한 국 축 산 식 품 학 회 지
Korean J. Food Sci. Ani. Resour.
Vol. 28, No. 5, pp. 623~628(2008)

Evaluation of Environmental Circumstance Within Swine and Chicken Houses in South Korea for the Production of Safe and Hygienic Animal Food Products

Young-Hwan Kim, Hyung-Joo Suh[1], Jin-Man Kim[2], Yeon-Hoon Jung[3], and Kyong-Whan Moon*
Department of Environmental Health, Korea University, Seoul 136-703, Korea
[1]Department of Food and Nutrition, Korea University, Seoul 136-703, Korea
[2]Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea
[3]Department of Atmospheric Chemistry, Gyonggi-do Institute of Health and Environment, Uijeongbu 480-764, Korea

일부지역 양돈장 및 양계장 공기중 박테리아, 진균, 내독소 농도

김영환 · 서형주[1] · 김진만[2] · 정연훈[3] · 문경환*
고려대학교 보건과학대학 환경보건학과, [1]고려대학교 보건과학대학 식품영영학과
[2]건국대학교 축산식품생물공학과, [3]경기도 보건환경연구원

Abstract

This study was undertaken to determine the concentrations of airborne bacteria, fungi, particles, and endotoxin in swine and chicken houses. Six swine buildings and seven chicken houses were randomly selected in southern Gyonggi Province, South Korea. The geometric mean concentrations of airborne bacteria in swine and chicken houses were 2.7×10^5 CFU/m^3 and 5.6×10^7 CFU/m^3, respectively. The airborne bacteria concentrations in chicken houses were significantly higher than those of swine houses ($p<0.05$). The geometric mean concentration of airborne fungi in swine houses was 4.9×10^3 CFU/m^3, which was higher than the value of 2.1×10^3 CFU/m^3 found in chicken houses. The mean concentrations of airborne particles and endotoxin in swine houses were 3.48 mg/m^3 and 943.1 EU/m^3, and they were 15.43 mg/m^3 and 1,430.5 EU/m^3 in chicken houses, respectively. A significant difference between swine and chicken houses was found for total dust ($p<0.05$), but not for endotoxin. In this study, the concentrations of endotoxin in both swine and chicken houses as well as particles in chicken houses were high, and in about 50% of the samples exceeded the worker health safety levels of 614 EU/m^3 suggested in previous studies. These results may indicate a considerable respiratory hazard for workers in these environments.

Key words : swine house, chicken house, airborne bacteria, fungi, particle, endotoxin

Introduction

Agricultural work, particularly livestock farming, is considered to be a notable risk factor for respiratory disease (Rudolf *et al.*, 2007; Rylander and Carvalheiro, 2006). The air in livestock farms is contaminated with large amounts of biological agents, including allergens of plant and animal origin, bacteria, moulds, and microbial products such as endotoxin (Pomorska *et al.*, 2007). A number of studies have indicated that indoor levels of airborne bacteria or endotoxin are associated with respiratory diseases (Michel, 1996; Ross *et al.*, 2000; Zuckeri *et al.*, 2000). In a study conducted in Europe, 24% of poultry farmers had work-related symptoms, such as wheezing, breathlessness and cough, and lower lung function (Radon *et al.*, 2002). In other studies, it was shown that swine confinement workers had a high prevalence of airway symptoms and an increased number of inflammatory cells (Larsson *et al.*, 1997; Wang *et al.*, 1998).

According to statistic data, there are 8,000 commercial swine farms raising over 1,000 pigs each and 3,761 chicken feeding farms with more than 3,000 chickens each in South Korea. It has been estimated that about 200,000 people work at these farms (www.krei.re.kr). However, most of the swine

*Corresponding author : Kyong-Whan Moon, Department of Environmental Health, Korea University, Seoul 136-703, Korea. Tel: 82-2-940-2865, Fax: 82-2-943-5304, E-mail: kwmoon@korea.ac.kr

and chicken facilities in densely stocked confinement facilities in Korea are operated under poor environmental conditions. In these densely populated and enclosed facilities, microorganisms originating from fecal matter or feeding materials accumulate if not controlled and are easily aerosolized. Aerosolized contaminants may contain bacteria, fungi, viruses, and toxins, and these may affect employee's health (Venter *et al.*, 2004). However, to our knowledge, little exposure assessment regarding the levels of aerosolized contaminants in such facilities has been conducted in South Korea. Therefore, this study was performed to obtain data in relation to bacteria, fungi, and toxins present in swine and chicken houses. These results were then compared to the published data for enclosed swine and chicken facilities.

