Geothermal Systems for Heating and Cooling in Swine Production

B.Z. Predicala, A.C. Alvarado, and L.T. Dominguez

Bernardo Predicala

Alvin Alvarado

SUMMARY

This study assessed the applicability of a geothermal system in swine production facilities. In-barn evaluation of the impact of the geothermal system on energy use, thermal environment, greenhouse gas emissions, and animal performance was conducted by comparing a swine grow-finish room with geothermal system to a conventional production room with a forced-convection gas-fired heater system over summer and winter seasons. Results showed that the room with the geothermal system consumed about 36% less total energy for heating and ventilation during cold season compared to the conventional room. However, during the warm season, the use of the geothermal system to cool the room resulted in larger energy use compared to the control room. Levels of greenhouse gases, namely, methane and carbon dioxide in the geothermal room when the system was in operation were significantly lower than that in the room with the conventional gas-fired heater during both heating and cooling periods.

INTRODUCTION

Previous studies showed that energy costs in swine operations range from about $7 to $12 per pig sold; this has steadily increased over recent years and now represents the third largest variable cost in hog production (after feed and labour). Maintaining the desired conditions year round in a production barn requires significant amount of energy, particularly in cold climate regions. A survey of 28 swine farms in Saskatchewan showed that heating and ventilation costs constitute almost 80% of energy used in various types of swine barns. Compared with conventional heating systems using either gas, oil or electricity, a geothermal system utilizes ground heat to provide primary heating and cooling.

RESULTS AND DISCUSSION

Computer simulation analysis was done to calculate the overall heating energy use in a production room operated under normal management practices; this served as the basis for designing the required capacity and the associated components of the geothermal system needed to meet the projected heating energy consumption in the pig room.

The geothermal system, or alternatively known as ground source heating system was composed of a heat pump and 550 m of 1.9-centimetre diameter polyethylene pipes buried in 2.6 m to 3 m deep trenches on the ground outside the PSCI barn. The buried pipes contained 20% methanol - 80% water solution for absorbing heat from the ground for heating and for using the ground as heat sink during the cooling trial. A 5-ton heat pump which used R-410a refrigerant was installed in the geothermal room and its air-handling unit was connected to the room's air recirculation duct. A 22-kW forced convection heater was also installed in the room as back-up heater.

Energy consumption for heating and ventilation

Energy consumption for heating and ventilation comprised the total energy use in each experimental room. Energy consumption for heating included both the electrical and heating fuel consumption of the geothermal heat pump and heaters while that for ventilation included the electrical consumption for both ventilation and recirculation fans. For the three heating cycles used in this analysis, the heaters needed to operate only during the first 3 to 6 weeks of the trial when the pigs were still small and the room temperature setpoint were the highest (i.e., supplemental heat from the heaters were required to maintain the setpoint temperature). On subsequent weeks of the room cycle, the heaters were only needed minimally with negligible energy usage because the heat generated by the pigs was sufficient to maintain the setpoint temperature in the room.

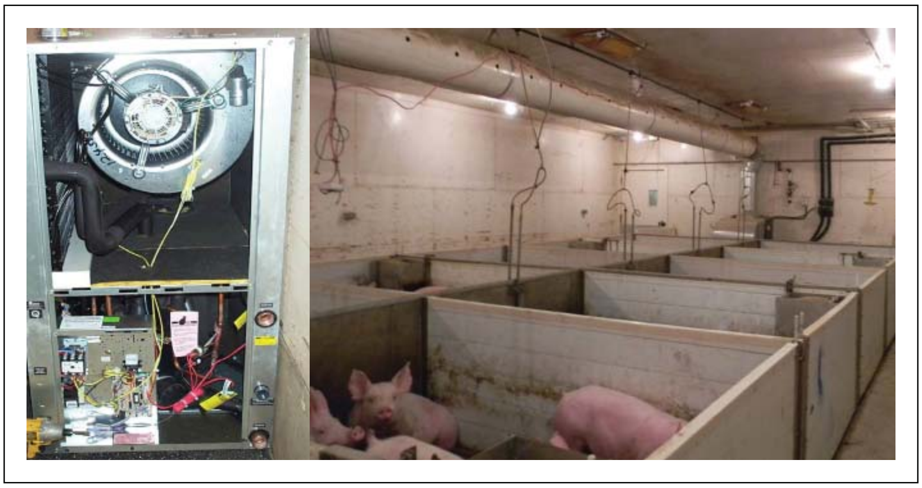

Figure 1. Heat pump used in the geothermal system installed in a grow-finish room.

