Effect of airborne dust on health and performance of growing pigs

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Jansen, A. and Feddes, J.J.R. 1995. **Effect of airborne dust on health and performance of growing pigs.** Can. Agri. Eng. 37:211-216. The effect of high concentrations of airborne dust on the health and performance of growing pigs (55-82 kg) was determined by introducing mechanically ground fecal dust into the air space of the pigs in the first trial and feed dust in the second trial. Mean respirable dust levels during the light hours in the rooms injected with feed and fecal dust were 111 and 56 particles/mL, respectively, while the mean level in the control rooms was 25 and 17 particles/mL, respectively. Lungs from 115 animals were collected during slaughter. No relationship was found between dust concentration and lung score or between dust concentration and average daily gain. For the fecal and the feed dust trials, 38% and 23% of the pigs had pneumonic involvement in over 10% of the lung. The average daily gain was not significantly different between treatments (mean 0.78 kg/d) and it was not affected significantly by the percentage of pneumonic involvement. A large amount of energy was required to reduce feed to the respirable range relative to that required for fecal dust suggesting that most of the respirable dust is of fecal origin.

.On a mesuré les impacts des poussières sur la santé et le taux de croissance de porcs à l'engraissement (55-82 kg) en introduisant, dans l'air que respirent les porcs, de la poussières fécale et, lors d'un deuxième essai, de la poussière d'aliments. Les taux diurnes de poussières respirables dans les chambres où l'on introduit la poussière étaient de 111 particules/ml pour la poussière d'aliments et de 56 particules/ml pour la poussière fécale. Dans les chambres de contrôle, les taux étaient de 25 particules/ml pour la poussière d'aliments et de 17 particules/ml pour la poussière fécale. A l'abattage, on a récupéré les poumons de 115 animaux. Aucune relation entre les concentrations de poussières et les lésions aux poumons et entre la concentration de poussière et le gain de poids journalier n'a pu être établie. Lors de essais avec la poussière fécale et la poussière d'aliments, 38% et 23% des porcs avaient des problèmes pulmonaires sur plus de 10% des poumons. Le gain de poids journalier moyen n'était pas significativement différent entre les traitements (moyenne de 0.78 kg/j) et n'était pas significativement influencé par le pourcentage de problèmes pulmonaires. Une grande quantité d'énergie a été nécessaire à la réduction de poussières d'aliments en poussière respirable, comparativement à ce qui a été requis pour la poussière fécale. Cela tend à indiquer que la majeure partie de la poussière respirable est d'origine fécale.

INTRODUCTION

Several airborne contaminants in the animal house have been identified as being harmful to animal health or detrimental to animal productivity. One of these contaminants is respirable dust. A threshold limit value (TLV) of 500 particles/mL for dust in industrial settings has been in existence for a number of years (ACGIH 1992). A TLV has not been established for animal housing even though respiratory health problems exist for both the animal (De Boer and Morrison 1988) and for the long term producer or worker (Donham et al. 1989). The exposure to dust in the animal environment is unique in that this dust consists largely of organic material, consisting of about 25% protein (Donham et al. 1986), and thus is likely to be biologically active. The airborne dust is generally present in high concentrations and co-exists with other potentially harmful contaminants.

Respirable dust is considered to be a major contributor to respiratory disorders for both the animals and people who work within the confinement unit. It is necessary to determine the animal response to dust exposure to aid in determining required control levels. Respirable airborne particles in animal housing are primarily of a fecal or feed origin (Donham et al. 1986; Feddes et al. 1989; Dawson 1990) and have a high composition of protein, ammonia, bacteria, and endotoxins (Donham et al. 1986). Pig production systems utilizing floor feeding or drop feeding of dry meal result in high levels of airborne feed particles. Welford et al. (1992) reported that the addition of canola oil to feed reduced the airborne non-respirable particles but not the airborne respirable particles. This suggests that feed particles are largely non-respirable and fecal/skin particles are largely respirable. Animal response data from these two types of respirable dust will be required to design control systems for dust control to reduce the respiratory challenge to animals and barnworkers. The effects of aerial contaminants on the health and performance of growing animals are not well known and need to be defined to determine the acceptable level of dust control.

