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Effect of Ground Channel Ventilation System on Gaseous Emissions, Air Contaminants, Performance and Behavior of Growing Pigs during Winter Season

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ABSTRACT

Internal environment can ensure the productivity and welfare of animals; which could be affected by the ventilation system of animal house. In our previous study, we observed that, ground channel ventilation system was beneficial for saving energy cost of heating during winter season for pig production. Present study was undertaken to observe the effect of ground channel ventilation system on gaseous emissions and microbial contaminants, growing pig performance, immunity and behavior during winter season. One hundred twenty crossbred pigs (Landrace × Yorkshire) of similar aged were assigned to mechanical and ground channel ventilated pig houses with 3 replications having 20 pigs per replication. The experiment was conducted for six weeks where the treatment groups were: 1) MV = Mechanical ventilation system house group and 2) CV = Channel ventilation system house group. Result revealed that, average ammonia emission was significantly lower in CV compared to MV ($p<0.05$). Average total bacterial count was found significantly lower, but mold count was significantly higher in CV compared to MV ($p<0.05$). There was observed no significant differences on growth performance and immunoglobulin status between MV and CV ($p>0.05$). Among the different behaviors, biting and lying was lower but huddling and mounting was found higher in CV compared to MV. Therefore, ground channel ventilation system was environmental friendly during winter season with lower noxious gaseous emission and total microbial count without adverse impact on growth performance, immunity and behavior of growing pigs. Further detail research required to observe the impact of ground channel ventilation system on carcass composition and quality of growing pigs.

KEYWORDS: Gaseous Emission, Microbial contaminants, Growth Performance, Animal Behavior, Ventilation System.

1. INTRODUCTION

Global consumption of meat is increasing tremendously, where for developing countries it is projected to grow 106 Tg between late 1990s and 2020 (Delgado, 2003). Among the different meat, demand of pork is increasing in the world and expected to increase 75% by 2020 (Fiala, 2008). Management of this large population could be the big challenge for the swine industry, because so many factors are related with this management. For example, cost of production, gaseous emission and other related matters are related with this management which are the important issues to be considered for the environment. Pig producers are under high risk of chronic respiratory disorders and cardiac problems (Rylander et al., 1989); since swine industry as a part of animal industry and agriculture, is the source of environmental pollution directly or indirectly (Steinfeld et al., 2006). Therefore, scientists are worried about the environmental pollution to protect the biodiversity and ecosystem, and human and animal welfare (Holgate et al., 1999; Banhazi et al., 2008).

Modern swine industry caused air pollution through contributing to noxious gases and greenhouse gases like ammonia, hydrogen sulfide, sulfur dioxide, methane and carbon dioxide (Barrasa et al., 2012; Dong et al., 2007). That industry is globally responsible for about 15% of NH_3 emissions (associated to livestock); which is an important pollutant that plays a crucial role in the acidification and the eutrophication of ecosystems; adversely impact on the production, health and welfare of animals and humans (Banhazi et al., 2008; Barrasa et al., 2012). Different types of gases and microorganisms are usually carried out by the dust and particles which reduces the air quality of the indoor and outdoor animal environment (Zhang, 2004) and detrimental to performance and efficiency of animals (Donham and Leininger, 1984; Pope et al., 2002; Al Homidan and Robertson, 2003). Intensive pig production can contribute 30% of air polluting particulate matter which can affect the well-being of animals as well as human (EMEP-CORINAIR, 2007). Dust particles with gaseous emissions and microorganisms can have adverse effects on production and health of animals showing coughing, sneezing, salivation, loss of appetite and lethargic behavior and other abnormal behavior (Donham, 2000; Banhazi et al., 2008).

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In our previous study, it was observed that, ground channel ventilation system was efficient in saving energy cost of heating and reducing greenhouse gas emission during winter season. However, ground channel type ventilation system is effective or not regarding minimization of noxious gas emissions and microbial contaminants to protect the animal environment; there is limited research. Therefore, present study was undertaken to observe the effect of ground channel ventilation system on gaseous emission, microbial contaminants, growth performance, immunity and behavior on growing pigs during winter season.

2. MATERIALS AND METHODS

The experiment was performed at the experimental farm of Sunchon National University, Jeollanam-do, South Korea and the protocol of the current experiment was approved by the Animal Care and Use Committee of Sunchon National University, South Korea.

2.1. Experimental house and animals

Sunchon National University experimental farm situated in the location, Latitude: 34˚56′53″ N, Longitude: 127˚29′22″ E, Elevation above sea level: 16m, Suncheon, Republic of Korea. There were two types ventilated pig houses for the management of growing pigs. Experimental houses were: MV = Mechanical ventilation system house and CV = Channel ventilation system house. Experimental houses were slatted floor type and of same size (4m×9.2m), MV house was with three air inlets and three outlets for controlling the house environment; while CV house was with the ground channel ventilation structure for air inlet under the floor; chimney for air exchange on the middle of roof; and an emergency air exchange window for controlling the house environment. One hundred twenty crossbred growing pigs (Landrace × Yorkshire) of similar age were assigned to mechanical and channel ventilated pig houses with 3 replications having 20 pigs per replication. Floor space for growing pig was 1.3m^2/pig for both MV and CV houses. All pigs were randomly allotted to different pen of each house according to body weight for proper observation and were reared for 6 weeks during winter season. Basal diets were provided for each house separately to meet the nutrient requirements of growing pigs recommended by the NRC (2012). Pigs were allowed ad libitum access to feed and water; heating, lighting, ventilation and other management were maintained according to requirement and general practice.

