View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by University of Southern Queensland ePrints

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Conference Presentation

Paper Number: ILES12-1567

Quantification of Environmental Conditions in Australian Livestock Buildings

Thomas M. Banhazi, PhD. Associate Professor

University of Southern Queensland, West St, Toowoomba, QLD, 4530 Australia

Email: Thomas.banhazi@usq.edu.au

Written for presentation at the
Ninth International Livestock Environment Symposium
Sponsored by ASABE
Valencia Conference Centre
Valencia, Spain
July 8 - 12, 2012

Abstract. *Concentrations and emissions of airborne endotoxins and microorganisms within and from 160 piggery buildings were surveyed in four states of Australia. Respirable dust samples collected on filter papers in the buildings were used to determine endotoxin concentrations. The total airborne microorganisms were measured using six-stage Andersen sampler. A refereed methodology was used to predict the emission rates from all buildings studied. An overall mean microorganism emission rate of 1.6 x 10^7 cfu/h/pig and a mean internal building concentration of 1.17 x 10^5 cfu/m^3 were measured in the piggery buildings. An overall mean emission rate of 3.31 x 10^3 EU/h/pig and a mean internal concentration of 33.1 Endotoxin Units (EU)/m^3 were measured for respirable endotoxins. The lowest endotoxin concentrations were measured in dry sow buildings (23.3 EU/m^3), while measurements taken in straw based shelters had the highest concentrations (84.98 EU/m^3). Straw based shelters also had the highest mean bacteria concentration (3.27 x 10^5 cfu/m^3) and emission rate (44.1 x 10^7 cfu/h/500 kg live weight).*

Keywords. Air quality, bacteria, survey, risk factors, endotoxin, microorganisms, emission

Introduction

Generally, the airspace of intensive piggery buildings is filled with the mixture of different airborne microorganisms and bacterial products, such as endotoxins (Wathes *et al.*, 1998). Airborne microorganisms are usually attached to airborne particles and often referred to as 'viable' airborne particles as opposed to the ones that are not displaying biological activity expected from a living organism (Seedorf *et al.*, 1998b). The finer fraction of the biologically active airborne material is often referred to as 'bioaerosol', which is a complex mixture of different microorganisms, bacterial products (such as endotoxins), airborne particles acting as carriers for the microbes and different gasses absorbed in them (Seedorf *et al.*, 1998b). Endotoxins are a cell wall component of gram negative bacteria and have been associated with production problems in the livestock industries. There are essentially three major areas of concern in relation to airborne viable particles and endotoxin, such as (1) emission issues, (2) human and (3) animal health effects (Banhazi *et al.*, 2009). High airborne microorganism and endotoxin concentrations are a concern for livestock managers as a number of studies demonstrated the association between viable airborne particles, endotoxins and different lung-related diseases in animals and humans (Crook *et al.*, 1991; Donham *et al.*, 1989). A number of studies have also demonstrated significant effects of sub-optimal air quality on production efficiency (Urbain *et al.*, 1999). The interaction between noxious gases found in piggery buildings and the bacterial component of organic dust has also been implicated in respiratory disorders of pigs (Curtis *et al.*, 1975). Therefore, the two main objectives of this study were to (1) document internal concentrations of airborne endotoxins and microorganisms in different types of piggery buildings used in commercial production systems in Australia; and to (2) calculate, using refereed methodology, the emission levels of airborne endotoxins and microorganisms from different types of piggery buildings in Australia.