Materials and Methods

Sampling

Six swine houses and seven chicken houses were randomly selected in southern Gyonggi Province, South Korea. All houses are passively ventilated through open doors and windows. Sampling was performed from July to August 2008. The samples were taken at the central walkway in each of the selected houses at the height of 1.5 m during day-to-day routine activities.

Total bacteria and fungi sampling

Total airborne bacteria and fungi were collected with an microbial air sampler (MAS-100, Merk, MBV AG, Switzerland) at a flow rate of 100 L/min. Air volumes of 20 L were sampled for total airborne bacteria; 100 L for fungi. Airborne bacteria were impacted onto trypticase soy agar with cyclohexamide (0.1 g/L) and fungi were impacted onto dichloran glycerol 18 agar with chloramphenicol (0.1 g/L). Plates for airborne bacteria and fungi were incubated at 35°C and 25°C, respectively. Results are expressed in colony forming units (CFU).

Total airborne particles

Total airborne particles were collected onto polycarbonate filters (37 mm diameter, 0.4 μm pore size) placed in a ready to use polystylene cassette. Air was continuously sampled for 2 hr by means of a personal pump (SKC Inc, USA) set at a flow rate of 2.0 L/min. After sampling, the cassette was stored in a cold box and transported to the laboratory.

Endotoxin

Endotoxin analysis was performed on the total particle samples collected using the filters. The filters were extracted by rapid shaking with 10 mL pyrogen-free water (Endosafe, 99732034, USA) for 2 hr. The extracts were centrifuged at 1,000×g and the supernatants were diluted 1:100 and 1:1000. An aliquot of 100 μL was added to a microtitre plate (BD Falcon™, BD Biosciences, USA) and assayed using a quantitative kinetic chromogenic *Limulus* amoebocyte lysate method at 37°C with an automated reader (Sunrise, Austria). *Escherichia coli* O55:B5 endotoxin (Endosafe, EX41892, USA) was used as a standard. Data from the samples were compared with the standard curve, which ranged from 0.05 to 50 EU/mL. Levels for airborne endotoxin were expressed as EU/m^3.

Statistical methods

The concentrations of bacteria and fungi were distributed log-normally; therefore, geometric mean (GM) values and geometric standard deviation (GSD) were used. The levels of total dust and endotoxin were presented as arithmetic mean and standard deviation since data were normally distributed. The data were analyzed using the Mann-Whitney test for determining the differences between swine and chicken houses and using the Spearman's test for determining a correlation between the contaminants. All statistical analyses were performed using the Statistical Package for the Social Sciences® (SPSS) version 13.0 software for Windows (SPSS Inc., USA).

Results and Discussion

Table 1 shows the geometric mean concentration and range of total airborne bacteria and fungi in six swine houses and seven chicken houses. The concentrations of total airborne bacteria ranged from 5.3×10^4 to 1.1×10^6 CFU/m^3 in swine houses and from 2.5×10^5 to 5.4×10^8 CFU/m^3 in chicken houses. Overall GM concentrations in swine and chicken houses were 2.7×10^5 CFU/m^3 and 5.6×10^7 CFU/m^3, respectively. The airborne bacteria concentration in chicken houses was significantly higher than in swine houses ($p<0.05$). On the other hand, the GM concentration of airborne fungi in swine houses was 4.9×10^3 CFU/m^3, which was about 2-fold higher than the value of 2.1×10^3 CFU/m^3 in chicken houses. However, no significant differences could be shown for the concentrations of fungi between in swine and chicken houses.