2.2. Observations, measurements and analyses

2.2.1.Measurement of gas emissions

The noxious gas was measured for three consecutive days for every week from the MV and CV experimental houses. Gas was measured by using a Gastec (model GV-100) gas sampling pump (Gastec Corp., Japan) and Gastec detector tube. Gas detector tube No. 3L (0.5-78 ppm), 3La (2.5-200 ppm) and 3M (10-1000 ppm) for NH_3 measurement; 4LT (0.1-4 ppm) and 4LK (1-400 ppm) for H_2S measurement; and 5Lb (0.05-10ppm) for SO_2 measurement was used. The measurements were conducted directly from the slurry pit (different position) and repeated three times for more accuracy; and the concentration of each gas was determined based on the average of three measurements. Finally all data were set for making average for each MV and CV type house separately. The gaseous emission was presented in ppm for MV and CV house.

2.2.2. Measurement of microbial contaminants

Different dust particles were observed regularly for the gross estimation to compare between MV and CV. To measure the air contaminants of microbial counts, agar media were prepared for the growth of specific microorganisms. Tryptic soy agar was used for total bacterial count; Sabouraud agar was used for fungal count; Potato dextrose Agar was used for mold count; Mannitol-Egg Yolk-Polymyxin agar was used for *Bacillus* count; MacConkey Sorbitol Agar was used for *Escherichia coli* count; Salmonella Shigella Agar was used for *Salmonella* count. After 20 minutes of the placement of agar plates in open condition were collected, and then incubated for 48 h at 37°C. Microbial colonies were counted for total microbial count after removal from the incubator. The total number of microorganisms was expressed as colony-forming-units (CFU).

2.2.3. Measurement of slurry pH

To measure slurry pH, collected slurry sample was weighed (4g) and diluted in distilled water (36 mL) to a 1:9 (weight : volume) ratio in test tube. Then pH was measured directly using the Uni pH testa (Trans Instruments (S) PTE Ltd, 5 Jalan Kilang Barat, Petro Centre, Singapore).

2.2.4. Measurement of growth performance and immunological status

Body weight was measured on weekly basis from the starting to the end of the experimental period. Feed intake was determined by measuring feed residue subtracting from the total supplied feed for every week for each replication. The gain:feed ratio was then calculated by dividing the body weight gain by the feed intake.

For immunological analysis, at the end (6^{th} week) of experimental period, blood samples were collected

from the jugular vein of individual pigs using a 22-gauge sterile needle in a 10 ml syringe and then transferred to a BD Vacutainer (Becton Dickinson, Franklin Lakes, NJ) without anticoagulant. Following collection, sera were separated from blood samples by centrifugation (3,000 rpm for 15 minutes) 1610×g at 4°C in a cold chamber. The sera were carefully removed to plastic vials and stored at -20°C until immunoglobulin analysis was performed. Immunoglobulins (IgG, IgA, and IgM) were then determined using pig IgG (Cat. No. E 100-104), IgA (Cat. No. E 100-102) and IgM (Cat. No. E 100-100) ELISA Quantification kits (Bethyl Laboratories Inc., Montgomery, TX, USA) according to manufacturer's instructions. Each experiment was run in duplicate and the results represent the means of three experiment. The absorbance of each well was measured using a micro plate reader (Thermo Lab Systems, Helsinki, Finland) at 450 nm (Correction wavelength, 570 nm). The results were expressed as mg/mL of serum.

2.2.5. Observation of behavior and activities

Each group of pigs was observed two times per day for 20 minutes over the experimental period. During each observation, the frequency of occurrence of behaviors listed in Table 7 was recorded.

2.3. Statistical analysis

All data were analyzed by following the PROC GLM model of SAS (2003). Means was compared based on Duncan's Multiple Range Test (DMRT). The significance level was considered at $p<0.05$.

3. RESULTS

3.1. Effect of ventilation system on noxious gas emissions

Among the different gases, ammonia emission was presented in Table 2. Present study revealed that, during 3rd week of experimental period the lower ammonia (NH_3) emission was found from CV compared to MV ($p<0.05$). The average ammonia emission was lower (21%) in CV compared to MV ($p<0.05$); with the range of 8 to 18 ppm (MV), and of 4 to 11ppm (CV). However, there was found no significant differences of H_2S emission (Table 3) and SO_2 emission (Table 4) between CV and MV ($p>0.05$). Hydrogen sulfide emission was in the range of 0.20 to 0.85 ppm for MV; and 0.20 to 0.65 ppm for CV. While sulfur dioxide emission was found minimum of 0.20 ppm for both MV and CV; maximum 0.65 ppm and 0.55 ppm for MV and CV respectively.

