentrations in perchery and aviary housing systems often were four to five times higher than in cage systems. Factors affecting dust concentrations are animal category, activity, bedding materials and season.
Whyte (2002) reported that average inhalable dust exposure by poultry stockmen for a complete working day in free range systems was 10.8 mg m^{-3} compared to 4.8 mg m^{-3} in cage systems.

Guarino *et al.* (1999) found that dust concentration in an enclosed laying house was significantly higher during periods with feed distribution and scraper cleaning than during the night.

Dust produced in animal production may affect the workers (Donham, 1987; Tielen *et al.*, 1995; Takai & Iversen, 1990; Larsson *et al*., 1993; Malmberg *et al*., 1993, Iversen *et al.* 2000) as well as the animals (Donham, 1991; Robertson *et al.*, 1990; Robertson, 1993; Hamilton *et al*., 1993).

Melbostad and Eduard (2001) concluded that work related symptoms of respiratory irritations are associated with exposure to total dust, fungal spores and endotoxins.

Larsson *et al*. (1999) reported a tendency to stronger inflammatory reactions in the upper airways among previously non exposed subjects who were exposed for three hours in a loose housing system compared to subjects exposed in a cage rearing system. Inhalable dust levels were approximately 4 mg m^{-3} in the loose housing system and 2 mg m^{-3} in the cage rearing system.
Donham & Cumro (1999) reported a threshold concentration of 2.4 mg m^{-3} for human health inside poultry buildings.

Measures to reduce the contamination of the air with dust in loose housing systems for laying hens are therefore urgent.
In order to study the generation and concentrations of dust and their correlation to other factors a small scale poultry house (climate chamber) at the university research station Alnarp Södergård was equipped with a floor housing system. Between 333 and 392 hens were kept in the system during the investigations.
The objective of the investigations was to evaluate the influence of following factors on dust concentration and generation:

* Age of hens
* Storage of manure
* Ventilation rate
* Bedding materials
* Fogging water droplets
* Spraying a rape seed oil mixture

1. THE MASS BALANCE OF DUST

The mass balance of generated dust in animal houses has been described by Nilsson and Gustafsson (1987) as:

$$V \frac{dC_o}{dt} = p - q(C_o - C_i) - SA \qquad (1)$$

where: V is the building volume in m^3 ; C_o and C_i are the total dust concentrations in air outlets and inlets in mg m^{-3} ; t is time in h; p is the production of dust in mg h^{-1} ; q is the ventilation rate in m^3 h^{-1}; S is the settling rate of dust on floor surfaces in mg m^{-2} h^{-1}; and A is the area of the floor in m^2.
The settling of dust may be described by:

$$S = v\ C_0 \qquad (2)$$

where v is the mean total settling velocity (m h^{-1}), which is dependent on the properties of the dust, e.g. size, shape and density.
The mean generation of dust can be described as:

$$p = q\ (C_o - C_i) + S\ A \qquad (3)$$

2. MATERIALS AND METHODS

How age of hens, storage time of manure, ventilation rate, bedding materials and spraying water droplets or an rape seed oil mixture affected generation and concentration of dust were investigated during two production cycles at JBT:s research station Alnarp Södergård.

3.1 Housing System

The investigations were carried out in a climate chamber equipped with a floor housing system, Figure 1. The chamber was surrounded by a temperature controlled air space where the air temperature and supply air temperature to the chamber were varied between 0 and 16 º C.

The total area of the chamber including walking alleys was 87 m^2 and the area where the laying hens were kept was 47 m^2. The total area 87 m^2 was used in the mass balance equation 3.
The housing system contained a bedding area, a manure bin area with manure conveyors below a draining floor and laying nests which were placed close to one of the walls. The bedding area was 1.5 m wide where six different bedding materials were investigated successively, namely; gravel, clay pellets, peat, wood shavings, chopped straw and chopped paper. The rest part of the floor which was 3.0 m wide was elevated to a height of 0.6 m and equipped with a draining floor.

Feed troughs, drinking nipples and perches were placed in the manure bin area with the draining floor.