Material and methods

Farm selection and sampling

In total 160 piggery buildings were included in the study. Each herd received 4 two-day visits during a period of 1 month with a different section of the farm monitored at each visit. On each farm, dry sow, weaner, grower/finisher sheds, farrowing rooms and on some farms, straw based shelters, were surveyed during the study (Banhazi *et al.*, 2008b; Banhazi *et al.*, 2008c). Details of the techniques used for measurement of endotoxin and bacteria concentrations have been described by other articles and thus only the outline of the methods is described here (Banhazi *et al.*, 2008b; Banhazi *et al.*, 2008c). The respirable dust fraction was sampled for 8 h at 1.90 L/min and a commercially available endotoxin test kit was used to determine the endotoxin concentrations in the dust samples. The endotoxin analysis used was based on the Limulus Amoebocyte Lysate (LAL) test. The subsequent measurement of endotoxin concentration was performed using a microplate method as described previously (Banhazi *et al.*, 2008c). The results were expressed in Endotoxin Units (EU). Sampling of airborne microorganisms was carried out using a standard Anderson sampler or six-stage bacterial impactor. Horse-blood-Agar (HBA) was used for the determination of the total amount of bacteria. The flow rate during sampling was 1.9 L/min and sampling duration was 5 min. as per previous studies (Banhazi *et al.*, 2008c). The exposed HBA plates were incubated at 37 ^{o}C under aerobic conditions, as described previously (Banhazi *et al.*, 2008c). The results were expressed as colony-forming units per cubic meter (cfu/m^3).

Emission estimation and data analysis

The estimate of emission rate was determined from the product of the ventilation rate, which was based on the carbon dioxide balance method. For predicting emission levels, the European ANIPRO (developed from the early version of "Stalkl") program was used (Seedorf *et al.*, 1998a). Carbon dioxide were monitored continuously using a Multi Gas Monitoring (MGM) machine developed in-house (Banhazi *et al.*, 2008d). Window based STATISTICA 6.0 (StatSoft Inc., 1996) was used to conduct basic statistical manipulation of the data, such as grouping and descriptive statistics. A detailed model was later developed to test various interactions and the results of the detailed analysis have been published previously (Banhazi *et al.*, 2008a; Banhazi *et al.*, 2008c; Banhazi *et al.*, 2008d). However, in this paper grouping (one-way ANOVA) was used to report on average values recorded in different buildings.

Results

Airborne microorganisms concentrations

The results of internal concentrations of airborne microorganisms measured in different types of piggery buildings included in the study are shown in Table 1 and Figure 1. The highest total airborne microorganism concentrations were detected in straw based shelters with mean concentrations of 3.27 x 10^5 cfu/m^3. In contrast to straw based shelters, houses for farrowing sows had lowest concentrations of airborne microorganisms of 0.69 x 10^5 cfu/m^3. The highest minimum and maximum concentrations of airborne microorganisms were also measured in straw based shelters, indicating (which was demonstrated in a previous study) that this type of buildings had a significantly and consistently higher airborne microorganisms population, compared to traditional buildings (Banhazi *et al.*, 2008c; Banhazi *et al.*, 2010).

Table 1. Bacteria concentrations (x 10^5 cfu/m^3) inside the study buildings (Summary table of means)

Building type	Mean	No of buildings	Minimum	Maximum
Grower	1.34	28	0.45	3.49
Finisher	0.96	26	0.36	3.13
Straw based shelters	3.27	10	1.20	6.06
Dry sow	0.76	15	0.25	1.96
Farrowing	0.69	19	0.17	1.35
Weaner	0.94	24	0.22	2.55
All groups	1.17	122	0.17	6.06

The mean airborne microorganism concentrations were very similar in weaner (0.94 x 10^5 cfu/m^3) and finisher (0.96 x 10^5 cfu/m^3) buildings. Grower buildings had the second highest airborne microorganisms concentrations recorded (1.34 x 10^5 cfu/m^3), while the second lowest airborne microorganism concentrations were measured inside buildings housing dry sows (0.76 x 10^5 cfu/m^3).

In Figure 1 the distribution of airborne microorganism concentrations measured in all buildings is presented. This graph is probably more useful demonstrating the extent of the problems with bacteria concentrations in piggery buildings, than summary tables of means. It is generally reassuring, that 62% of the measured bacteria concentrations in Australian piggery buildings

were between 0.50 and 1.50 x 10^5 cfu/m^3. Nineteen percent of all measurements were below 0.50 x 10^5 cfu/m^3 and the remaining 19% were above the 1.50 x 10^5 cfu/m^3 cut off point. Because in Australia the maximum recommended concentration is 1.0 x 10^5 cfu/m^3, 41% of all sheds were above that concentration.