A study was undertaken from November, 1991 to June, 1992 to assess the effect of airborne fecal and feed dust on the health and performance of growing pigs. The effects of high concentrations of fecal or feed dust artificially created in two rooms were compared to those in two control rooms which had relatively low dust concentrations. In the first trial, fecal dust was introduced to the rooms while feed dust was introduced to the rooms during the second trial. In each trial, the two treatments (dust and control) were replicated twice. Dust was introduced over the duration of a grow-out period (approximately 90 days).

METHODOLOGY

The experiment was conducted in the grower barn at the Swine Research Unit at the Edmonton Research Station. Four enclosed rooms with individual ventilation systems were

available. Each of the rooms (4.8 x 9.1 m) confined a total of 60 pigs within four pens (15/pen). Two of the pens in each room were 2.0 m by 4.8 m and the remaining two pens were 2.6 m by 4.8 m. Animals were introduced to the smaller pens at 35 to 40 kg and moved to larger pens at about 55 kg where they remained until market time.

The rooms were separated from each other by a 100-mm, non-insulated wall extending from the common exterior wall to the central alley. The front of each room was covered by a plastic curtain which extended the length of the room, from floor to ceiling. The curtain was lifted by pulleys when moving and managing the animals. Each room was ventilated under negative pressure, by a single variable-speed fan located in the centre of the exterior wall. Each room had a ceiling-attached 300 x 300 mm recirculation duct across its width. The fresh air entered each room through a continuous, counter balanced-inlet located 460 mm downstream from the recirculation duct. Fans were operated by a controller whose sensor was located inside the recirculation duct. Supplemental heat was added to each room by two black-steel hot-water pipes located in front of the fresh air inlets.

The pens were separated by 50 mm, metal frame penning filled with concrete slabs, over the solid portions of the floor area. Over the slotted area, the 50-mm metal frame was fitted with 12-mm metal rods spaced vertically 75 mm apart. The pens were partially slatted by 1.5 m slats that covered a gutter 600 mm in depth, located along the exterior walls of the barn.

Feed was supplied from overhead lines and dropped via a vertical tube into a hopper that metered feed into each feeder. The number of hopper volumes emptied into each feeder was recorded. Four feeding ports were available in each pen.

Ground dried fecal or feed material was introduced into the recirculation ducts of two rooms by a dust generator fabricated by department staff. The dust generator consisted of a hopper, horizontal auger, and a blower. An horizontal auger in the hopper (800 x 300 x 300 mm) transported the dust into an air duct downstream from the blower fan. The particle laden air was conveyed to the recirculation ducts in the two rooms. A 24-h timer operated the dust generator continuously between 600h and 2000h at a rate that would result in high concentrations (approximately 80 particles/mL). The control rooms were expected to have a respirable dust concentration of approximately 25 particles/mL, which is considered acceptable (Donham et al. 1989). Fecal dust was produced by collecting the feces from the solid floor of an adjacent barn. The feces were dried and coarse ground through a 2-mm screen. The feces material was further dried for 24 h at 60°C and then ground by a rotary mill using a 1-mm screen. This may have killed the bacteria, however the response of the pigs to the dried fecal material was of primary interest due to its high protein content.

A pig finishing ration was used as the source for the feed dust. The ration was dried for 24 h at 60°C and then ground in the rotary hammer mill using the 1-mm screen. This material was then ground by a bench top plate grinder which further reduced the feed material. The feed dust material was less powdery than the fecal material even after passing through the plate grinder.