Between 333 and 392 Lohmann Selected Leghorn (LSL) layers were kept in the system during the investigations. The layers were fed *ad libitum* from automatic feed conveyors above the draining floor. The metabolisable energy content of the feed was 11.2 MJ/kg. The layers also had free access to water through the water nipples above the draining floor. Spillage water was thereby collected on the manure conveyors.

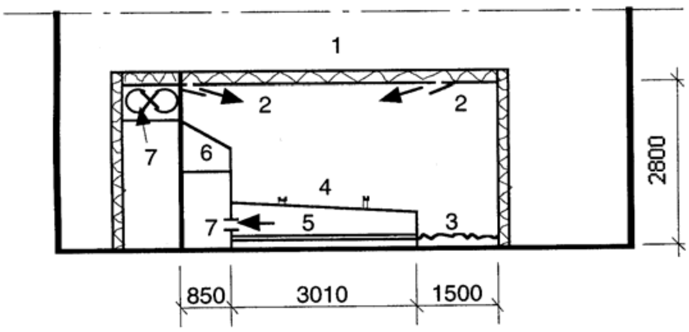

Figure 1. The climate chamber equipped with a floor housing system.

3.2 Ventilation and Climate Control

Mechanical ventilation was provided by a negative pressure system (Figure 1). Air inlets in the ceiling provided the chamber with supply air from the climate controlled area surrounding the chamber. In these studies an exhaust fan removed air at floor level close to the manure conveyors via a slit in a duct below the laying nests.

The temperature inside the chamber was kept at a constant level of 20 - 21 °C during each trial. The ventilation rate could thereby also be kept constant. The constant air temperature was maintained by controlling the amount of extra heat from heat pipes in the chamber.

The ventilation rate was manually regulated with a damper in an exhaust air duct. The ventilation rates were set to values ranging from about 0.9 $m^3\ h^{-1}\ hen^{-1}$ up to 6.8 $m^3\ h^{-1}\ hen^{-1}$. After adjustment of the damper the ventilation rate in the duct was determined with a hot wire anemometer (GGA- 65P, Alnor Instrument CO, Skokie, Illinois, USA) in five positions in the cross section of the exhaust air duct. Temperatures and ventilation rates were kept to specific set point values for three or four days during days used for evaluations.

3.3 Measurements

The ventilation rate was calculated from air velocities measured two times per trial in 5 positions of the cross section of the exhaust air duct (ϕ 400 mm) by using a hot wire anemometer (GGA- 65P, Alnor Instrument CO, Skokie, Illinois, USA).

The efficiencies of different treatments were determined by gravimetric measurements of sampled dust masses on 37 mm diameter dust filters (Millipore with an air flow rate of 1.9 l/min) in SKC cassettes located in the middle of the barn at 1.7 m height above the floor (breathing zone of humans) but also in the exhaust air. Each sampling period was 3-4 days. Sampling was done 15 minutes each hour controlled by a timer. Blank filters were used as control. The results are finally expressed as mg m^{-3} air. Settled dust, which was sampled on five 0.230 m^2 settling plates located at a height of 2.0 m (height was chosen so that they could not be moved during work operations) was also gravimetrically determined. Each measurement was carried out over a period of 3-4 days in order to collect enough dust on the settling plates. Different treatments were compared to reference values measured before and after the treatments.
The generation of dust was determined according to equation 3.

3.4 Analyses

Different measures to reduce the generation and concentration of dust was analysed by using the following properties in the mass balance in Eqn 1: averages of total dust concentrations C_o measured in the exhaust air; average of settling rate of dust on settling plates S; generation of dust p as defined by Eqn 3; mean total settling velocity v in equation 2. Concentration in inlet air , C_i, was assumed neglectable compared to C_o in equation 3.

3.5 Investigations

3.5.1 Age

The influence of age of the hens on release of dust was investigated during two production cycles.

3.5.2 Storage of Manure

The influence of increasing storage time of manure in the bedding area was investigated during periods with daily manure removal from the conveyors.

3.5.3 Ventilation Rate

The influence of ventilation rate was determined at constant air temperature (20-21 ºC) at varying ventilation rates.