3.2. Effect of ventilation system on microbial contaminants

There was observed less visible dust particles in the CV compared to MV. The total bacterial counts were presented in figure 2, which was found significantly lower in CV compared to MV during 6th week of experimental period ($p<0.05$). The mean value of total bacterial count showed that in CV it was 20% lower than MV ($p<0.05$). In addition, fungal count did not differ significantly for MV and CV ($p>0.05$) (Fig. 3). However, as shown in figure 4, the average mold count was observed higher (26%) in the CV compared to MV ($p<0.05$). Moreover, the *Bacillus*, *Salmonella* and *E. coli* count was not significantly different for CV and MV ($p>0.05$) (Fig. 5A, Fig. 5B and Fig. 5C).

3.3. Effect of ventilation system on slurry pH

The pH of slurry was found significantly ($p<0.05$) lower in CV in comparison to MV during 1st, 3rd and 6th week of experimental period (Fig.6). In addition to that, mean value of pH was significantly lower in CV (mean value: 6.7) compared to MV (mean pH value: 7.1).

3.4. Effect of ventilation system on growth performances and immunity of pigs

The growth performances indices were presented in Table 5. The growth performance result indicated that, there was no significant differences in body weight gain, feed intake and gain: feed ratio between CV and MV ($p<0.05$); although it was found somewhat higher intake value in case of CV it was not significant ($p>0.05$).

The serum immunoglobulin status of CV and MV was presented in Table 6. The result of the serum immunoglobulin (IgG, IgA and IgM) value suggested that there was found no significant differences between CV and MV ($p>0.05$).

3.5. Effect of ventilation system on behavior and activity of pigs

The result of the animal behavior and activity (Table 7) indicated that there was found no differences in feeding, watering, excretion in both CV and MV. There was observed lower lying, tail biting and ear sucking in CV compared to MV; whereas, the mounting and huddling behavior was found higher in CV compared to MV. The excretion was found in the different corners of the pen in case of MV; while in case of CV groups the excretion was found in one side and other side was clear and were concentrated their movements.

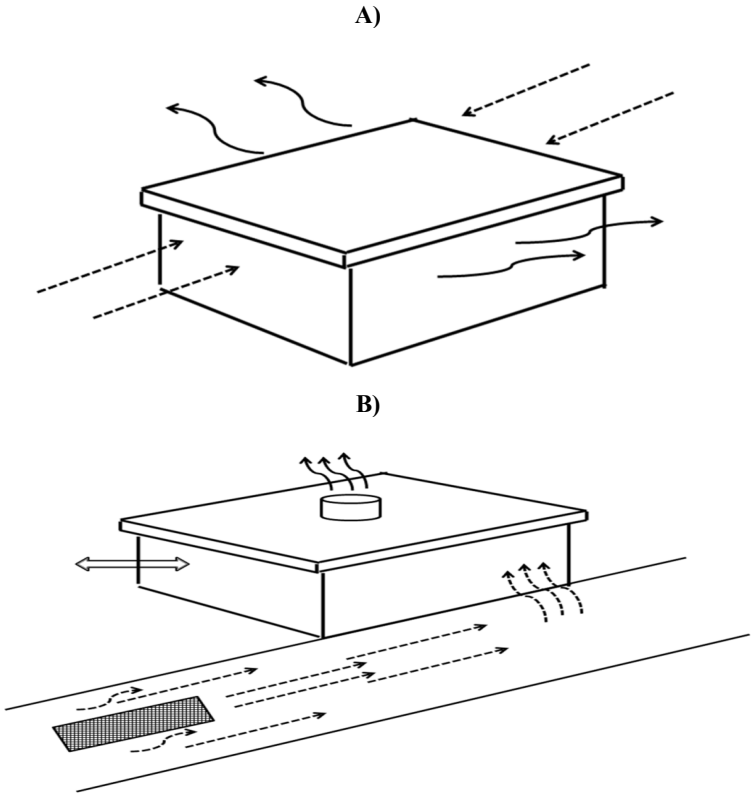

Fig. 1. Schematic diagram of A) Mechanical ventilation system house (MV) and B) Ground channel ventilation system house (CV)

Different arrow indicated the airflow pattern for both mechanical and channel ventilation system pig house

	Indicated incoming fresh air
	Indicated outgoing of stale air
	Indicated emergency air exchange
MV house:	Three inlets and three outlets for air exchange
CV house:	One ground channel inlet, one chimney outlet and one emergency air exchange window

