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RESEARCH ARTICLE

POTENTIAL OF GEOTHERMAL AND GROUND CHANNEL SYSTEM HOUSE ON REDUCTION OF ENERGY CONSUMPTION AND CO_2EMISSIONS WITH MAINTENANCE OF PERFORMANCE OF GROWING PIGS

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ABSTRACT

Energy consumption in animal production is important issue, which is associated with CO_2 emissions as well as involved in the maintenance of internal animal house and performance of animals. Therefore, a preliminary study was undertaken to investigate potentiality of conventional, geothermal and ground channel system house on energy consumption and CO_2 emissions as a main focus of study; where additionally it was investigated internal house temperature, relative humidity, odorous gas concentrations, microbial concentrations and performance of growing pigs. Both geothermal and ground channel system substantially reduced the energy and emitted lower CO_2 emissions (28% and 37%, respectively) relative to conventional system house (P<0.05). Internal temperature was found lower in ground channel house compared to conventional and geothermal house; however, relative humidity was found higher in ground channel house in comparison to conventional and geothermal house (P<0.05). Odorous gas concentrations (NH_3, H_2S and SO_2) was significantly lower in geothermal and ground channel house compared to conventional house (P<0.05). Total microbes and aciduric bacteria was significantly lower in geothermal and ground channel relative to conventional house; whereas, mold count was higher in ground channel than the geothermal and conventional house (P<0.05).Although weight gain of individuals was somewhat higher in geothermal and ground channel house, no significant differences were observed on growth performance among houses. In conclusion, geothermal and ground channel houses are potential to save energy consumption and reduce CO_2 emissions; while able to substantially suppress odorous gas emissions and microbial concentrations without negative impact on performance of growing pigs.

INTRODUCTION

The population in the world, living on the earth is estimated about 7.3 billion on July 2015 and it would be 11.2 billion in 2100 (*United Nations Department of Economic and Social Affairs Report*).Due to the economic development, the level of status is increasing all over the world and peoples are becoming more relaxed and comfort loving. Hence technological advances triggers to be dependent on the technology and peoples are prone to use different technologies in all aspects of life; the use of energy become the sole part and become ubiquitous entity trough shaping and driving every single instant of our life; and therefore energy is ever-increasing matter in the today's world (Hadjipaschalis *et al*., 2009) and is the most important issue of the 21st century.The global consumption of the energy in the 21st century is equivalent to 13 terawatt (TW), which indicates a steady 13 trillion watts of the demand of power (Simmons, 2006; Armaroli and Balzani, 2007). Where, for both household and industrial use of different technology, the required energy mostly dependent on the conventional sources of energy. The progressive decrease of the proven fossil fuel is being happened due to taking astounding opportunities by the rich countries of the western world during the 20th century (Armaroli and Balzani, 2007). To minimize the limitation of conventional sources of energy, nuclear fission power is in commercial stage; while the renewable energy sources (wind power, solar power, hydroelectricity, wave power and biomass energy) are becoming the alternative source of energy (Lund, 2007;

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Jacobson and Delucchi, 2011). The utilization of renewable energy sources helps in the sustainable energy development through saving energy, improving efficiency of energy production and replacement of fossil fuel (Blok, 2005; Lund, 1999; Lior, 1997; Lior, 2002; Afgan and Crvalho, 2002).

On the other hand, currently, the threats to biodiversity is the global worming which is the contributor of the large environmental alterations and considered the important reason of research on the conservation of energy because it is the source of emission of greenhouse gases (Gardner and Stern, 2002). In the United Sates CO_2 emissions was reported to rise around 2.4% per year since 1990 from the electricity use (US department of Energy, 2005).The majority of energy is used for heating, lighting and air-conditioning (Gardner and Stern, 2002; Milieu Centraal, 2005) which incurred more than 50% of energy use in the modern world (Armaroli and Balzani, 2007). The CO_2 emitted from the energy mainly due to the burning of fuel biomass. It is reported that, a total of 2700 to 6800 Tg of carbon is exposed to fire annually, where 1800 to 4700 Tg of carbon are burn in the tropics (Crutzen, and Andreae,1990). Therefore, in the global scale, the growth rate of CO_2 emissions from the fossil-fuel burning becomes more than 3% per year during 2000 to 2004, where developing and least developing countries accounted 73% of the global emissions growth (Raupach *et al*., 2007). The increase of anthropological CO_2 is the greatest challenge for the energy producers because it is linked with the climate change (Middleton *et al*., 2002)

Thus to solve the energy crisis, need to limit energy consumption; need energy sufficiency (or conservation) and energy efficiency; increase the utilization of available renewable sources; increase the efficiency of utilization of renewable sources; increase the technological approaches to minimize the energy consumption (Herring, 2006); which would also a realistic means to reduce the CO_2 emissions from the atmosphere (Anderson and Newell, 2004).