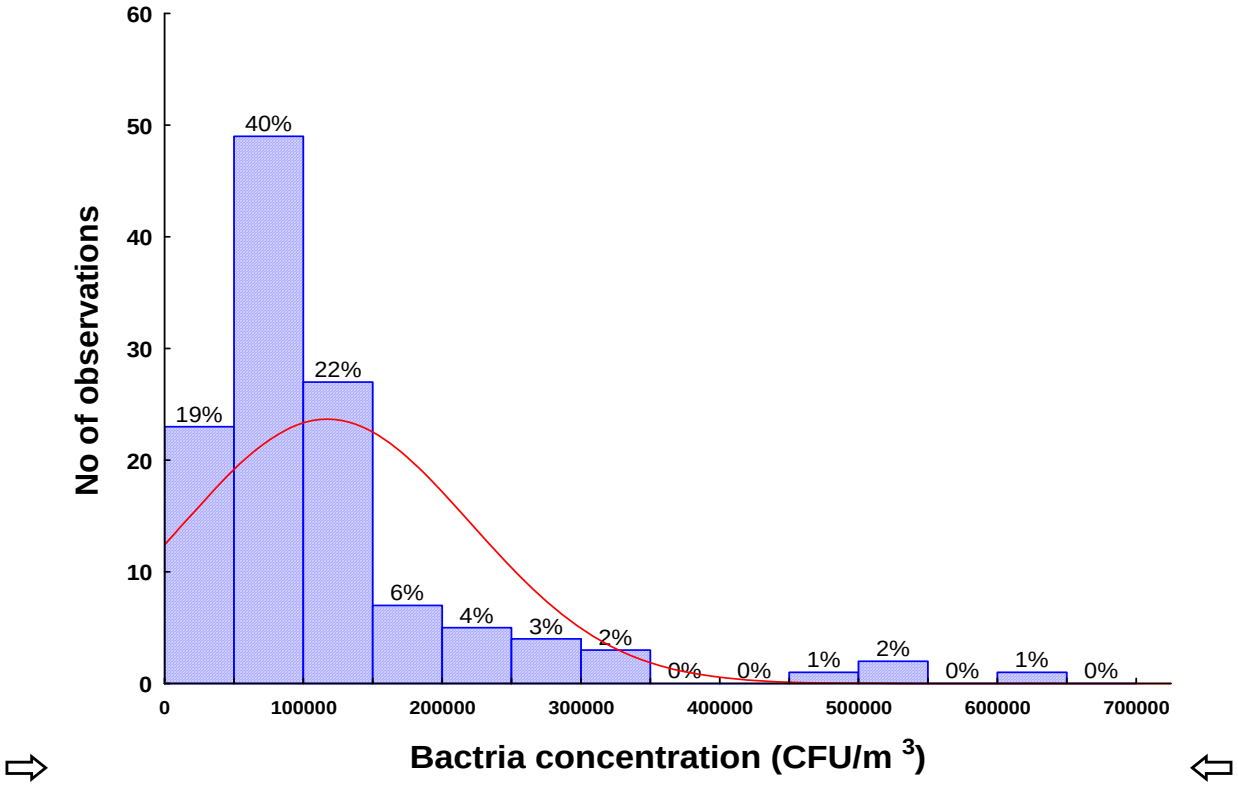

Figure 1. Distribution of airborne viable particle concentrations (cfu/m^3) in Australian piggery buildings