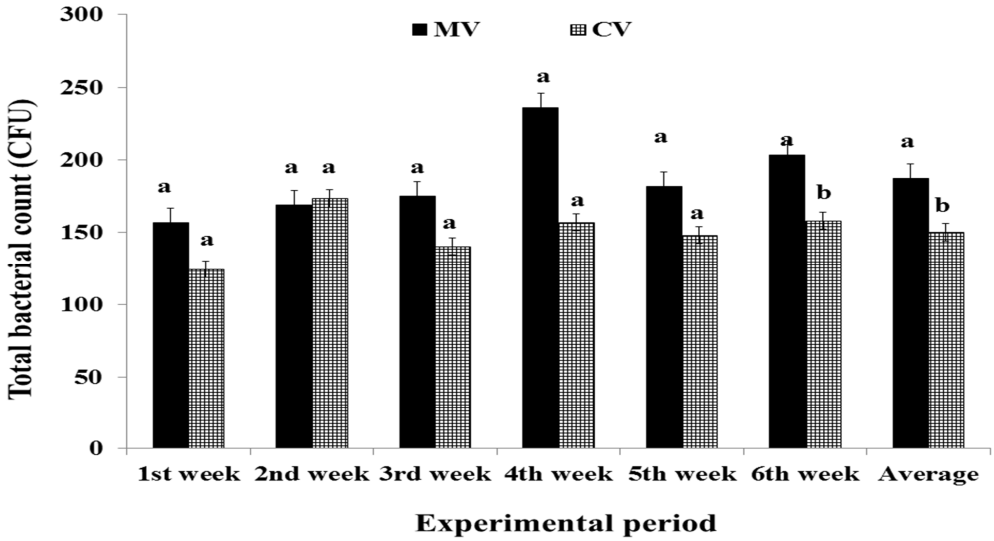

Fig. 2. Effect of ground channel ventilation system on total bacterial count in the experimental pig house

[a, b] Mean with different superscript letters within the same week bars are significantly different ($p<0.05$).

Error bar indicated standard error

MV = Mechanical ventilated house; CV = Channel ventilated house;

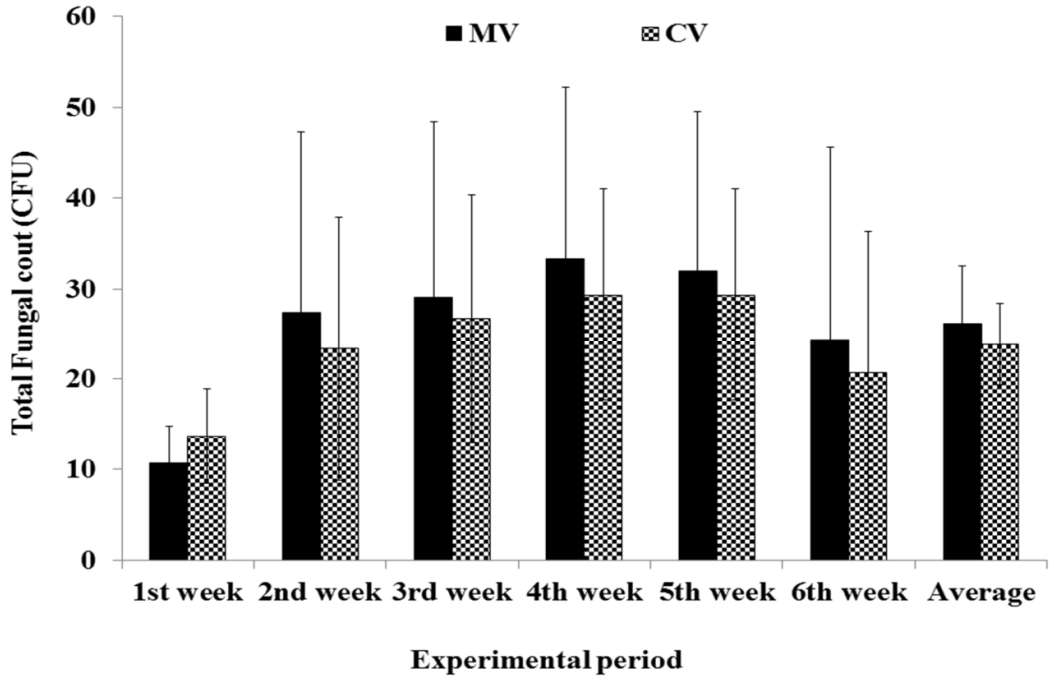

Fig. 3. Effect of ground channel ventilation system on total fungal count in the experimental pig house Significance level considered at $p<0.05$.