The results of airborne particle and endotoxin concentration determinations are shown in Table 2. The mean concentration of airborne particles in swine houses was 3.48 mg/m^3 and 15.43 mg/m^3 in chicken houses, indicating an approximate 4-fold higher concentration in chicken houses than in swine houses. Mean concentrations of airborne endotoxin in swine and chicken houses were 943.1 and 1,430.5 EU/m^3, respectively, and the concentration range in swine houses was 464.4 to 1,573.3 EU/m^3 compared to 376.2 to 2,509.5 EU/m^3 in chicken houses. A significant difference between swine and chicken houses was found for total dust ($p<0.05$) but not for endotoxin.

Table 3 shows the Spearman rank correlation of different contaminants in swine and chicken houses. A strong correlation was observed between bacteria and endotoxin levels in chicken houses.

Several studies have suggested that persons working in livestock houses have a higher prevalence of airway inflammation and chronic bronchitis compared to workers engaged in other employment. Larsson *et al.* and Wang *et al.* have reported that the cell concentrations of interleukin 8 (IL-8) and IL-6, which were released in the upper and lower airways, increased more than 12-fold, and the concentration of neutrophils in nasal lavage and bronchoalveolar lavage fluid increased 19-fold following inhalation of large amount of contaminants from swine buildings (Larsson *et al.*, 1997; Wang *et al.*, 1998). Rylander *et al.* demonstrated that poultry workers had a higher prevalence of toxic pneumonitis, airway inflammation, and chronic bronchitis compared to individuals who did not work in these facilities (Rylander and

Table 1. Airborne concentrations of bacteria and fungi in swine and chicken houses

	Swine house (n=6)			Chicken house (n=7)			*p*-value
	GM[1)]	GSD[2)]	Range	GM	GSD	Range	
Total bacteria (CFU/m^3)	2.7×10^5	6.0	5.3×10^4-1.1×10^6	5.6×10^7	6.4	2.5×10^5-5.4×10^8	0.041
Total Fungi (CFU/m^3)	4.9×10^3	2.8	1.2×10-2.5×10^4	2.1×10^3	2.6	6.8×10^2-1.0×10^5	0.223

1) GM : geometric mean
2) GSD : geometric standard deviation

Table 2. Airborne total particles and endotoxin concentrations in swine and chicken houses

	Swine house (n=6)			Chicken house (n=7)			*p*-value
	Mean	SD	Range	Mean	SD	Range	
Particle (mg/m^3)	3.48	2.22	0.94- 6.41	15.43	5.61	6.41- 31.50	0.035
Endotoxin (EU/m^3)	943.1	403.7	464.4-1,573.3	1,430.5	982.9	376.2-2,509.5	0.435

Table 3. Spearman rank correlation of different contaminants in swine and chicken houses

	Swine house				Chicken house			
	Bacteria	Fungi	particle	Endotoxin	Bacteria	Fungi	particle	Endotoxin
Bacteria	1.000				1.000			
Fungi	0.400	1.000			0.214	1.000		
Particle	-0.131	0.700	1.000		-0.571	-0.393	1.000	
Endotoxin	0.700	0.500	0.600	1.000	0.857*	0.393	-0.571	1.000

* $p<0.05$

Table 4. Levels of contaminants found in other studies

House	Total bacteria (10^5 CFU/m^3)	Fungi (10^3 CFU/m^3)	Endotoxin* (ng/m^3 or EU/m^3)	Airborne particle (mg/m^3)	Reference
Swine	1.51-5.44			1.6-8.8	Cormier *et al.*, 1990
	4	20	180-240 ng/m^3	4.3-6.8	Donham *et al.*, 1989
	5.9		20-1,900 ng/m^3	4.9	Haglind *et al.*, 1987
	1.077		130 ng/m^3	4.0	Heederik *et al.*, 1991
	9.306			5.2-9.4	Mackiewicz., 1998
	1.3	1.38		0.53-4.37	Kim *et al.*, 2007
			45-707 EU/m^3	0.33-2.46	Yoo *et al.*, 2003
	2.7	4.9	464-1,537 EU/m^3	0.94-6.41	This study
Chicken			20.6-26.8 ng/m^3	21.3	Golbabaei *et al.*, 2000
			634-918 ng/m^3	0.72-1.13	Olenchock *et al.*, 1982
	560	2.1	1,430 EU/m^3	15.4	This study

* endotoxin 1 EU=0.2 ng/m^3

Carvalheiro, 2006). It is not clear which agents or mixtures are responsible for the symptoms. Recently bioaerosols, which contain bacteria, fungi and endotoxins, have emerged as important agents in causing adverse respiratory health effects in swine and chicken feeding operation workers (Dana Cole., 2000).