3.5.4 Bedding Materials

Six different bedding materials were investigated in following trials namely; gravel, clay pellets, peat, wood shavings, chopped straw and chopped paper at ventilation rates in the range of 1.04 – 1.13 m^3 hen^{-1} h^{-1}.

3.5.5 Fogging Water Droplets

How different amounts of water which was fogged influenced dust concentration was investigated using four different bedding materials (chopped paper, clay pellets, peat and wood shavings). Full cone nozzles (Fulljet 5LVS) were used. The equipment for controlling the spraying time is presented in Figure 2. Spraying was done twice per hour during the light period 4.30 a.m. – 5.30 p.m.. Different amounts of water were investigated by varying the spraying time with a time relay.
The effect on dust concentration by fogging water droplets was compared with reference periods without any fogging.

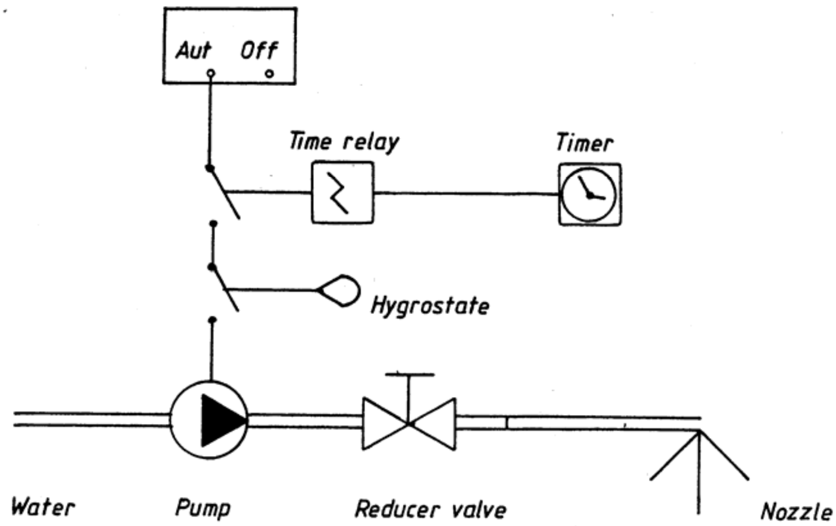

Figure 2. Equipment for control of spraying time and intervals for the spraying nozzle

3.5.6 Spraying a Rape Seed Oil Mixture

The effect of spraying different amounts of a mixture of 10% rapeseed oil in water on dust concentration was also investigated. The mixture was supplied once per day with the same equipment as for water droplets.

4. RESULTS AND DISCUSSION

4.1 Age of Hens

It could not be proved that the age of the hens had any influence on the generation of dust.

Obviously the dependence of age in this type of housing system for layers differs with the generation of broilers were it has been reported that the generation of dust increases with age and weight of chickens (Gustafsson & Mårtensson, 1990). An explanation may be that the weight of the hens is relatively constant during the production period.

4.2 Storage of Manure

The storage time of manure in the bedding had no significant influence on the generation of dust. Accumulation of manure in the bedding seems therefore not to be the major source for the generation of dust.

4.3 Ventilation Rate

The ventilation rate had a limited diluting effect on dust concentration, Figure 3. Even if dust concentration decreased at increasing ventilation rate, it was not an ideal dilution depending on ventilation rate. The variations in dust concentrations were large which indicates that there were other factors as activity in the building environment which were more important for the dust concentration than ventilation rate. The ventilation rate did not either have any significant influence on the generation of dust. The average dust generation was 27.9 mg hen^{-1} h^{-1} when the ventilation rate was in the range of 0.9 – 3.4 m^3 hen^{-1} h^{-1}. The investigations showed that it was a limited amount of the dust generated which was exhausted with the ventilation air, Figure 4. The reason was that the major part of the dust produced settled on different surfaces. This result is in accordance with results earlier reported for swine and chickens (Nilsson & Gustafsson, 1987; Gustafsson and Mårtensson, 1990).

