



Seasonal trends in emission of odorous gases from growing-finishing swine houses

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Received: 1 October 2018; Accepted: 4 April 2019

ABSTRACT

The air quality in swine houses has caught attention of scientists and general public. The swine waste generates various odorous gases, which affects the health of farm workers and local residents. In this study, we investigated the composition and concentrations of three major groups (i.e. acidic, sulfuric and phenolic) of odorous gases in growing and fattening swine houses during winter and summer, and studied their relationship with aerial parameters (i.e. temperature and relative humidity). Among 10 different odorous gases measured, acetic acid was the most abundant odorous gas across both seasons. Except iso-valeric acid, dimethyl sulfide and dimethyl disulfide, the concentrations of other odorous gases varied significantly between winter and summer. The concentrations of these odorous gases were significantly higher in winter, except for *p*-cresol, which was significantly higher in summer. The aerial temperature showed significant positive correlations with concentrations of most of the acidic and sulfuric groups odorous gases, whereas, relative humidity was negatively correlated with concentrations of relatively fewer members of acidic and sulfuric groups odorous gases. The relationships studied here could be useful in regulating the emission of odorous gases from growing and fattening swine houses.

Key words: Air quality, Odorous gases, Season, Swine houses

Modern swine houses are designed to house as many swines as possible in a limited space with controlled aerial parameters. The swine excretions and residuals of feed, which are accumulated within the swine houses, emit various odorous gases (Radon *et al.* 2002, Guffanti *et al.* 2018, Ni *et al.* 2018). Prolonged exposure to these odorous gases can cause adverse health effects such as conjunctive irritation, nose and throat discomfort, headache, allergic skin reaction, nausea, emesis, epistaxis, fatigue, and dizziness in farm workers and local residents (Douglas *et al.* 2018, Ganpat *et al.* 2019).

A diverse group of odorous gases are known to be emitted from swine houses (Hartung and Phillips 1994, Schiffman *et al.* 2001, Yao *et al.* 2011). Hartung and Phillips (1994) reported that there are about 130 gases found in livestock buildings. Schiffman *et al.* (2001) classified 331 volatile organic compounds (VOCs) emitted from swine facilities including many acids, alcohols, aldehydes, amides, amines, aromatics, esters, ethers, fixed gases, halogenated hydrocarbons, hydrocarbons, ketones, nitriles, phenols, other sulfur- and nitrogen-containing compounds, and steroids. Yao *et al.* (2011) studied the key VOCs emitted in nursery swine house, and found various dominant VOCs

including acidic (acetic acid, propionic acid, butyric acid, iso-butyric acid, valeric acid and iso-valeric acid), sulfuric (mercaptans methanol, dimethyl sulphide (DMS), dimethyl disulphide (DMDS)), and phenolic (*p*-cresol) groups. Yao *et al.* (2011) showed that air temperature negatively influenced the emission of these compounds, while examining the seasonal trends of ammonia, DMS and DMDS in nursery swine houses. However, most of these studies were focused on nursery stage of swine, and the emission of odorous gases in growing and fattening swine houses is still poorly understood. Thus, there is a need to systematically study the odorous gases emitted from growing and fattening swine houses.

The objective of this study was to investigate the seasonal (winter and summer) trends in emission of odorous gases from growing and fattening swine houses besides examining the relationship between odorous gases and aerial parameters (temperature and relative humidity).

MATERIALS AND METHODS

Experimental design: This study was conducted in 6 different growing and fattening swine houses, located in different provinces of South Korea in two seasons (winter and summer). All swine houses were of similar capacity (ranged from 300 to 400 head) and dimension. Average swine age and body weight were 9–12 weeks old and 60 to 85 kg, respectively. The average stocking density was 1.02 m²/head. Floors of the swine houses were fully slatted and installed with pit manure collection systems. The manure

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storage period inside the pit was about three to four months. Walls of the swine houses were made of brick with Styrofoam on the outer sides for insulation.

Sampling strategies: In swine house, the aerial parameters and odorous gases were measured at three points in the aisle outside the pens at the height of one meter above the floor (Fig. 1). All the collections were done in afternoon after feeding, when swine's were relaxed during both seasons. Also, to eliminate the limitations imposed by climate and to ensure the safety of equipment, all the samples were collected only on sunny days. A total of 18 samples were collected for each parameter from six swine houses in one season.

Measurement of aerial parameters and odorous gases: Air temperature and relative humidity were measured with digital thermohygrometer (SK-110TRH, SATO, Tokyo, Japan). Before taking measurements the equipment was calibrated.