Table 4 lists the levels of particles and bioaerosols found in other manuscripts. The levels of total airborne bacteria and fungi found in this study were higher than the levels reported by Heederik *et al.* and Kim *et al.*, but lower than the results presented by Donham *et al.*, Haglind *et al.*, and Mackiewicz. Airborne particle concentrations in this study were similar to or relatively lower compared to those found other studies. However, the concentrations of endotoxin in this study were found to be slightly higher than other reports.

There are no health guidelines for airborne microorganisms and endotoxin in South Korea or other countries. However, in a study performed in the United States, Donham *et al.* suggest that concentrations of 6.3×10^5 CFU/m^3 for bacteria and 1.3×10^4 CFU/m^3 for fungi can be related to the presence of respiratory symptoms in workers (Donham *et al.*, 1989). In our study, airborne bacteria and fungi concentrations, which were detected at mean values to 2.7×10^5 CFU/m^3 and 2.1×10^3 CFU/m^3, respectively, were less than the values suggested by Donham *et al.* On the other hand, several studies suggest that there is no adverse health effects at endotoxin levels of 614, 850, and 900 EU/m^3 (Donham *et al.*, 1989; Donham *et al.*, 1995; Haglind and Rylander, 1984). In this study, the concentrations of endotoxin in swine and in chicken houses were 1,314.3 and 1,476.8 EU/m^3, respectively, which exceeded these suggested levels. Endotoxin is potentially toxic, natural compound found inside pathogens such as bacteria. Endotoxin is not secreted in soluble form by live bacteria, but it is a structural component of the bacteria that is released when bacteria are lysed. The prototypical endotoxin is lipopolysaccharide (LPS), found in the outer membrane of various gram-negative bacteria (Chang *et al.*, 2001 and Clark *et al.*, 1983). Endotoxins have high biological potency and a relationship between acute symptoms among workers in swine houses and high concentrations of airborne endotoxin have been shown (Cole *et al.*, 2000; Donham *et al.*, 1989). Species of airborne bacteria were not identified in this study; however, the airborne bacteria typically include 68-96% gram-positive bacteria and 7-53% gram-negative bacteria (Heederik *et al.*, 1991). Endotoxin can be found abundantly in airborne dust that contains feces and plant materials of fodder origin, especially when contaminated with gram-negative bacteria. Although chicken and swine workers are exposed to a mixture of contaminants in their work environment, endotoxin is thought to be most important of these because of its adverse health effects (Kirychuk *et al.*, 2006). Higher endotoxin levels are often found together with increased particle levels. The dust is heterogeneous, containing feed grains, fecal materials, animal skin and hair, insects, and dead microorganisms. Research by a number of investigators has shown that high levels of dust increases the risk for respiratory disease (Donham *et al.*, 1995 and Zejda *et al.*, 1994). Airborne particle levels in swine houses were commonly in the 0.94 to 6.41 mg/m^3 range. These values did not exceed the ACGIH (American Conference of Governmental Industrial hygienists) TLV-TWA (Threshold Limit Values-Time Weight Average) level for organic dust of 10 mg/m^3 and OSHA (Occupational Safety and Health Administration) level of 15 mg/m^3. Whereas, the mean concentration of airborne particles increased drastically in chicken houses and exceeded these recommended threshold levels. Generally, in chicken feeding facilities, large amount of particles are emitted into the air because of shedding feathers barbules, refuse, and food.

The study presented here has found significantly higher endotoxin levels both in swine and chicken houses as well as high airborne particle levels in chicken houses. This study did not investigate the health effects for persons working in swine and chicken houses; however, the high levels of airborne dust and endotoxin implied the probability of health hazards for workers in some of the investigated swine and chicken houses.