A "test" group of 15 animals in each of the four rooms was "monitored" up to market time. Upon entry into the rooms, each animal was ear tagged for individual identification and the mass, sex, and birth date were recorded. The test animals were then weighed every two weeks until market mass was reached. The feed consumed by each test group was recorded on a volume basis. These data were used to calculate the individual test animal rate of live mass gain and the average test group feed conversion (kg feed/kg mass gain). All of the animals from a given test pen were marketed at the same time when the average group mass was near 105 kg. These pigs were cared for according to the guidelines of the Canadian Council of Animal Care. At the time of slaughter, all the lungs from each animal were collected and identified. The lungs were then submitted to the Alberta Agriculture Diagnostics Laboratory for biopsies. The lung sections were scored for pneumonic involvement on a percentage basis. Each anterior lobe was allocated 10%, each middle lobe 10%, each posterior lobe 25%, and the intermediate lobe 10%; for a total of 100%. The amount of pneumonic involvement in each lobe was estimated, thus involvement of half of an anterior lobe would score 5%. The sum of all the scores for the lobes became the final score. Four of the lungs from the fecal dust trial and six lungs from the feed dust trial were cultured.

All four rooms were instrumented for the continuous sampling of dry bulb temperature, dewpoint, ventilation rate, and airborne particulate concentration. The temperature and ventilation rate were monitored on 4-min intervals while the dewpoint was sampled from each room on a 30-min interval. The concentration of respirable dust (<10 μm) was sampled on an hourly basis. The rooms were monitored 24h every two weeks.

The environmental data, with the exception of the dust, were acquired using a DataTaker 100 (Data Electronics Aust Pty Ltd., Boronia, Victoria, Australia) data logger and a personal computer. One sampling location near the centre of each room and 1.5 m above the floor was used to monitor temperature, respirable dust, and dewpoint. In all four rooms and the attic, the sampling tubes for transporting the air to the analyzers were 10 m in length.

The temperature was measured by recording the resistance of a thermistor placed at the sampling location. Dewpoint was monitored with a dewpoint hygrometer (Model Hygro-M1, General Eastern, Watertown, MA). Each room and the attic were sampled sequentially every 4 min. The fans were calibrated on three occasions throughout each trial. The fan flow rate was calculated by measuring the velocity at 25 points in the cross-section of a duct (46 x 46 mm) placed upstream from the exhaust fan. Fan flow rates were calculated at five controller settings representing a fan speed of 100%, 80%, 60%, 45%, and 30% of full capacity. Voltage supplied to the fan was measured by a transforming and rectifying circuit. The ventilation rate during each monitoring period was determined from the voltage - fan flow rate relationship. During the 24-h sampling period, carbon dioxide (CO_2) and ammonia (NH_3) concentrations were measured periodically by chemical reaction tubes.

Particle counts were accumulated over the 4-min sampling periods at a sampling rate of 5 L/min. Sample lines were connected to ball valves that were controlled by a computer. The four rooms and the attic were sampled sequentially once

per hour. The dust particles were counted and sized by an aerodynamic particle sizer (APS Model 3300, TSI Inc. St. Paul, MN) that drew air from the ball value unit.

Environment

A summary of the spatial environmental data for the fecal and feed dust trials is tabulated in Tables I and II, respectively. A large difference in the spatial environments was observed between the two trials since the fecal and feed dust trials occurred during the winter and summer period, respectively.

The fecal dust trial had a lower average ventilation rate than that with feed dust by approximately 300 L/s. Because of the higher ventilation rates due to warm weather in the feed dust trial, the mean ambient temperatures were approximately 1°C higher, relative humidity was approximately 10% lower, CO_2 concentrations were approximately 1000 ppm lower, and NH_3 concentrations were approximately 4 ppm lower.