With a broad view of minimization of energy consumption from the livestock sector to contribute in the global energy crisis and global CO_2 emissions (animal agriculture accounts 9% of the total CO_2 emissions) reductions; the present investigation was undertaken to compare the conventional, geothermal and ground channel system of house on the potentiality to reduce the energy consumption and CO_2 emissions from growing pig production. Additionally, if it is potential in substantial reduction of energy and CO_2 emissions; then whether it is effective or not in maintenance of internal temperature and relative humidity; reduction of emissions of odorous gases (NH_3, H_2S and SO_2) and microbial load in the house; and positive or negative impact on the performance of the growing pigs.

MATERIALS AND METHODS

The experiment was conducted by following the detail guidelines of care and management of animals which approved by the animal management committee of the Sunchon National university, Republic of Korea. The experimental period was during winter season for four weeks which was conducted in the Sunchon National University experimental farm, Republic of Korea.

Experimental house, design, animal and diet

The experimental houses were conventional heating system house, geothermal heating system house and ground channel airflow heating system house. All houses were slatted floor type and of similar size (4.0m X 9.0m).A total of 36 growing pigs (Duroc X Yorkshire) were allocated to the each of three experimental pig houses with 12 in each house following completely randomized design. Feed and water supply was *ad libitum*, where basal diet of similar composition were provided to meet the nutrient requirement of the animals following NRC (1998). Conventional house was equipped with general ceiling heater; where geothermal and ground channel was equipped with specific ground level heating system. The detail design of geothermal and ground channel system was shown in Fig. 1 and Fig. 2, respectively.

Measurement and analysis

Recording indoor air temperature and relative humidity

The temperature of the experimental pig houses was recorded by hanging thermo-couple temperature sensors (type T) from the ceiling at the entry (near the door), center and back of the house to measure the temperature at two points; 10 cm below the ceiling (upper point) and 10 cm above the floor (lower point). To record the data every hour, all measurement instruments were connected to a data acquisition system (CR10X data logger, Campbell Scientific Inc., Edmonton, AB, Canada). The humidity was recorded for all houses separately using a digital hygrometer (Electronic Digital Hygrometer HTC-1**,** Jinggoal International Ltd., Guangdong, China)**.** Data were recorded two times a day (morning and evening) and compiled to generate the daily average. Recorded data were compiled every seven days to determine the weekly average.

Measurement of electricity consumption and CO_2 emissions

Electricity consumption for individual pig house management (mainly heating, lighting and ventilation) was recorded based on the electricity consumption recorded by individual meters (Model: LD 1210DRa-040, LSis, South Korea). For comparison, electricity consumption were measured separately for each experimental house per unit (m_2) of house space.

One of the most important greenhouse gases is carbon dioxide (CO_2). Carbon dioxide emissions associated with electricity use; and from slurry were measured for each experimental pig house separately using different formulas.

Formula for CO_2 emissions from electricity use
The following equation was used to predict equivalent CO_2 emissions from energy according to Intelligent Energy Europe (IEE) (http://ec.europa.eu/energy/environment).

$E\text{-}CO_2 = g_{el}E_{el}$ ---Eq. (1)
where,

E-CO_2 = Equivalent carbon dioxide (CO_2) emissions from electricity use, kg.day^{-1}
g_{el} = 0.547 kg CO_2/kWh, which is the specific CO_2 emission factor for electricity
E_{el} = Amount of electricity consumed, kWh.

Measurement of odorous gas (NH_3, H_2S and SO_2) emissions

Odorous gases emitted from the conventional, geothermal and ground channel experimental houses were measured for three consecutive days every week. Gas was measured using a Gastec (model GV-100) gas sampling pump (Gastec Corp., Japan) and Gastec detector tubes. Specifically, gas detector tubes No. 3L (0.5–78 ppm), 3La (2.5–200 ppm) and 3M (10–1000 ppm) were used for NH_3 measurement, while 4LT (0.1-4 ppm) and 4LK (1-400 ppm) was used for H_2S measurement and 5Lb (0.05-10ppm) was used for SO_2 measurement. All measurements were conducted by using the Gastec pump 0.2m above the slurry level (different position) and repeated three times for more accuracy. The concentration of each gas was determined based on the average of the three measurements. Finally, the entire dataset was used to determine the average for all houses separately. The noxious gaseous emissions were expressed in ppm for the houses.