There are several limitations to this study. The first of which is sample size. It is acknowledged that a small sample size results in a lower statistical power and increased uncertainty. Second, environmental data collections included only total particles and not respirable particles. Respirable particles, with a diameter of 2.5-10 μm, reach deep into the gas exchange region of the lungs. Therefore, further research is needed to acquire a better understanding of respiratory disorders among swine and chicken producers compared to non-farm workers.

Conclusion

Swine and chicken feeding house workers commonly develop acute respiratory symptoms. These problems have a considerable negative effect on the health of the workers and their ability to remain employed in this industry. The swine and chicken facility environment is characterized by the presence of multiple factors that can cause respiratory tract inflammation as well as systemic symptoms. Features of this environment that appear to cause symptoms in workers include airborne bacteria, fungi, particles, and endotoxin. In this study, the concentrations of endotoxin both in swine and chicken houses and particles in chicken houses were high, and in around 50% of the samples they exceeded the worker health safety levels suggested by some investigators. These results indicate that these environments may present a respiratory hazard to workers. Thus, prevention measures aimed at lowering the concentrations of endotoxin and particles in swine and chicken facilities are highly desirable.

Acknowledgement

This study was financially supported by Korea University.

References

1. Adel, A. A., Hameed., Shakour, A. A., and Yasser, H. I. (2003) Evaluation of bio-aerosols at an animal feed manufacturing industry. *Aerobiologia* **19**, 89-95.
2. Chang, C. W., Chung, H., Huang, C. F., and Su, H. J. J. (2001) Exposure of workers to airborne microorganisms in open-air swine houses. *Appl. Environ. Microbiol.* **67**, 155-161.
3. Clark, S., Rylander, R., and Larsson, L. (1983) Airborne bacteria, endotoxin and fungi in dust in poultry and swine confinement buildings. Am. *Ind. Hyg. Assoc. J.* **44**, 537-541.
4. Cole, D., Todd, L., and Wing, S. (2000) Concentrated swine feeding operations and public health : A review of occupational and community health effects. *Environ. Health Persp.* **108**, 685-699.
5. Cormier, Y., Tremblay, G., Meriaux, A., Brochu, G., and Lavoie, J. (1990) Airborne microbial contents in two types of swine confinement buildings in Quebec. *Am. Ind. Hyg. Assoc. J.* **51**, 304-309.
6. Cormier, Y., Tremblay, G., Meriaux, A., Brochu, G., and Lavoie, J. (2000) Airborne microbial contents in two types of swine confinement buildings in Quebec. *Am. Ind. Hyg. Assoc. J.* **51**, 304-309.
7. Donham, K., Haglind, P., Peterson, Y., Rylander, R., and Belin, L. (1989) Environmental and health studies of farm workers in Swedish swine confinement buildings. *Br. J. Ind. Med.* **46**, 31-37.
8. Donham, K., Reynolds, S., Whitten, P., Merchant, J., Burmeister, L., and Popendorf, W. (1995) Respiratory dysfunction in swine production facility workers : dose-response relationships of environmental exposure and pulmonary function. *Am. J. Ind. Med.* **27**, 405-418.
9. Donham, K. J., Reynolds, S. J., and Whitten, P. (1995) Respiratory dysfunction in swine production facility workers : dose-response relationships of environmental exposures and pulmonary function. *Am. Ind. Hyg. Assoc. J.* **27**, 405-418.
10. Dosman, J. A., Graham, B. L., Hall, D., Pahwa, P., McDuffie, H. H., Lucewicz, M., and To, T. (1988). Respiratory symptoms and alterations in pulmonary function tests in swine producers in Saskatchewan: Results of a survey of farmers. *J. Occp. Med.* **30**, 715-720.