Airborne microorganisms emissions

The mean bacteria emission was 8.2 x 10^7 cfu/ h (500 kg) live weight (Table 2). Emission rates by large followed the order observed in the internal airborne microorganism concentrations between different piggery buildings. Farrowing buildings had very low emission rates with mean emission rate of 2.82 x 10^7 cfu/ h (500 kg) live weight, while straw based shelters had the highest emission rates calculated by far (44.15 x 10^7 cfu/ h/LU). Maximum values for airborne microorganisms emission rates were also compared (Table 2). In straw based shelters, maximum emission rates of airborne microorganisms were approximately fifteen times higher than in farrowing buildings. The mean airborne microorganism emission rates were again very similar in weaner (5.23 x 10^7 cfu/h/LU) and finisher (5.80 x 10^7 cfu/h/LU) buildings. The second lowest mean airborne microorganism emission rates were calculated for buildings housing dry sows (3.83 x 10^7 cfu/h/LU), while on average grower buildings emitted the most airborne microorganisms after straw based shelters (7.61 x 10^7 cfu/h/LU). Emission rates per animal are also presented in Table 2. Straw based shelters again recorded the highest emission rates per pigs. The next highest emission rates per animal were recorded in dry and farrowing sow buildings, while weaner pigs had the lowest value recorded per animal.

Table 2. Bacteria emission values per livestock units (LSU=500 kg live weight) and per animal from different piggery buildings (x 10^7 cfu/h)

Building type	Mean	No of buildings	Minimum	Maximum
Grower (LSU)	7.61	28	1.18	31.29
Finisher (LSU)	5.80	19	1.97	17.82
Straw based shelters (LSU)	44.15	8	2.72	143.32
Dry sow (LSU)	3.83	14	1.10	11.44
Farrowing (LSU)	2.82	18	0.41	8.64
Weaner (LSU)	5.23	22	1.00	15.69
All groups (LSU)	8.22	109	0.41	143.32
Grower (per animal)	0.69	28	0.12	2.4
Finisher (per animal)	0.89	19	0.29	3.46
Straw based shelters (per animal)	5.69	8	0.35	27.23
Dry sow (per animal)	1.27	14	0.39	4.00
Farrowing (per animal)	1.32	18	0.19	4.04
Weaner (per animal)	0.13	22	0.03	0.41
All groups (per animal)	1.16	109	0.03	27.23

Airborne endotoxin concentrations

The concentrations of airborne endotoxins results are summarized in Tables 3. The endotoxin concentrations in straw based shelters were clearly very high, ranging between 10.80 and 238.4 EU/m3. Straw based shelters had the highest endotoxin concentrations, followed by grower and finisher buildings. Endotoxin concentrations of traditional piggery buildings were quite similar. Dry sow and farrowing buildings recorded the lowest means numerically as well as the lowest maximum concentrations.

Table 3. Endotoxin concentrations (EU/m^3) inside the study buildings (Summary table of means)

Building type	Mean	No of buildings	Minimum	Maximum
Grower	32.48	36	6.39	126.88
Finisher	33.71	26	6.08	225.85
Straw based shelters	84.98	10	10.80	238.38
Dry sow	23.30	21	9.15	75.44
Farrowing	25.35	29	9.48	83.24
Weaner	30.60	31	0.00	108.80
All groups	33.13	153	0.00	238.38

The frequency distribution of endotoxin concentrations in different classes of pig houses is shown in Figure 2. Approximately 55%, of the respirable endotoxin samples had concentrations in the range of 0-20 EU/m^3. A bit over 30% of all samples had concentrations between 20 and 60 EU/m^3. The remaining 27% of all samples had concentration above 60 EU/m^3.