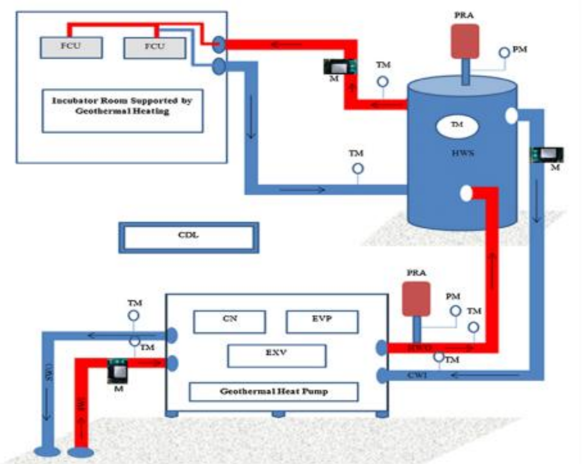

Figure 1 Geothermal heating system. SWI = source water in, SWO = source water out, M = motor, CN = condenser, EVP = evaporator, EXV = expansion valve, HWO = hot water out, CWI = cold water in, PRA = pressure release absorber, PM = pressure meter, HWS = hot water sink, FCU = fan-coil unit and CDL = central data logger.

Measurement of microbial contaminants

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 aciduric bacteria 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).

Statistical analyses

Temperature, relative humidity, energy consumption, gaseous emissions and microbial contaminants data were analyzed using SAS (2003). Means were compared based on Duncan's Multiple Range Test (DMRT). A $P<0.05$ was considered to indicate significance.

RESULTS

The result of the temperature and relative humidity (Table 1) of the present investigation elucidated that, temperature was significantly lower in channel house in comparison to control and geothermal house ($P<0.05$); while relative humidity was significantly higher in channel house ($P<0.05$).

Table 1 Comparison of conventional, geothermal and ground channel system house on temperature and relative humidity with weaned pigs.

Parameters	Experimental pig houses			SEM	P-value
	Conventional	Geothermal	Channel		
		Temperature (°C)			
1st week	23.18^a	22.80^a	20.37^b	0.40	<0.0001
2nd week	23.61^a	23.05^a	20.86^b	0.33	<0.0001
3rd week	23.41^a	22.95^a	21.20^b	0.34	0.002
4th week	23.48^a	22.64^{ab}	20.31^b	0.71	0.055
Mean	23.42^a	22.86^b	20.69^c	0.13	<0.0001
Difference (%)	Con vs Geo	Con vs Chan	Geo vs Chan		
	2.40	11.67	9.50		
		Relative humidity (%)			
1st week	38.71^b	39.29^b	53.85^a	2.38	<0.0001
2nd week	44.00^b	43.43^b	52.16^a	2.12	<0.0001
3rd week	48.21^{ab}	42.29^c	51.31^a	2.44	<0.0001
4th week	36.50^b	38.14^b	50.36^a	2.48	<0.0001
Mean	41.86^b	40.79^b	51.92^a	1.54	0.0025
Difference (%)	Con vs Geo	Con vs Chan	Geo vs Chan		
	2.56	-24.05	-27.30		

a, b, c Means with different superscripts within the same row are significantly different (P<0.05). SEM = Standard error of mean
Conventional: Conventional heating system; Geothermal: Geothermal heating system; Channel: Ground channel airflow heating system.

Table 2 Comparison of conventional, geothermal and ground channel system house on energy consumption and equivalent CO_2 emissions.

Parameters	Experimental pig houses			SEM	P-value
	Conventional	Geothermal	Channel		
		Energy consumption (kWh/m^2)			
1st week	2.280	1.731	1.393		
2nd week	2.232	1.595	1.463		
3rd week	2.356	1.563	1.387		
4th week	2.258	1.696	1.474		
Mean	2.282^a	1.646^b	1.429^c	0.030	<0.0001
		CO_2 emission (kg/m^2)			
1st week	1.247	0.947	0.762		
2nd week	1.221	0.872	0.800		
3rd week	1.289	0.855	0.759		
4th week	1.235	0.928	0.806		
Mean	1.248^a	0.901^b	0.782^c	0.016	<0.0001
Saving potential (%)	Con vs Geo	Con vs Chan	Geo vs Chan		
	27.844	37.355	13.181		

a, b Means with different superscripts within the same row are significantly different (P<0.05).
SEM = Standard error of mean
Conventional: Conventional heating system; Geothermal: Geothermal heating system; Channel: Ground channel airflow heating system.
Con vs Geo = Control versus Geothermal; Con vs Chan = Control versus Channel; Geo vs Chan = Geothermal versus Channel.