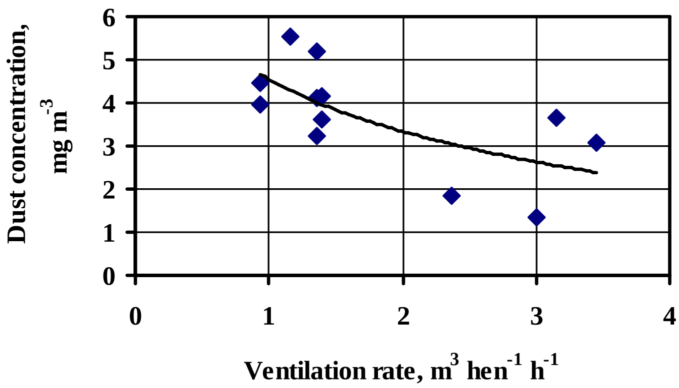

Figure 3. Total dust concentrations at different ventilation rates in a trial with gravel as bedding material.

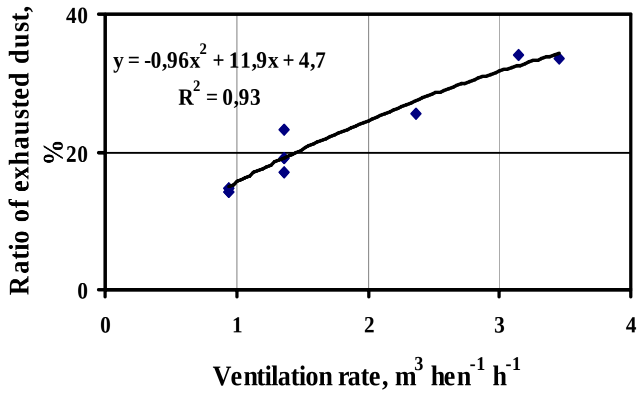

Figure 4. Ratio of exhausted dust at different ventilation rates in a trial with gravel as bedding material.

4.4 Settling of Dust

The settling rate of dust, S, was also analysed as function of the dust concentration in the air, see Figure 5. The settling rate increased with increasing concentration which is in accordance with equation 2 where the coefficient v (settling velocity) corresponds to the slope (29.7 m h^{-1}) of the curve. Earlier reported values for broilers have been in the range of 25.7 and 35.6 m h^{-1} (Gustafsson & Mårtensson, 1990). The tendency for dust particles to settle in this housing system is therefore in the same range as for broilers with a similar body weight kept on bedding.

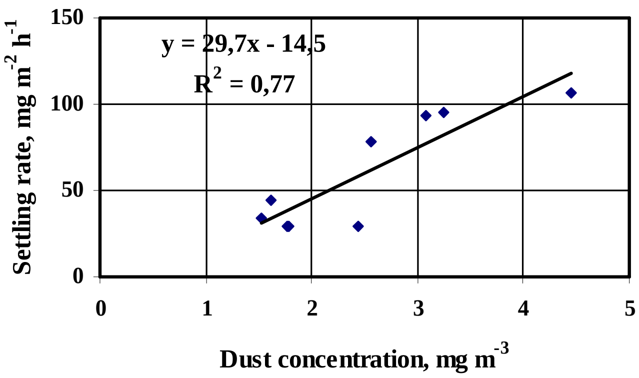

Figure 5. Settling rate of dust as function of dust concentration when gravel was bedding material.

4.5 Bedding Materials

Total dust concentrations with different bedding materials are presented in Table 1 when the ventilation rates were in the range of 1.04 – 1.13 m^3 hen^{-1} h^{-1}.

The level of concentration of dust was about the same for the bedding materials wood shavings, clay pellets, peat and chopped straw. Especially gravel resulted in higher concentrations, however, not statistically different.

Regarding the generation of dust was the picture about the same as for concentration of dust except for peat and chopped paper as bedding materials, Table 2. The high dust production with peat depended on a high settling rate.

Table 1. Total dust concentration (mg m^{-3}) with different bedding materials. Ventilation rate in the range of 1.04 – 1.13 m^3 hen^{-1} h^{-1}.

Bedding:	Average, mg m^{-3}	Minimum, mg m^{-3}	Maximum, mg m^{-3}
Gravel	4.7	4.0	5.5
Wood shavings	2.3	2.1	2.4
Clay pellets	1.8	1.7	1.9
Peat	1.7	1.2	2.3
Chopped straw	2.1	1.8	2.3
Chopped paper	2.6	2.2	2.9

Table 2. Total dust production (mg hen^{-1} h^{-1}) with different bedding materials. Ventilation rate in the range of 1.04 – 1.13 m^3 hen^{-1} h^{-1}.