Table I: Summary of environmental data (fecal dust trial)

Treatment	Fecal dust added	No dust added
Ventilation rate (L • s^{-1})	627	595
Temperature (°C)	18.0	17.3
Relative humidity (%)	47	50
Carbon dioxide (ppm)	2480	2780
Ammonia (ppm)	8.9	11.6
Respirable dust: particles < 5µm		
- average (particles/mL)	45	23
- day (particles/mL)	56	25
- night (particles/mL)	23	20

Table II: Summary of environmental data (feed dust trial)

Treatment	Feed dust added	No dust added
Ventilation rate (L • s^{-1})	902	930
Temperature (°C)	18.9	19.2
Relative humidity (%)	43	41
Carbon dioxide (ppm)	1607	1488
Ammonia (ppm)	5.7	6.7
Respirable dust: particles < 5µm		
- average (particles/mL)	79	14
- day (particles/mL)	111	17
- night (particles/mL)	15	9

Statistical Analysis

Data obtained were analyzed using the General Linear Model for analysis of variance on the SAS software package (SAS 1990). Liveweight and lung score data for each trial were transformed using the arcsine of the square root of the percentage prior to analysis (Steel and Torrie 1980). Significance was evaluated at the 0.05 level.

RESULTS AND DISCUSSION

Production

Results pertaining to animal productivity for the fecal and feed dust trials are presented in Tables III and IV, respectively. These data indicate that pigs exposed to airborne fecal dust had an improved feed conversion rate (3.61). The reason for this occurrence is unclear other than this group was 10 kg lighter and 15 days older when introduced to the rooms. Table VII shows that pigs in the fecal dust trial had fewer lesions which supports the increased performance. The animals in the feed dust trial required 30 more days to reach 105 kg live mass due to the lower initial masses. Although the average daily gain during the monitoring period was similar (0.78 kg/d) between the two dust trials, the animals in the feed dust trial consumed 0.3 kg more feed per unit gain, which amounted to 16.5 kg of feed per pig housed from 50 to 105 kg.

Table III: Summary of animal production results (fecal dust trial)

Treatment	Fecal dust added	No dust added
Initial mass (kg)	49.5 (4.7)[1]	51.1 (6.0)
Number of pigs	15	15
Initial age (days)	99	98
Ave. daily gain (kg• day^{-1})	0.78 (0.12)	0.79 (0.075)
Feed/Gain (kg• kg^{-1})	3.61	3.90
Age to 105 kg (days)	170	166

( )[1] - Standard deviation

Table IV: Summary of animal production results (feed dust trial)

Treatment	Feed dust added	No dust added
Initial mass (kg)	37.4 (3.7)[1]	42.7 (5.0)
Number of pigs	15	15
Initial age (days)	112	117
Ave. daily gain (kg• day^{-1})	0.80 (0.094)	0.75 (0.110)
Feed/Gain (kg• kg^{-1})	4.16	4.11
Age to 105 kg (days)	196	201

( )[1] - Standard deviation

Dust

The feed material used in the feed dust trial required a tremendous amount of energy to reduce particles to the respirable range compared to that with the fecal material. The fecal dust had a lower density and was more powdery than the feed dust. When disturbed, the fecal dust would produce a small dust cloud which the feed dust would not.

The fecal and feed dust used in the two dust trials had different particle size distributions. The mean particle distribution for one day during each of the two trials is shown in

Figs. 1 and 2, respectively. In the fecal dust trial, the largest portion of the dust particle sizes was in the 2 μm range, while that of the feed dust trial was 4 μm. The non-respirable particle concentrations for both dust trials were considered to be less than 5 particles/mL.

The average dust concentrations recorded for the fecal and feed dust trial runs are summarized in Table III and IV, respectively. The dust concentrations in the control treatment of the feed dust trial were consistently lower than those recorded during the fecal dust trial. This appears to be a result of additional dilution of feed dust particles occurring due to the higher summer ventilation rates (Gao and Feddes 1991; Liao and Feddes 1991).

The night time (2000h to 800h) dust concentrations in the dust and control treatments for both trials were also similar in magnitude. The control treatment groups did, however, have a slightly lower night time average particle concentration than did the dust added treatment for both dust trials. In the dust added treatments, much of the introduced dust settled on the floor and appeared to resuspend with a minimal amount of activity. The control treatments for both dust trials also showed a lower concentration during the night than during the day as a result of reduced air speed due to reduced nighttime ventilation rates and reduced animal activity. The feed dust treatment (Table IV) had a higher mean respirable dust concentration (79 particles/mL) than did the fecal dust treatment (Table III) (45 particles/mL) due to dust metering problems encountered during the fecal dust trial.