As shown in the Table 2, energy consumption and equivalent CO_2 was significantly lower in both geothermal and channel house relative to control house (P<0.05). In addition to that, geothermal system can potentially reduce energy consumption and CO_2 emission around 28% relative to conventional system; where ground channel system can potentially reduce around 37% energy consumption and CO_2 emissions. Moreover, it was observed that, ground channel system can efficiently reduce around 13% energy consumption and CO_2 emission in comparison to geothermal system.

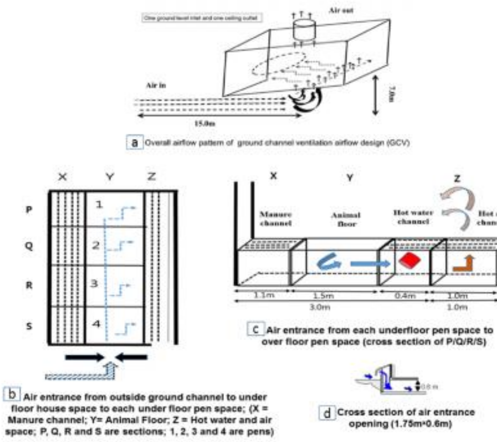

Figure 2 Ground channel airflow heating system. a. Overall airflow heating system; b. airflow entrance from outside to underfloor inside; c. airflow from under floor pen space to over floor pen space; d. cross section of airflow entrance.

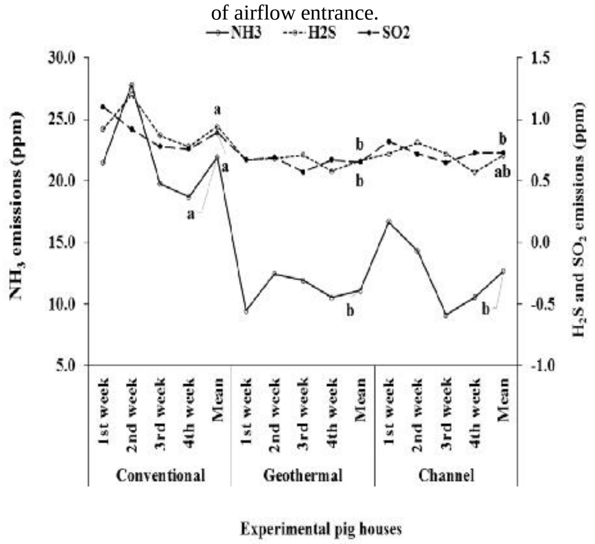

Figure 3 Comparison of conventional, geothermal and ground channel system house on odorous gas emissions.

[a, b] Means with different superscripts within the same line are significantly different (P<0.05).
SEM = Standard error of mean
Conventional: Conventional heating system; Geothermal: Geothermal heating system; Channel: Ground channel airflow heating system.

The result of the odorous gas emissions from the experimental pig houses were shown in figure 3. It was found that, ammonia and hydrogen sulfide was significantly lower in geothermal and channel house than the control house (P<0.05); while sulfur dioxide was only lower in geothermal house relative to control house (P<0.05).

Table 3 Comparison of conventional, geothermal and ground channel system house on microbial concentration.

Microbiology (cfu)	Experimental pig houses			SEM	P-value
	Conventional	Geothermal	Channel		
Total microbes	235.75^a	182.50^b	187.50^b	7.23	0.002
Aciduric bacteria	26.75^a	18.50^b	19.50^b	1.86	0.024
Mold	43.00^b	43.75^b	56.75^a	3.14	0.023
Bacilli	52.75	36.75	48.00	6.46	0.256
Salmonella	0.47	0.22	0.44	0.11	0.260
E. coli	0.53	0.35	0.31	0.13	0.465

[a, b] Means with different superscripts within the same row are significantly different (P<0.05).
SEM = Standard error of mean
Conventional: Conventional heating system; Geothermal: Geothermal heating system; Channel: Ground channel airflow heating system.

Table 4 Comparison of conventional, geothermal and ground channel system house on growth performance of weaned pigs.