Error bar indicated standard error
MV = Mechanical ventilated house; CV = Channel ventilated house;

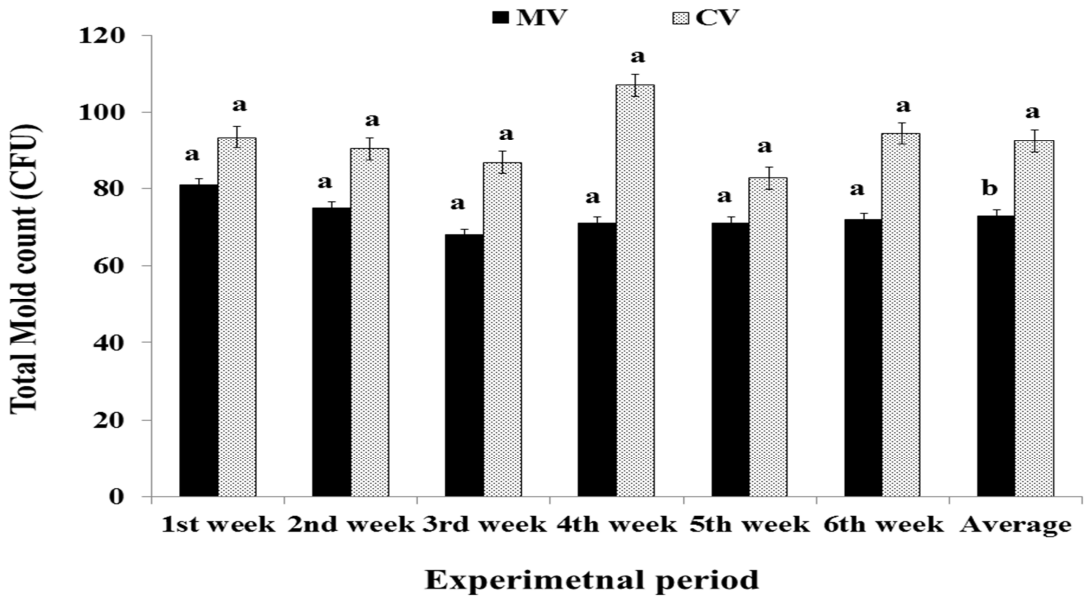

Fig. 4. Effect of ground channel ventilation system on total mold count in the experimental pig house
[a, b] Mean with different superscript letters within the same week bars are significantly different ($p<0.05$).
Error bar indicated standard error
MV = Mechanical ventilated house; CV = Channel ventilated house;