For odorous gases, air was sampled for 5 m into a one liter Tedlar bag (SKC Inc., Eighty-four, PA, USA) connected with a polypropylene septum fitting to an air sampler (Gilian, Clearwater, FL, USA) (flow rate = 1.0 L/min). The Tedlar bags were transported to the laboratory immediately after sampling. The air samples were analyzed using solid-

phase micro extraction (SPME) fibres (Supelco, Bellefonte, PA, USA); the fibre type used was 75 μ m carboxen/polydimethylsiloxane (CAR/PDMS). After extraction, the SPME fibres were inserted into the injection port of the gas chromatograph-mass spectrometer (GCMS) (Agilent GC6890N/5975C MS, Youngin, Korea) to quantify the odorous gases. Details of GCMS analysis protocol was taken from Yao *et al.* (2011). The concentrations of odorous gases were calculated in parts per billion (ppb). In this study, 10 different types of VOCs were measured, including acetic acid, propionic acid, butyric acid, iso-butyric acid, valeric acid, iso-valeric acid, p-cresol, methyl mercaptan, DMS, and DMDS.

Statistical analyses: The statistical analyses were performed in SPSS software (SPSS Inc., Chicago, IL). Comparisons of each variable across both seasons were first performed using a standard t-test at a 5% significance level. Pearson correlation coefficients were calculated to show the relationship between aerial parameters and concentrations of odorous gases.

RESULTS AND DISCUSSION

Composition of odorous gases in swine houses: Among the 10 different odorous gases measured in swine houses