Parameters	Experimental pig houses			SEM	P-value
	Conventional	Geothermal	Channel		
IBW (kg/pig)	17.75	17.65	17.69	0.11	0.84
FBW (kg/pig)	41.64	42.18	41.84	0.75	0.90
Weight gain (kg/pig)	23.89	24.53	24.15	0.73	0.87
Feed intake (kg/pig)	45.59	44.45	44.29	0.77	0.52
Gain: Feed	0.53	0.55	0.54	0.02	0.74

[a, b] Means with different superscripts within the same row are significantly different (P<0.05).
SEM = Standard error of mean
Conventional: Conventional heating system; Geothermal: Geothermal heating system; Channel: Ground channel airflow heating system.

In the Table 3, microbial analysis revealed that, total microbes and aciduric bacteria were significantly lower in geothermal and channel house; however, mold count was significantly higher in channel house in comparison to control and geothermal house (P<0.05). While other microbial concentration (*Bacilli*, *Salmonella* and *E. coli*) did not differ significantly among the experimental houses.

As shown in Table 4, the growth performance data of the growing pigs elucidated that, body weight gain, feed intake and feed efficiency did differ significantly among the houses (P>0.05). However, the bodyweight gain and feed efficiency value was found somewhat higher in the geothermal and ground channel houses.

DISCUSSION

With a part of the energy crisis mitigation and reduction of CO_2 emissions; minimization of the utilization of energy in the agriculture sector (where livestock is the sub-sector) should be given priority. Because large amount of energy is utilized directly and indirectly for the total inter cultural operations as well as for the manufacturing, processing and transportation of agricultural commodities (Singh, 2000; CAEEDAC, 2000; Kennedy, 2000). Whereas subsector of agriculture, livestock production accounts energy consumption for animal management (especially intensive confinement), heating, cooling, ventilation, production and processing of the animal products; feed production and processing; operation of the farm machinery (Steinfield *et al*., 2006). Due to the different management of agriculture, greenhouse gas emissions accounts for about 22% of global total emissions where the contribution is similar to that of industry and greater than that of transport. Where the animal agriculture (including transport of livestock and feed) accounts for approximately 80% of the sector's emissions (McMichael *et al*., 2007). Hence, ground level systematic approach of the geothermal and ground channel required lower energy consumption compared to the conventional system house, consequently it could incurred lower energy cost as well as lower CO_2 emission through the burning of carbon skeleton and biomass. Wajman, (2011) and Lee and Choi (2012) also reported that, ground level heat exchanger and underground airflow are efficient and required lower price.

The lower temperature and higher relative humidity in the ground channel than the geothermal and conventional house implicated that, general principle of negative correlation between temperature and relative humidity was existed; however, extra care should be taken in the ground channel house if the temperature requirement of the growing pigs is not sufficient. The lower temperature might be attributable to the airflow and higher heat removal potential of the ground channel system (Van Wagenberg and Smolders, 2002).

The lower odorous gas and microbial concentration in the geothermal and ground channel might be ascribed as the fresh air supply and the contaminant removal potential airflow through geothermal system and the ground channel system; (Van Wagenberg and Smolders, 2002; Choi *et al*., 2012). Supporting to our study, Choi *et al*. (2010) reported lower NH_3, H_2S in case of geothermal heating system in case of furrowing pig house.

The insignificant differences of growth performance of the weaned pigs among the conventional, geothermal and ground channel system house indicated that, there was no negative impact of geothermal and ground channel system. Rather, it was observed somewhat higher weight gain and gain to feed ratio. Choi *et al*. (2010) also found some higher weaning weight during furrowing pig experiment. The prevailing lower gaseous and microbial concentrations both in the geothermal and ground channel system might be attributable in the better performance of the weaned pigs.

CONCLUSION

Both geothermal and ground channel system was effective compared to conventional heating system on the aspect of saving energy consumption as well as reducing CO_2 (potentially reduce 28% and 37%, respectively). Additionally both geothermal and ground channel system was efficient in substantially suppressing the odorous gas emissions (NH_3, H_2S and SO_2), and the risk of microbial contaminants (Total microbes and aciduric bacteria) into the animal house environment and ensure no negative impact on the growth performance of the growing pigs. Our result also implicated that, geothermal system was more effective in maintenance of internal house temperature compared to ground channel; whereas, ground channel system was more effective in saving energy consumption and reducing CO_2 emissions. Thus, present result suggested on a broader view that, geothermal and ground channel system can contribute to the global energy crisis and global gas emissions reduction through potential saving of energy consumption and reduction of CO_2 and odorous gas emissions.

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