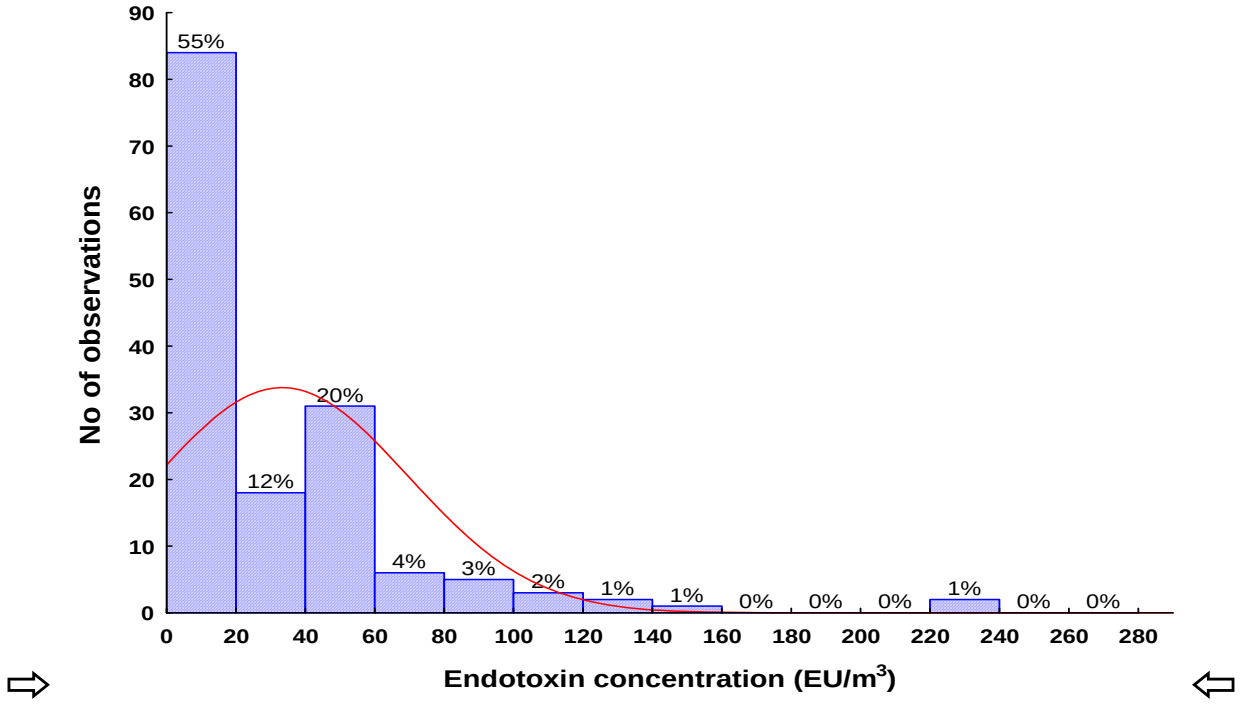

Figure 2. Distribution of endotoxin concentrations (EU/m^3) in Australian piggery buildings

Airborne endotoxin emissions

The mean respirable endotoxin emission rates calculated from different piggery buildings are shown in Table 4. The results are expressed in two different ways, i.e. on an animal and per livestock unit (500 kg live weight) basis. The overall emission rate was 20.15 x 10^3 EU/h (500 kg) live weight and 3.31 x 10^3 EU/h/animals for respirable endotoxins. Buildings with bedding material had the highest endotoxin emissions, while all other buildings had very similar emission levels per EU. Endotoxin emission rates in straw based shelters ranged between 10.30 and 247.06 x 10^3 EU/h. Endotoxin emissions from weaner buildings recorded the second highest levels numerically (19.08 x 10^3 EU/h). Endotoxin emission per animal followed the pattern of the airborne microorganism emissions. Here again straw based shelters had the highest emission levels, followed by dry sow and farrowing buildings.

Table 4. Endotoxin emissions per livestock unit (LSU=500 kg live weight) and per animal from different piggery buildings (x 10^3 EU/h)

Building type	Mean	No of buildings	Minimum	Maximum
Grower (LSU)	16.10	27	0.66	51.42
Finisher (LSU)	15.93	18	3.97	39.17
Straw based shelters (LSU)	77.47	7	10.30	247.06
Dry sow (LSU)	14.04	13	3.17	38.38
Farrowing (LSU)	13.37	17	3.07	40.28
Weaner (LSU)	19.08	20	2.07	59.21
All groups (LSU)	20.15	102	0.66	247.06
Grower (per animal)	1.50	27	0.06	5.66

Finisher (per animal)	2.39	18	0.63	6.11
Straw based shelters (per animal)	11.00	7	1.36	46.94
Dry sow (per animal)	4.72	13	1.11	13.43
Farrowing (per animal)	6.26	17	1.44	18.85
Weaner (per animal)	0.48	20	0.05	1.54
All groups (per animal)	3.31	102	0.05	46.94