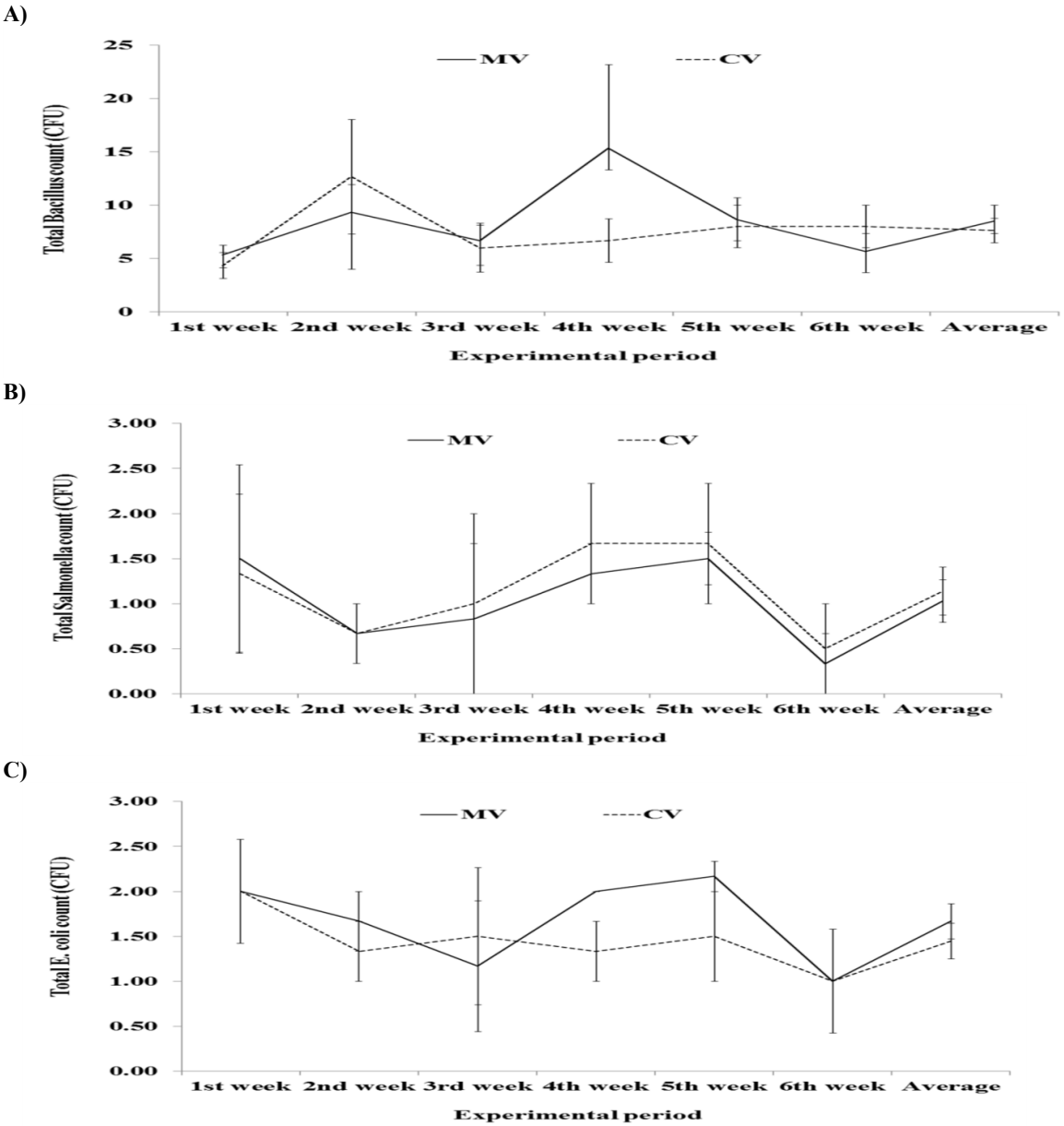

Fig. 5. Effect of ground channel ventilation system on total A) *Bacillus* count B) *Salmonella* count and C) *E. coli* count in the experimental pig house

Significance level considered at $p<0.05$
Error bar indicated standard error.
MV = Mechanical ventilated house; CV = Channel ventilated house.

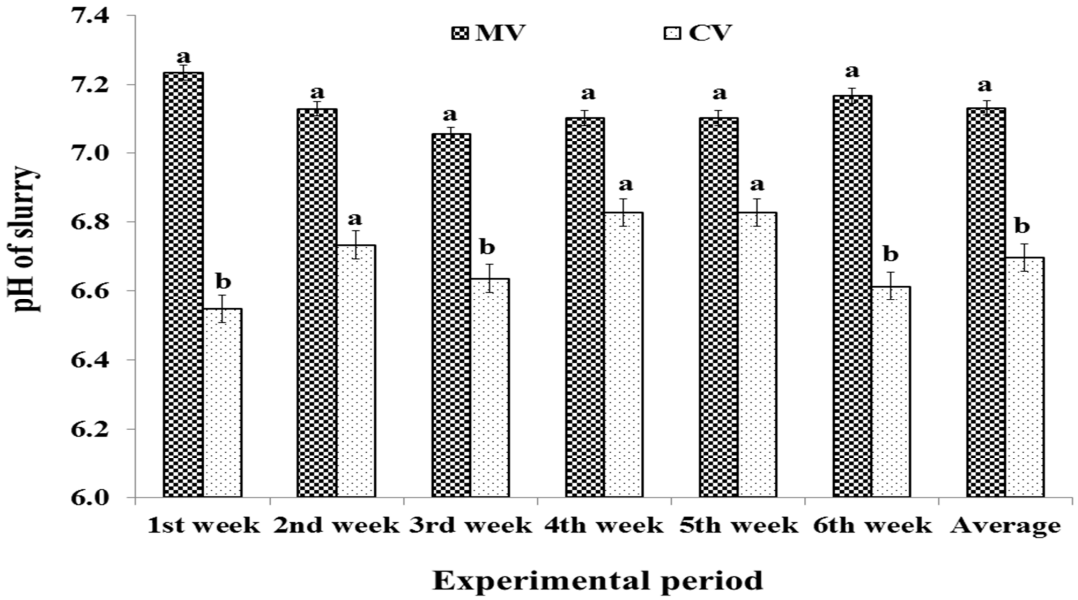

Fig. 6. Effect of ground channel ventilation system on pH of slurry in the experimental pig house.
Significance level considered at $p<0.05$.
MV = Mechanical ventilated house; CV = Channel ventilated house.

Table 1 Ingredients and nutrient composition of basal diets provided to the experimental pigs

Item	Grower pigs
Ingredients (%, as-fed basis)	
Yellow corn	45.15
Wheat	23.00
Wheat bran	4.00
Soybean meal	18.00
Limestone	0.98
Calcium phosphate	1.10
Salt	0.25
Vitamin premix*	0.55
Animal fat	2.50
Molasses	4.30
L-Lysine	0.17
Chemical composition(as fed basis)†	
ME (kcal/kg)	3265
Crude protein (%)	18.0
Ca (%)	0.70
Available phosphorus (%)	0.55
Lysine (%)	0.95
Methionine (%)	0.30

*Contains the following nutrients per kg of diet: vitamin (V) A 6000 IU; VD_3 800 IU; VE 20 IU; VK_3 2mg; VB_1 2mg; VB_2 4mg; VB_6 2mg; VB_{12} 1mg; pantothenic acid 11mg; niacin 10mg; biotin 0.02mg; Cu 21mg; Fe 100mg; Zn 60mg; Mn 90mg; I 1.0mg; Co 0.3mg; Se 0.3mg.
†Calculated values

Table 2 Effect of ground channel ventilation system on ammonia emission from experimental pig house

Period	Experimental pig house		SEM	P-value
	MV	CV		
1st week	15.00	13.33	1.18	0.37
2nd week	11.67	8.17	1.17	0.10
3rd week	20.67[a]	10.00[b]	2.41	0.04
4th week	10.17	8.83	1.39	0.54
5th week	14.33	15.33	4.10	0.87
6th week	13.67	10.83	2.25	0.42
Average	14.25[a]	11.08[b]	1.07	0.04