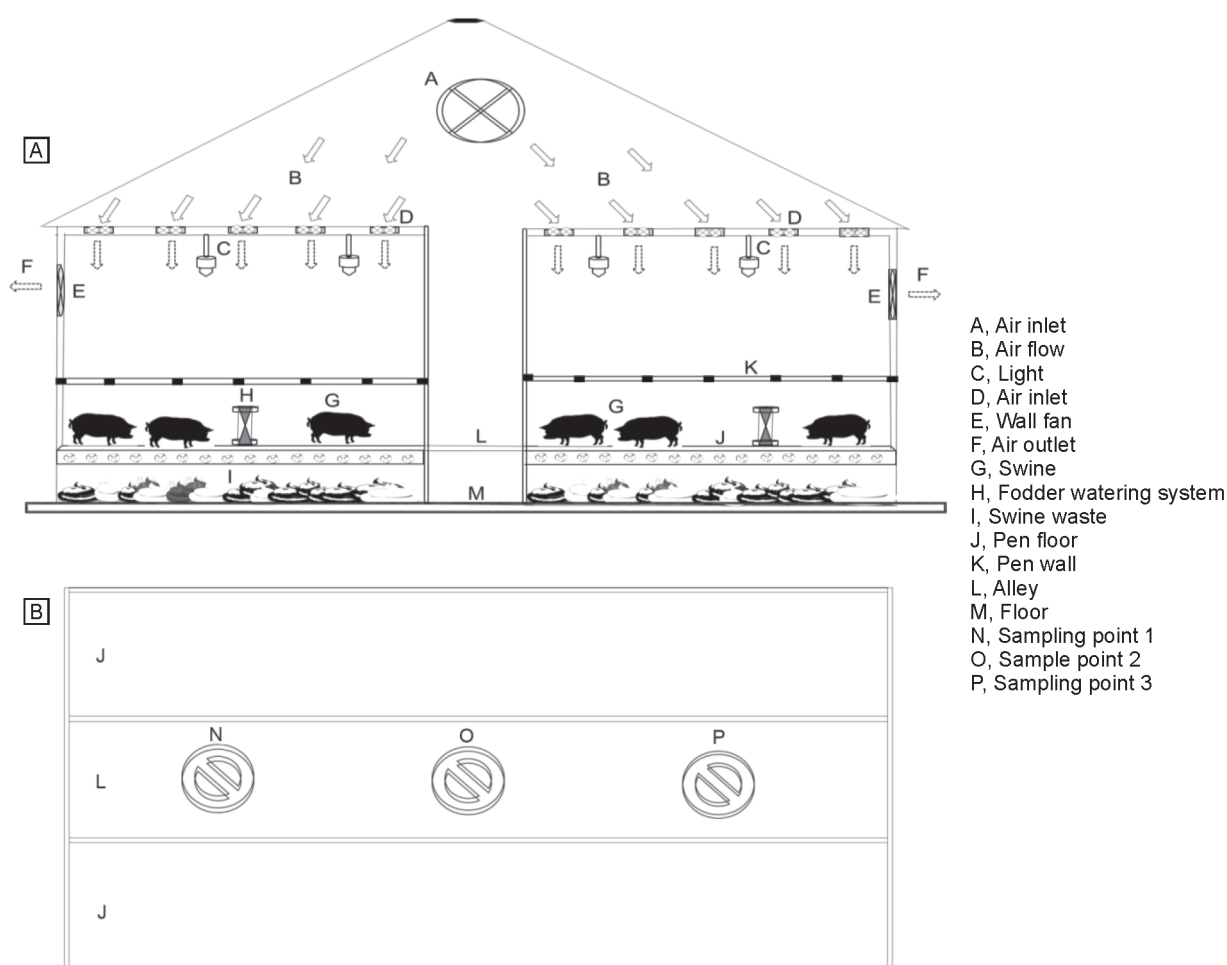


Fig. 1. Indoor arrangement of a swine house (a) and sampling points (b).

across both seasons, the percentage of acetic acid was highest (51%) followed by propionic acid (22%), butyric acid (10%), methyl mercaptans (5%), DMS (5%), iso-butyrac acid (2%), valeric acid (2%), iso-valeric acid (2%), DMDS (1%), and p-cresol (0.5%) (Fig. 2). Our results are consistent with the findings of some previous studies (Yao *et al.* 2011, Jo *et al.* 2015, Yuan *et al.* 2017), which also showed the highest emission of acetic acid compared to other VOCs in livestock facilities. Most of the volatile fatty acids are mainly generated as the result of incomplete anaerobic degradation of animal feces stored in the pit under slatted floor (Mackie *et al.* 1998, Osaka *et al.* 2018), and one of the possible reasons for prevalence of acetic acid in swine houses could be related to the stability of acetic acid production pathway over varying physico-chemical conditions (Huang *et al.* 2016).

Seasonal variations in emissions of odorous gases: Most of the odorous gases measured in this study varied significantly between winter and summer, except iso-valeric acid, DMS and DMDS (Table 1). The concentrations of these odorous gases were significantly higher in winter (Table 1), except p-cresol which was more abundant in summer (Table 1). Similar trends were observed previously in a nursery swine house (Yao *et al.* 2011). The lower concentrations of most of the odorous gases in summer could be related with ventilation rate (Van Huffel *et al.* 2016). Due to higher ventilation rate during summer, more and more odorous gases would be transferred out of the swine house, which reduces the indoor air concentrations of odorous gases in summer. Whereas, increase in temperature could also enhance the solubility of odorous

Table 1. Concentration (in ppb) of odorous gases in swine houses between winter and summer

Odorous group	Parameter ²	Season ¹		
		N ³	Winter (n=6) ⁴	Summer (n=6) ⁴
Acidic group	AA	18	90.5 (±17.5)	38.1 (±10.4)
	PA	18	43.9 (±11.2)	6.5 (±1.2)
	BA	18	18.8 (±5.5)	11.9 (±3.1)
	VA	18	3.9 (±1.2)	1.3 (±0.3)
	i-BA	18	3.1 (±0.7)	0.9 (±0.4)
	i-VA	18	3.4 (±0.8)	2.7 (±1.1)
Phenolic group	p-cresol	18	0.2 (±0.1)	0.7 (±0.1)
Sulphur group	MM	18	11.2 (±2.8)	2.0 (±0.3)
	DMS	18	11.9 (±7.4)	0.2 (±0.0)
	DMDS	18	0.8 (±0.4)	0.3 (±0.2)

¹Data are presented as arithmetic means±standard error. AA, acetic acid; PA, propionic acid; BA, butyric acid; VA, valeric acid; i-BA, iso-butyrac acid; i-VA, iso-valeric acid; MM, methyl mercaptans; DMS, dimethyl sulfide; and DMDS, dimethyl disulfide. ³N = 6 swine houses × 3 replications. ⁴Winter sampling was conducted in January and February, and summer sampling time was June and July. Bold values indicate significance of means between the seasons (P<0.05).

gases (Charles 2017), which could further reduce the concentrations of odorous gases in swine houses during summer.

Relationship between aerial parameters and odorous gases: The means of aerial parameters (temperature and relative humidity) measured in swine houses during winter and summer are shown in Table 2. Both aerial temperature and relative humidity varied significantly between seasons (Table 2) with both parameters recorded significantly higher in summer compared to winter (Table 2). Similar results were observed in previous studies that reported significantly higher values of aerial temperature and relative humidity during winter in swine houses (Yao *et al.* 2011, Kumari Choi 2014, Kumari *et al.* 2016).