11. Golbabaei, F. and Islami, F. (2000) Evaluation of workers' exposure to dust, ammonia and endotoxin in poultry industries at the province of Isfahan, Iran. *Ind. Health* **38**, 41-46.
12. Hagland, P. and Rylander., R. (1984) Exposure to cotton dust in an experimental cardroom. *Br. J. Ind. Med.* **41**, 340-345.
13. Haglind, P. and Rylander, R. (1987) Occupational exposure and lung function measurements among workers in swine confinement buildings. *J. Occp. Med.* **29**, 904-907.
14. Heederik, D., Brouwer, R., Biersteker, K., and Boleij, JSM. (1991) Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers. *Int. Arch. Occup. Environ. Health* **62**, 595-601.
15. Kim, K. Y., Ko, H. J., Kim, H. T., Kim, Y. S., Roh, Y. M., Lee, C. M., and Kim, C. N. (2007) Monitoring of aerial pollutants emitted from swine houses in Korea. *Environ. Monit. Access* **133**, 255-266.
16. Kirychuk, S. P., Dosman, J. A., Reynolds, S. J., Willson, P., Senthilselvan, A., Feddes, J. J. R., Classen, H. L., and Guenter, W. (2006) Total dust and endotoxin in poultry operations : Comparison between cage and floor housing and respiratory effects in workers. *J. Occup. Environ. Med.* **48**, 741-748.
17. Larsson, B.-M., Palmberg, L., Malmberg, P. O., and Larsson, K. (1997) Effects of exposure to swine dust on levels of IL-8 in airway lavage fluid, *Thorax* **52**, 638-642.
18. Mackiewicz, B. (1998) Study on exposure of pig farm workers to bioaerosols, immunologic reactivity and health effects. *Ann. Agric. Environ. Med.* **5**, 169-175.
19. Michel, O., Kips, J., and Duchateau, J. (1996) Severity of asthma is related to endotoxin in house dust. *Am. J. Respir. Crit. Care Med.* **154**, 1641-1646.
20. Olenchock, S. A., Lenhart, S. W., and Mull., L. (1982) Occupational exposure to airborne endotoxins during poultry processing. *J. Toxicol. Environ. Health* **9**, 339-349.
21. Pomorska, D., Larsson, L., Skorska, C., Sitkowska, L., and Dutkiewicz, J. (2007) Levels of bacterial endotoxin in air of animal houses determined with the use of gas chromatography-mass spectrometry and *Limulus* test. *Ann. Agric. Environ. Med.* **14**, 291-298.
22. Radon, K., Monso, E., and Weber, C. (2002) Prevalence and risk factors for airway diseases in farmers-summary of results of European farmers` project. *Ann. Agric. Environ. Med.* **9**, 207-213.
23. Ross, M. A., Curtis, L., Scheff, P. A., Hryhorczuk, D. O., Ramakrishna, V., Wadden, R. A., and Persky, V. W. (2000) Association of asthma symptoms and severity with indoor bioaerosols. *Allergy* **55**, 705-711.
24. Rudolf, S., Antje, H., Ulrich, E., Friedhelm, S., Robert, E., Stefan, N., and Dennis, N. (2007) Endotoxin concentration in modern animal houses in Southern Bavaria. *Ann. Agric. Environ. Med.* **14**, 129-136.
25. Rylander, R. and Carvalheiro, M. F. (2006) Airways inflammation among workers in poultry houses. *Int. Arch. Occuo.*

Environ. Health **79**, 487-490.
26. Venter, P., Lues, J. F. R., and Theron, H. (2004) Quantification of bioaerosols in automated chicken egg production plants. *Poult. Sci.* **83**, 1226-1231.
27. Wang, Z., Manninen, A., Malmberg, P., and Larsson, K. (1998) Inhalation of swine-house dust increases the concentrations of interleukin-1 beta (IL-1β) and interleukin-1 receptor antagonist (IL-1rα) in peripheral blood. *Resp. Med.* **92**, 1022-1027.
28. Zejda., JE., Barber, E., and Dosman, J. (1994) Respiratory health status in swine producers relates to endotoxin exposure in the presence of low dust levels. *JOM* **36**, 49-56.
29. Zuckeri, B. A., Trojan, S., and Muller, W. (2000) Airborne Gram-Negative Bacterial Flora in Animal Houses. *J. Vet. Med.* **B 47**, 37-46.

(2008.10.29 접수/2008.11.26 수정/2008.11.26 채택)