Discussions

Overall, the concentration of airborne respirable endotoxin was the highest in straw based shelters. The current "safe" concentration recommendation in Australia for exposure of respirable endotoxin is 50 EU/m^3. The concentrations of endotoxin in straw-based shelters are the greatest concern, since they exceeded recommended levels. Endotoxins are the cell-wall components of Gram -negative bacteria and these compounds are released after the death of the bacteria. In terms of respirable endotoxin levels, Australian piggery buildings generally recorded lower levels that previously published results (Seedorf *et al.*, 1998b). Differences observed in concentration between the published results from Europe and the Australian study might be due to the rate of endotoxin generation within the buildings and/or the clearance by various routes.

The concentrations of airborne microorganisms measured in different traditional piggery buildings are comparable with published results. The relatively low level of airborne microorganism could be related to the fact that in the Southern parts of Australia, where these measurements were taken, the temperatures are high and humidity levels are low and it is generally accepted that hot dry air does not usually sustain a high airborne bacteria populations. The second highest airborne microorganism concentrations were measured in buildings housing grower/finisher pigs. Relatively high concentrations of airborne microorganisms were measured in weaner buildings, however this was not surprising. Weaner sheds are usually kept warm all year around and ventilation levels in these buildings are typically low. Weaner pigs also tend to be fairly active, creating turbulences and therefore high dust concentrations in buildings housing them. It is generally accepted that airborne particles tend to act as carriers for different microorganisms; therefore the high particle concentrations in the air create more opportunities for microorganisms to remain airborne as well.

The current recommendations for acceptable airborne microorganisms concentrations in livestock buildings is $1x10^5$ in Australia (Banhazi *et al.*, 2008b). This recommendation is not enforced by legislation, but is recommended by most housing experts in Australia. From the results of the research presented, it can be concluded that the average viable microorganism concentrations measured in various piggery buildings in Australia is acceptable approximately in 60% of the buildings, while approximately 40% of the buildings (including all straw based shelters) recorded concentrations above the maximum recommended level.

Potentially affects of high endotoxin and bacteria emissions from piggery buildings on the rural environment need to be considered. The per animal emissions were very high for farrowing and dry sow sheds, because in these sheds are relatively small number of animals are housed, compared to weaner, grower or finisher buildings. Therefore when the overall emission is divided the relatively small number of animals the resulting figure is relatively large. On the other hand, in weaner buildings the emission per animal is always relatively small, due to the large number of weaner pigs in these buildings. However, it does not necessarily mean that the

overall emission is in any way smaller indeed when livestock units are compared, it can be seen that weaner sheds actually do contribute significantly to the overall emission rates.

Conclusions

Samples of dust from livestock buildings were analyzed for endotoxin content and an Anderson sampler was used to monitor the concentration of airborne bacteria in piggery houses. Straw based shelters showed the highest concentrations of airborne endotoxin with average values of 84.98 EU/m^3 for the inhalable fraction. The highest emission rates of airborne microbes (per LSU) were also observed in straw based shelters in contrast to farrowing buildings which had the lowest emission rates. The lowest concentration of total bacteria was measured in farrowing buildings, which also showed the lowest emission rates for total bacteria. Low bacteria concentrations were observed inside approximately 60% of Australian piggery buildings. Given the concentrations, it is unlikely that bacteria in isolation are affecting the health of stock or personnel working in piggery buildings in Australia. The emission rates calculated in the study sheds were also highly varied, indicating the need to carefully interpret and use these figures in the future to predict emission rates from various types of piggery buildings.

Acknowledgments

This study was part of a larger project funded by the Australian Pork Limited. It was also a collaborative effort between the South Australian Research and Development Institute (SARDI), Agriculture Western Australia, The Queensland based PigUnit and Agriculture Victoria and involved the contribution of many people. We wish to particularly acknowledge the contribution of pig producers involved in the study, Dr Colin Cargill for his professional advice and the assistance of all technicians involved in the study.