Table 1. Energy consumption for heating and ventilation in the geothermal and control rooms over three heating trials

Trial	Heating		Ventilation	
	Geothermal, kWh electricity	Control, m3 natural gas	Geothermal, kWh	Control, kWh
1	1232	226.5	476	426
2	705	201.2	194	199
3	1682	141.6	175	181
Average	1206 ± 489	189.8 ± 43.6	282 ± 169	268 ± 136

Table 1 shows the energy consumed by the geothermal and control rooms for heating and ventilation during the period when heaters were running. On average, the room with the conventional gas-fired heater (Control) consumed a total 189.8 ± 43.6 m^3 of natural gas for heating. The room with the geothermal heating system did not use any natural gas but consumed a total of 1206 ± 489 kWh of electricity mainly to run the heat pump. On the other hand, the energy consumption for ventilation in the control room was about 268 ± 136 kWh of electricity while the geothermal room used about 282 ± 169 kWh of electricity to ventilate the room during the heating season.

Since the heating fuel consumption was expressed in terms of cubic metres (m^3) of natural gas while electrical consumption of heaters and fans was in kWh, the weekly average energy consumption data of the two rooms were converted to gigajoules (GJ) to be able to compare the two heating systems. Results showed that the weekly energy consumption for heating the geothermal room was significantly lower ($p<0.10$) than in the control room. Additionally, the two rooms did not differ significantly in average weekly energy consumption for ventilation. Thus, over one growth cycle, the geothermal heating system required less energy (5.36 GJ) to extract heat from the ground and to heat the room air compared to the conventional natural gas-fired heater (8.43 GJ); this is about 36% significant reduction ($p<0.10$) in total energy needed for heating and ventilation compared to the control room.

Temperature and relative humidity

Average air temperature at the center of the rooms as well as the temperature and relative humidity near the exhaust fans when heaters were in operation are presented in Table 2. Both rooms had almost the same room air temperature and relative humidity over the three heating trials. On average, the temperature at the center of the room with the geothermal heating system was about 21.3 ± 0.5 ^{0}C while the control room had 21.8 ± 0.6 ^{0}C. Furthermore, an average temperature of about 19.6 ± 1.0 ^{0}C and relative humidity of 60.2 ± 6.9 % were observed near the exhaust area of the geothermal room; these were about 4.8% less than the corresponding temperature and relative humidity in the control room, respectively.

CONCLUSION

Based on the findings of this study, the following conclusions can be made:

i. In-barn evaluation of the geothermal system showed about 36% reduction in energy consumption for heating and ventilation in the room with the geothermal system during the heating season relative to the room with the conventional forced-convection heater. The mean air temperature, relative humidity, and air quality within the two rooms were relatively similar during winter season.

ii. During the cooling season, the geothermal room had higher total energy for heating and ventilation (1475 kWh higher) than that in the conventional room, mainly for the operation of the heat pump. Average room air temperature was cooler in the geothermal room compared to the conventional room.

iii. Significant reduction in methane and carbon dioxide concentration during heating and cooling trials was observed in the room with the geothermal system relative to the room with the conventional gas-fired heater.

ACKNOWLEDGEMENTS

Project funding provided by Saskatchewan Agriculture Development Fund and the Saskatchewan Pork Development Board. Strategic funding provided by Sask Pork, Alberta Pork, Ontario Pork, Manitoba Pork Council and Saskatchewan Agriculture Development Fund.

Table 2. Average air temperature (^{0}C) and relative humidity (%) in the geothermal and control rooms when heaters were in operation.

Trial	Temperature at center of room, ^{0}C		Temperature near the exhaust fans, ^{0}C		Relative Humidity, %	
	Geothermal	Control	Geothermal	Control	Geothermal	Control
1	20.9	21.2	18.4	19.2	67.3	67.5
2	21.8	22.3	20.0	19.8	59.9	65.9
3	21.3	21.9	20.3	20.2	53.5	61.5
Average	21.3 ± 0.5	21.8 ± 0.6	19.6 ± 1.0	19.7 ± 0.5	60.2 ± 6.9	65.0 ± 3.1