[a, b] Mean with different superscript letters within the same row are significantly different ($p<0.05$).
SEM = Standard error of mean
MV = Mechanical ventilated house; CV = Channel ventilated house

Table 3 Effect of ground channel ventilation system on hydrogen sulfide emission from experimental pig house

Period	Experimental pig house		SEM	P-value
	MV	CV		
1st week	0.48	0.42	0.15	0.77
2nd week	0.35	0.42	0.12	0.71
3rd week	0.45	0.42	0.09	0.81
4th week	0.38	0.47	0.10	0.69
5th week	0.52	0.43	0.14	0.71
6th week	0.33	0.42	0.07	0.52
Average	0.42	0.43	0.04	0.89

[a, b] Mean with different superscript letters within the same row are significantly different ($p<0.05$).
SEM = Standard error of mean
MV = Mechanical ventilated house; CV = Channel ventilated house

Table 4 Effect of ground channel ventilation system on sulfur dioxide emission from experimental pig house

Period	Experimental pig house		SEM	P-value
	MV	CV		
1st week	0.23	0.27	0.03	0.52
2nd week	0.35	0.37	0.06	0.85
3rd week	0.38	0.37	0.10	0.92
4th week	0.27	0.37	0.05	0.25
5th week	0.38	0.45	0.11	0.69
6th week	0.42	0.45	0.10	0.82
Average	0.34	0.38	0.03	0.40

[a, b] Mean with different superscript letters within the same row are significantly different ($p<0.05$).
SEM = Standard error of mean
MV = Mechanical ventilated house; CV = Channel ventilated house

Table 5 Effect of ground channel ventilation system on growth performance of growing pigs

Measurements	Experimental pig house		SEM	P-value
	MV	CV		
Initial live weight (kg/pig)	38.85	38.96	0.87	0.93
Final live weight (kg/pig)	72.97	71.98	2.77	0.81
Body weight gain (kg/pig)	34.12	33.02	2.28	0.75
Feed intake (kg/pig)	129.69	131.20	2.89	0.72
Gain: Feed	0.26	0.25	0.01	0.57

Significance level considered at $p<0.05$
SEM = Standard error of mean
MV = Mechanical ventilated house; CV = Channel ventilated house

Table 6 Effect of ground channel ventilation system on serum immunoglobulin status (mg/mL) of growing pigs

Parameter	Experimental pig house		SEM	P-value
	MV	CV		
Immunoglobulin G (IgG)	203.37	202.56	4.58	0.90
Immunoglobulin A (IgA)	12.33	10.91	0.78	0.21
Immunoglobulin M (IgM)	31.77	32.09	2.91	0.94

Significance level considered at $p<0.05$
SEM = Standard error of mean
MV = Mechanical ventilated house; CV = Channel ventilated house

Table 7 Effect of ground channel ventilation system on observable behavior and activity of growing pigs

Observable behavior and activity	Experimental pig house	
	MV	CV
Feeding	**	**
Watering	**	**
Excretion	**	**
Lying	***	**
Tail biting	***	**
Ear sucking	***	**
Wall threshing	***	**
Mounting	**	***
Huddling	**	***

*** Indicate higher frequency
** Indicate normal frequency
MV = Mechanical ventilated house; CV = Channel ventilated house.

4. DISCUSSION

4.1. Gaseous emissions from experimental pig houses

Animal industry significantly contributes to noxious gases like ammonia, hydrogen sulfide, and sulfur dioxide (Barrasa et al., 2012). The ammonia emission for CV was lower compared to MV in the present study which might be due to ground channel ventilation system and cumulative effect of internal environment (Arogo et al., 2003). The variations in air temperature, relative humidity and ventilation affect the gas volatilization levels in pig buildings (Olesen and Sommer, 1993; Arogo et al., 2003). The position of the air inlet and outlet (Philippe et al., 2011) and the ventilation structure (Topisirovic and Radivojevic, 2005) can affect the ammonia emission of the pig house. In case of CV house air direction was vertical through ground channel and chimney ventilation system (Fig. 1A); while for MV house air direction was horizontal through horizontal inlet and outlet (Fig 1B); variation in flow of air might be attributable in ammonia emission. According to Hayes et al. (2006), higher air velocity due to location of the ventilation fan can increase volatilization and ammonia emission. As the exhaust fan for MV was in the sidewall and for CV was in the roof, so there was chance of the increment of ammonia in the current study due to the direction of airflow (horizontal and vertical respectively). Correlation of ammonia emission from swine industry with ventilation flow (Blanes-Vidal et al., 2008) supports our assumption. In addition, gases from swine buildings are variable and originated from manure pits; and from the accumulated urine and feces existed on the top of the floor (Donham et al., 1988) which could be influenced by the ventilation flow. Moreover, convective airflow due to lying and excretory behavior of pigs can affect the ammonia emission (Aarnink et al., 1996; Arogo et al., 2003) which was concurred with the behavior of individuals of MV in the present study. Slurry pH was assumed to be another contributing factor of ammonia emission, because the pH of un-acidified slurry lies between 7.0 to 8.3 (Søgaard et al., 2002); and within this range the ammonia emission is increased (Sommer et al., 2003).