We found significant positive correlation between aerial temperature and most of acidic group compounds, and DMS in both seasons (Table 3). Whereas, relative humidity was negatively correlated with acetic acid, propionic acid, and DMS during both seasons (Table 3), but iso-butyrac acid and iso-valeric acid were negatively correlated with relative humidity only during winter and summer, respectively

Table 2. Seasonal means (±SE) of the aerial parameters in swine houses according to seasons

Parameter	N ²	Season ¹	
		Winter ³	Summer ³
Temperature (°C)	18	20.7 (±0.8) ¹	30.8 (±0.9) ¹
Relative humidity (%)	18	69.3. (±4.1) ¹	89.1 (±2.9) ¹

¹Data are presented as arithmetic means±standard error. ²N= 6 swine houses × 3 replications. ³Significant differences between seasons are indicated by bold values with P<0.05.

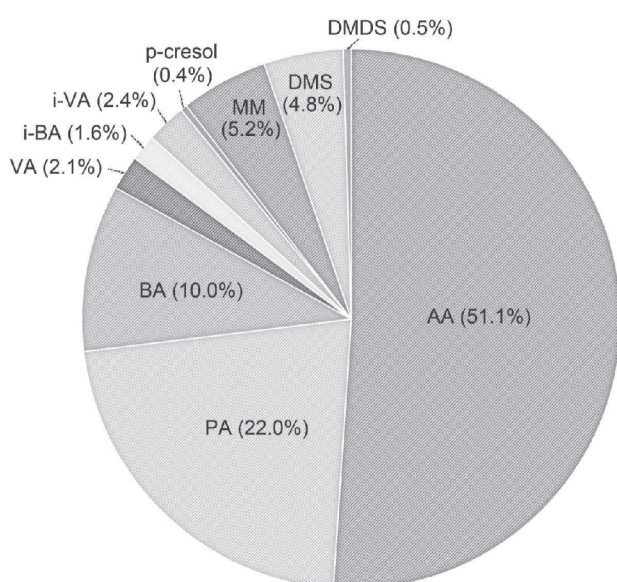


Fig. 2. Relative percentage of odorous gases in growing and fattening swine houses. AA, acetic acid; PA, propionic acid; BA, butyric acid; VA, valeric acid; i-BA, iso-butyrac acid; i-VA, iso-valeric acid; MM, methyl mercaptans; DMS, dimethyl sulfide; and DMDS, dimethyl disulfide.

Table 3. Pearson correlation coefficients for aerial temperature and relative humidity, and with odorous gases

Pearson correlation	Acidic group ¹						Phenolic group ¹		Sulfuric group ¹	
	AA	PA	BA	VA	i-BA	i-VA	p-cresol	MM	DMS	DMDS
<i>Temperature</i>										
Winter	0.846**	0.740**	0.618**	0.499*	0.718**	-0.027	0.080	-0.006	0.807**	0.040
Summer	0.846**	0.740**	0.499*	-0.030	0.618**	0.718**	0.080	-0.010	0.807**	0.040
<i>Relative humidity</i>										
Winter	-0.611**	-0.500*	-0.424	-0.230	-0.522*	0.182	-0.110	-0.034	-0.675**	-0.270
Summer	-0.611**	-0.500*	-0.230	0.180	-0.420	-0.522*	-0.110	-0.030	-0.675**	-0.270

*P<0.05; **P<0.01. AA, acetic acid; PA, propionic acid; BA, butyric acid; VA, valeric acid; i-BA, iso-butyric acid; i-VA, iso-valeric acid; MM, methyl mercaptans; DMS, dimethyl sulfide; and DMDS, dimethyl disulfide.

(Table 3). Kim *et al.* (2005) reported similar findings, positive correlations between concentrations of odorous gases and temperature. However, contrary to our results, Yao *et al.* (2011) found negative correlations between concentrations of VOCs and temperature, and relative humidity in a nursery swine house. The contradictory results indicate that these relationships are complex and are likely depend on relationship between many different factors such as airborne particles, water-carrying capacity of air, and affinity of water molecules to odorous compounds (Miller *et al.* 2003).

Our findings demonstrated that among the three different groups of odorous compounds examined in swine houses, the acidic group compounds were more prevalent across winter and summer seasons. The concentrations of most of the odorous gases varied significantly between seasons and their concentrations peaked during winter compared to summer. Aerial temperature was positively correlated with concentrations of most of the odorous gases, whereas relative humidity showed significant negative correlation with concentrations of relatively a small number of odorous gases. The data gathered in this study could be useful to prepare strategies to regulate odorous gases emissions from growing and fattening swine houses. Studying additional odorous compounds, aerial parameters in different livestock houses (eg. cattle, poultry etc.) to provide better understating of odorous gases emission from livestock houses is an important topic for further investigations.