References

Banhazi T.M., Rutley D.L. and Pitchford W.S. (2008a) Identification of risk factors for sub-optimal housing conditions in Australian piggeries - Part IV: Emission factors and study recommendations. Journal of Agricultural Safety and Health 14:53-69.

Banhazi T.M., Seedorf J., Rutley D.L. and Pitchford W.S. (2008b) Identification of risk factors for sub-optimal housing conditions in Australian piggeries - Part I: Study justification and design. Journal of Agricultural Safety and Health 14:5-20.

Banhazi T.M., Seedorf J., Rutley D.L. and Pitchford W.S. (2008c) Identification of risk factors for sub-optimal housing conditions in Australian piggeries - Part II: Airborne pollutants. Journal of Agricultural Safety and Health 14:21-39.

Banhazi T.M., Seedorf J., Rutley D.L. and Pitchford W.S. (2008d) Identification of risk factors for sub-optimal housing conditions in Australian piggeries - Part III: Environmental parameters. Journal of Agricultural Safety and Health 14:41-52.

Banhazi T.M., Currie E., Reed S., Lee I.-B. and Aarnink A.J.A. (2009) Controlling the concentrations of airborne pollutants in piggery buildings, in: A. Aland and F. Madec (Eds.), Sustainable animal production: The challenges and potential developments for professional farming, Wageningen Academic Publishers, Wageningen, The Netherlands. pp. 285-311.

Banhazi T.M., Rutley D.L. and Pitchford W.S. (2010) Validation and fine-tuning of a predictive model for air quality in livestock buildings. Biosystems Engineering 105:395-401.

Crook B., Robertson J.F., Glass S.A., Botheroyd E.M., Lacey J. and Topping M.D. (1991) Airborne dust, ammonia, microorganisms, and antigens in pig confinement houses and the respiratory health of exposed farm workers. American Industrial Hygiene Association Journal 52:271-279.

Curtis S.E., Anderson C.R., Simon J., Jensen A.H., Day D.L. and Kelley K.W. (1975) Effects of aerial ammonia, hydrogen sulfide and swine-house dust on rate of gain and respiratory-tract structure in swine. Journal of Animal Science 41:735-739.

Donham K.J., Haglind P., Peterson Y., Rylander R. and Belin L. (1989) Environmental and health studies of farm workers in Swedish swine confinement buildings. British Journal of Industrial Medicine 46:31-37.

Seedorf J., Hartung J., Schroder M., Linkert K.H., Pedersen S., Takai H., Johnsen J.O., Metz J.H.M., Groot Koerkamp P.W.G., Uenk G.H., Phillips V.R., Holden M.R., Sneath R.W., Short J.L., White R.P. and Wathes C.M. (1998a) A Survey of Ventilation Rates in Livestock Buildings in Northern Europe. Journal of Agricultural Engineering Research 70:39-47.

Seedorf J., Hartung J., Schroder M., Linkert K.H., Phillips V.R., Holden M.R., Sneath R.W., Short J.L., White R.P., Pedersen S., Takai H., Johnsen J.O., Metz J.H.M., Groot Koerkamp P.W.G., Uenk G.H. and Wathes C.M. (1998b) Concentrations and Emissions of Airborne Endotoxins and Microorganisms in Livestock Buildings in Northern Europe. Journal of Agricultural Engineering Research 70:97-109.

Urbain B., Mast J., Beerens D., N'Guyen T.Q., Goddeeris B., Ansay M. and Gustin P. (1999) Effects of inhalation of dust and endotoxin on respiratory tracts of pigs. American Journal of Veterinary Research 60:1055-1060.

Wathes C.M., Phillips V.R., Holden M.R., Sneath R.W., Short J.L., White R.P., Hartung J., Seedorf J., Schroder M., Linkert K.H., Pedersen S., Takai H., Johnsen J.O., Groot Koerkamp P.W.G., Uenk G.H., Metz J.H.M., Hinz T., Caspary V. and Linke S. (1998) Emission of Aerial Pollutants in Livestock Buildings in Northern Europe: Overview of a Multinational Project. Journal of Agricultural Engineering Research 70:3-9.