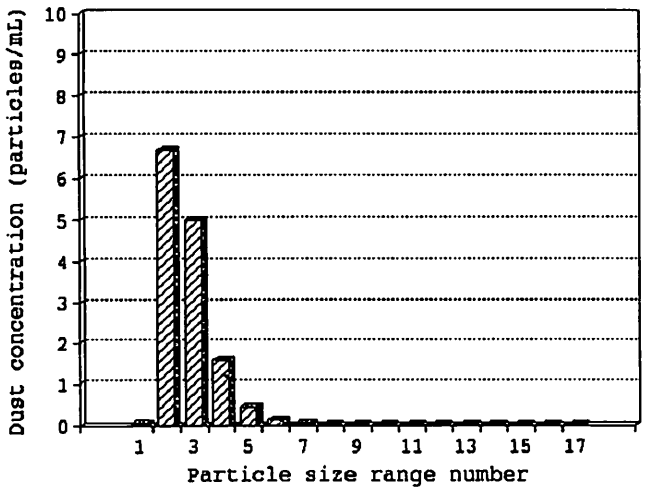

Fig. 1. Fecal dust size distribution.

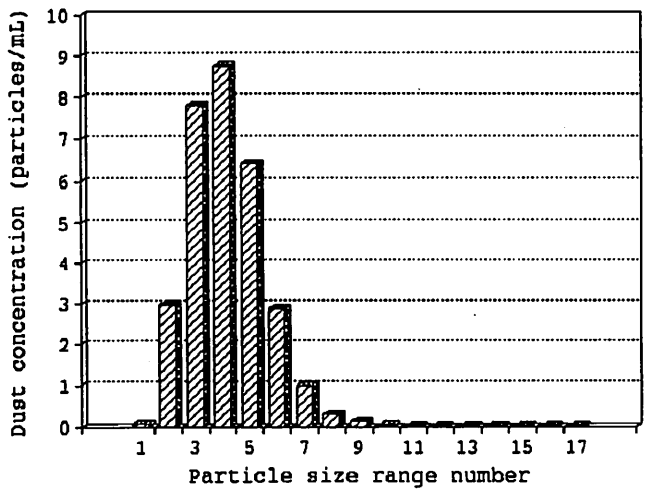

Fig. 2. Feed dust size distribution.

Lung scores and mortality

Pasteurella multocida was cultured from 9 of the 10 lungs and *Streptococcus suis* was found in 8 of the 10 lungs. Tables V and VI contain a summary of the lung scores and pig mortality for the fecal and feed dust trials, respectively. The average lung scores in the two dust trials were similar as there was no correlation between lung score and dust concentrations. The animals in the control treatments for both trials had a higher average lung score and a higher maximum lung score than those in both of the dust treatments. For all the experimental pigs (115 lungs in total), 67 of the animals had lung lesions, the average lung score ranged from 11 to 16% of the lung and the maximum lung score was 40%.

Table V: Summary of lung scores (and mortality) in fecal dust trial

	Fecal dust added	No dust added
Average lung scores (% of lung)		
- all lungs	5.0	12.3
- lungs with lesions	11.0	14.5
- maximum lung score	35	40
Number of lungs with lesions	13	24
Mortality	0	1

Table VI: Summary of lung scores (and mortality) in feed dust trial

	Feed dust added	No dust added
Average lung scores (% of lung)		
- all lungs	6.5	7.3
- lungs with lesions	11.1	16.1
- maximum lung score	38	40
Number of lungs with lesions	17	13
Mortality	1	2

The control group in the fecal dust trial had a much higher incidence of lung lesions than the other groups and a high average lung score. The incidence of lung lesions in this group did not appear to affect animal liveweight gain as this treatment had the second highest average daily gain and lowest average days to market (Table III). From an air quality point of view, this treatment had the lowest average ventilation rate, lowest average temperature and the highest concentration of NH_3 (Table I). Ammonia appears to have an additive effect on the incidence of lung lesions.