ACKNOWLEDGEMENTS

This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry, and Fisheries (IPET) from the Ministry of Agriculture, Food, and Rural Affairs (MAFRA).

REFERENCES

- Charles W and Ho G. 2017. Biological methods of odor removal in solid waste treatment facilities. pp 341–365. *Current Developments in Biotechnology and Bioengineering*. (Eds) Wong W C, Tyagi R D and Pandey A. Elsevier.
- Douglas P, Robertson S, Gay R, Hansell A L and Gant T W. 2018. A systematic review of the public health risks of bioaerosols from intensive farming. *International Journal of Hygiene and Environmental Health* 221: 134–73.
- Ganpat W, Ragoobar T and Gopalan K. 2019. Intensive swine production: impact on air quality and its association with community residents' respiratory illnesses. *Iranian Journal of Health, Safety and Environment* 6: 1190–97.
- Guffanti P, Pifferi V, Falciola L and Ferrante V. 2018. Analyses of odours from concentrated animal feeding operations: A review. *Atmospheric Environment* 175: 100–108.
- Hartung J and Phillips V. 1994. Control of gaseous emissions from livestock buildings and manure stores. *Journal of Agricultural Engineering Research* 57: 173–89.
- Huang W, Huang W, Yuan T, Zhao Z, Cai W, Zhang Z, Lei Z and Feng C. 2016. Volatile fatty acids (VFAs) production from swine manure through short-term dry anaerobic digestion and its separation from nitrogen and phosphorus resources in the digestate. *Water Research* 90: 344–53.
- Jo S H, Kim K H, Jeon B H, Lee M H, Kim Y H, Kim B W, Cho S B, Hwang O H and Bhattacharya S S. 2015. Odor characterization from barns and slurry treatment facilities at a commercial swine facility in South Korea. *Atmospheric Environment* 119: 339–347.
- Kim K Y, Ko H J, Lee K J, Park J B and Kim C N. 2005. Temporal and spatial distributions of aerial contaminants in an enclosed pig building in winter. *Environmental Research* 99: 150–157.
- Kumari P and Choi H L. 2014. Seasonal variability in airborne biotic contaminants in swine confinement buildings. *PLoS ONE* 9: e112897.
- Kumari P, Woo C, Yamamoto N and Choi H L. 2016. Variations in abundance, diversity and community composition of airborne fungi in swine houses across seasons. *Scientific Reports* 6: 37929.
- Mackie R I, Stroot P G and Varel V H. 1998. Biochemical identification and biological origin of key odor components in livestock waste. *Journal of Animal Science* 76: 1331–42.
- Miller G Y, Maghirang R G, Gerald L, Heber R, Robert M J and Muyot M. 2003. *Management and Other Factors that Influence Air Quality and Odour*. University of Illinois Pork Industry Conference on Swine Odour and Manure Management, Champaign, IL.
- Ni J Q, Heber A J and Lim T T. 2018. Ammonia and hydrogen sulfide in swine production. pp 69–88. *Air Quality and Livestock Farming*. (Eds) Banhazi T and Aland A. CRC Press, Florida.
- Osaka N, Miyazaki A and Tanaka N. 2018. Emissions of volatile organic compounds from a swine shed. *Asian Journal of Atmospheric Environment* 12: 178–191.
- Radon K, Danuser B, Iversen M, Monso E, Weber C, Hartung J, Donham K J, Palmgren U and Nowak D. 2002. Air contaminants in different European farming environments.

- Annals of Agricultural and Environmental Medicine* **9**: 41–48.
- Schiffman S S, Bennett J L and Raymer J H. 2001. Quantification of odors and odorants from swine operations in North Carolina. *Agricultural and Forest Meteorology* **108**: 213–240.
- Van Huffel K, Hansen M J, Feilberg A, Liu D and Van Langenhove H. 2016. Level and distribution of odorous compounds in pig exhaust air from combined room and pit ventilation. *Agriculture, Ecosystems and Environment* **218**: 209–219.
- Yao H, Choi H, Zhu K and Lee J. 2011. Key volatile organic compounds emitted from swine nursery house. *Atmospheric Environment* **45**: 2577–2584.
- Yuan B, Coggon M M, Koss A R, Warneke C, Eilerman S J, Peischl J, Aikin K C, Ryerson T and de Gouw J A. 2017. Emissions of volatile organic compounds (VOCs) from concentrated animal feeding operations (CAFOs): chemical compositions and separation of sources. *Atmospheric Chemistry and Physics* **17**: 4945–56.