Bedding:	Average, mg hen^{-1} h^{-1}	Minimum, mg hen^{-1} h^{-1}	Maximum, mg hen^{-1} h^{1}
Gravel	27.4	26.6	28.3
Wood shavings	11.4	10.4	12.4
Clay pellets	8.5	7.6	9.8
Peat	21.7	12.1	35.3
Chopped straw	16.8	15.7	17.8
Chopped paper	22.7	18.5	25.5

4.6 Fogging Water Droplets

How different amounts of water which was fogged influenced dust concentration was investigated using four different bedding materials. The effect of fogging was analysed as relative values compared to the levels without any fogging. Fogging resulted in a considerable reduction of dust concentration in all trials. The reduction in dust concentration was improved when the amount of water increased, which is exemplified in Figure 6 from a trial when wood shavings was used as bedding material.

Fogging water droplets is obviously an effective way of reducing dust concentration in this type of housing system. Von Wachenfelt (1999) has earlier reported up to 65% reduction by fogging water droplets in an aviary system for laying hens.

The feathers of the hens were in very good conditions.

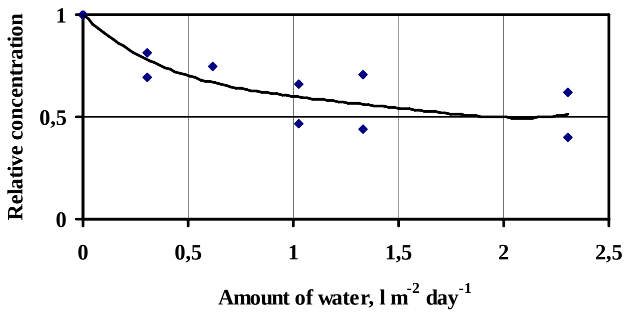

Figure 6. Relative dust concentration (1.0 is reference level) at different amounts of water sprayed. Wood shavings was bedding material.

4.7 Spraying a Rape Seed Oil Mixture

The effect of showering a mixture of 10 % rape seed oil in water on dust concentration was also investigated, Figure 7. The mixture was showered with full cone nozzles located above the draining floor. Showering the oil mixture reduced the dust concentration with 30 – 50 %. The oil mixture had effect at as low amounts as 0.003 l m^{-2} day^{-1}.

The results are similar to what has been reported by von Wachenfelt (1999) in an aviary system.

Even in these investigation the feathers were in very good conditions.

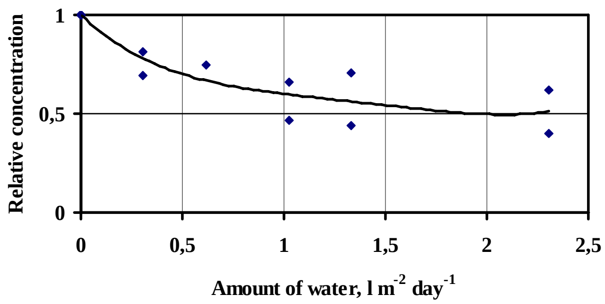

Figure 7. Relative total dust concentration (1.0 is reference level) at different amounts of a sprayed oil mixture.

5. CONCLUSIONS

The following conclusions can be drawn from the investigations:

- There were no ideal diluting effect of ventilation rate on dust concentration.
- A major part of the produced dust settled on different surfaces
- Spraying water droplets or an oil mixture reduced dust concentration
- The feather conditions were very good when water droplets or an oil mixture were sprayed
- Bedding of clay pellets or peat generated the lowest concentrations
- Gravel as bedding material generated the highest concentrations

From our findings from the investigations we will recommend using clay pellets as bedding material and using a sprinkler system spraying water droplets frequently in floor housing systems for laying hens.

6. ACKNOWLEDGEMENTS

Financial support from the Swedish Farmers´ Foundation for Research and the Swedish Board of Agriculture is gratefully acknowledged.

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