Table VII: Summary of pig production based on lung score (fecal dust trial)

	Pigs	Initial age (days)	Initial mass (kg)	ADG ($kg \bullet day^{-1}$)	Lung score (%)
Lung Score Range					
< 10%	36	99.1 (4.3)[1]	51.3 (6.4)	0.80 (0.13)	1.5 (2.2)
> 10% and < 20%	12	99.2 (4.1)	50.1 (3.8)	0.76 (0.08)	12.8 (2.7)
> 20%	10	96.9 (6.8)	47.4 (8.3)	0.77 (0.06)	28.8 (6.7)

( )[1] - Standard deviation

Table VIII: Summary of pig production based on lung score (feed dust trial)

	Pigs	Initial age (days)	Initial mass (kg)	ADG ($kg \bullet day^{-1}$)	Lung score (%)
Lung Score Range					
< 10%	46	89.2 (11.1)[1]	39.5 (8.5)	0.80 (0.09)	1.8 (2.9)
> 10% and < 20%	6	81.7 (14.2)	38.8 (11.4)	0.70 (0.15)	13.2 (1.1)
> 20%	8	87.9 (12.4)	44.1 (8.6)	0.67 (0.10)	29.3 (7.3)

( )[1] - Standard deviation

The control treatment group in the feed dust trial had the highest average lung score among those animals identified as having lesions. Although the incidence of lung lesions was not very high relative to the other treatment, the lungs of the animals were more severely affected by the lesions. This treatment group did have the lowest average daily gain and the highest average days to market (Table IV).

Tables VII and VIII categorize the lung scores, the average initial animal age and mass, and the average daily gain for all the animals in the fecal and feed dust trials, respectively. Younger animals may be more susceptible to lung lesions when exposed to poor air quality. There was no apparent difference in average daily gain. In the fecal dust trial, 22 of 58 hogs had a lung score greater than or equal to 10%. There was no difference in the average initial mass of the animals or the average daily gain of the animals when comparing animals with a lung score less than 10% and those with a lung score between 10% and 20%. Animals with a lung score greater than 20% were on the average younger and lighter in mass when they entered the experimental rooms.

In the feed dust trial, the animals with a lung score between 10 and 20% were younger when they entered the finishing barn (approximately 7 days) than the animals in the other two ranges of lung scores. There was little difference in the average starting mass for the three ranges of lung scores. In the feed dust trial, a difference in average daily gain was observed with respect to the control group. Animals with a lung score between 10 and 20% had a lower average daily gain (0.7 kg/d) than animals with a lung score less than 10% (0.8 kg/d). For animals with a lung score greater than 20%, this rate of gain decreased from 0.80 to 0.67 kg/d. This translates to 13 more days to reach 105 kg from a mass of 50 kg. In both trials, the maximum average daily gain was highest in the first range (<10 %) of lung scores. Also in the fecal dust trial, 38% of the pigs with lesions had a lung score greater than 10% whereas 23% of those in the feed dust trial had a lung score greater than 10%.

SUMMARY AND CONCLUSIONS

In general, the high concentrations of both fecal or feed dust imposed on the pigs had little effect on performance. There was some indication that dust concentration may have a greater effect on the incidence of lung lesions than on the severity of the lesions. The amount of energy required to create dust from the feed ration would also tend to indicate that fecal material is likely the major source of respirable dust in animal confinement housing.

The following conclusions were drawn from this study:

1. There was no apparent relationship between growth rate and dust concentration.
2. There was no apparent relationship between lung score and dust concentration.
3. There were no apparent differences in the effect of feed and fecal dust on pig performance and health.
4. *Pasteurella multocida* and *Streptococcus suis* were present in almost all of the lungs.
5. For the treatments in both trials, the average lung score ranged from 11 to 16% for the animals with lung lesions and the maximum individual lung score was 40%.

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