4.2. Microbial contaminants in experimental pig houses

Several types of microorganisms and their components can be carried by the dust and particulate matters inside the animal house (Bakutis et al., 2004; Cai et al., 2006; Seedorf, 2004). Feed, feces and animal debris are the source of dust and particles which could be influenced by the heating system in the MV of the present study (Honey and McQuitty, 1979). Along with different types of gram negative and gram positive bacteria (both pathogenic and non-pathogenic), particulate matters and dust causes respiratory problems (Harry, 1978; Matković et al., 2007); induce disease and even mortality of animals; and hamper the welfare of animals and human (Donham, 1991; Radon et al., 2002). The higher microbial count in the MV of the present observation has the risk of increment of endotoxins (lipopolysaccharides complex originating from outer membrane of microorganisms) since it is affected by other factors like presence of particulate matters; and *Salmonella* and *E. coli* (Auvermann et al., 2006; Bakutis et al., 2004; Radon et al., 2002). Higher temperature with relative humidity increase the ammonia emission and all together create secondary inorganic particles (Sharma et al., 2007; Vogt et al., 2005) which influence the increase of bacterial population, might be attributed in higher total bacterial count of the MV house. The higher amount of total bacterial count into the MV indicated the presence of higher particulate matter since it is biologically active and carrier of microorganisms (Curtis et al., 1975; Martin et al., 1996; Zhang, 2004). There is association among temperature, relative humidity and ventilation which determines the dust, microorganisms and gaseous emissions (Puma et al., 1999a, b).

4.3. Slurry pH in experimental pig houses

The lower pH of the CV could be due to the formation of crust type layer on the upper portion of slurry which can reduce the wind speed over it (Blanes-Vidal et al., 2008) and influenced the higher total mold count in case of CV. Internal room temperature can alter the pH which is associated with higher ammonia emission

that was concurred with ammonia emission value of MV (Andersson, 1996). In addition, microbial population is associated with the pH value of the slurry, as the microbial decomposition of organic components of slurry produces volatile fatty acids (VFA) and can increase the slurry pH (Cooper and Cornforth, 1978; Pain et al., 1990a,b). Since the bacterial population in the MV of the present study was higher, therefore it was speculated that, through heterogonous microbial fermentation it causes the generation of VFA and increase the pH value and vice versa for CV. According to Kisaalita and Pinder (1987) and Tang et al. (2004), micro-organism prefer an optimum pH for growth around 7.0, with the majority favoring in the pH range of 5.0-8.0 for heterogonous bacteria and its growth rate fall quickly at high and low pH values. While, according to Ye et al. (2007), higher bacterial diversity is happened at pH 6.0-8.0 and lower at pH 4.0 and 5.0. In addition, higher diversity of bacteria can cause effective fermentation while lower diversity inhibited the fermentation process (with higher and lower value of pH). Furthermore, fermentation process depends on heterogeneity and diversity of bacterial population as well (Epstein, 1996). Therefore, it was expected that, the variation on the microbial population as well as the fermentation process into the MV and CV had the effect on the pH value of slurry.

4.4. Growth performance and immunity of growing pigs

The result of insignificant differences in growth performances and serum immunoglobulin (IgG, IgA and IgM) between MV and CV indicated that, ground channel ventilation had no negative impact on the pig performance and immunity.

4.5. Animal behavior and activity of growing pigs

Behavior and activity can easily be observed by the pig producers and which is the indicator of the well-being of pigs (Altmann, 1974). Biting and ear sucking is usually happens due to the low fiber and mineral content in the diet, but these types of stereotypies might be attributable to the internal social and other facilities (Fraser, 1987; Appleby et al., 1989; Meunier-Salaün, et al., 2001). The higher tail and ear biting found in the MV group might be inferable to the heating system which was associated with the confinement environment and facility (Beattie et al., 1996). Huddling with littermates is the natural stimulus, which was found higher in CV group might be for thermoregulation and body heat production within the individuals as there was no halogen lamp heating system (Mount, 1979).

5. Conclusion

Present observation revealed that, average ammonia emission was significantly lower in CV compared to MV. In addition, total bacterial count was significantly lower but mold count was significantly higher in CV. Furthermore, there was found no significant differences of growth performance and serum immunoglobulin status between CV and MV. Moreover, some of the animal behavior and activity (lying, biting, huddling and mounting) was differed between MV and CV, but found no abnormality in both of the houses. To sum up, ground channel ventilation system (CV) was environmental friendly during winter season with lower noxious gas emissions and bacterial count; without adverse impact on performance, immunity and behavior on growing pig production. Further detail research required to assess the effect of ground channel ventilation system on carcass quality and composition of growing pigs.

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