Comparison of performance of radiant and forced-convection heaters in swine grow-finish rooms

Predicala, B.,[1], L. Moreno[1,2], E. Navia[1], A. Alvarado[1,2], L. Dominguez[1,2], Y. Jin[1], J. Price[3]
[1]Prairie Swine Centre Inc., Saskatoon, SK; [2]University of Saskatchewan, Saskatoon, SK; [3]Alberta Agriculture and Rural Development, Edmonton, AB

B. Predicala

SUMMARY
The goal of this study was to conduct a comparative evaluation of two heating systems in terms of energy efficiency as well as effect on barn environmental conditions and hog performance. An infrared radiant heater and a forced-air convection heater were installed separately in two grow-finish rooms at Prairie Swine Centre Inc (PSCI). Consumption of natural gas and electrical energy were monitored in each room, as well as air temperature, relative humidity, and ventilation rate. Additionally, gas sensors were installed to monitor hydrogen sulfide (H_2S), ammonia (NH_3), carbon monoxide (CO) and carbon dioxide (CO^2) concentrations in the rooms. The results from three completed trials showed that the room with infrared radiant heating system consumed more natural gas but less electrical energy compared to the room with forced-air convection heater. Mean air temperature was higher in the room with forced-convection heater than in the room with radiant heater, but air temperature distribution at various locations within each room was similar. Generally, the relative humidity, ventilation rate, gas concentrations (NH_3, H_2S, CO and CO^2), and pig performance were relatively similar between the rooms, indicating no significant impact of the type of heater on these parameters.

INTRODUCTION
Swine production entails energy-intensive operations such as space and creep heating, ventilation and lighting, feed and manure handling, power washing, among other things. Due to increasing energy prices, energy cost now ranks third among the variable cost components of the total hog production. As reported by Barber et al. (1989), heating and ventilation are major contributors to energy use in different types of hog barns. With the increase in energy prices in recent years, the cost of natural gas has increased almost fourfold from $0.11/m3 in 1998 to $0.42/m3 in 2006 and electricity costs have gone from $0.08/kWh to $0.11/kWh (Huffman and MacDonald, 2006). Natural gas-fired convection heaters is widely used for space heating in hog production rooms. In this research work, a gas-fired infrared heating system was investigated as a possible measure that can be adapted for space heating in barns. Unlike the forced-air convection heater that works by heating up the air within the room and then the heated air mass needs to be physically moved to the animal occupied zones, the radiant heater transmits heat to surfaces (i.e. floor, pen wall, animals, etc) through radiation heat transfer and thus speeds up the heating process at the pig level.

The overall goal of this study was to carry out a comprehensive comparison of convection and radiant heating systems in terms of energy efficiency and their effect on environmental conditions in the barn and on hog performance.

EXPERIMENTAL PROCEDURES
Two grow-finish rooms at PSC were used in this study. Each room has inside dimensions of 66 x 24 x 10 ft and has 20 pens that could accommodate 5 pigs each. Both rooms were operated on a negative pressure ventilation system, with fresh air entering through 10 modular ceiling inlets and exiting through three sidewall fans. Both rooms were operated with identical setpoints for the heating and ventilation system and managed according to typical production practices.

"No major differences in the overall energy use (natural gas and electrical energy) was observed between rooms with infrared radiant heater and forced-air convection heater systems."

A new gas-fired infrared radiant heater was installed in the Treatment room while a new gas-fired forced-air convection heater was installed in the Control room; both types of heaters has a heating capacity of 80,000 BTUh. Thermocouples, relative humidity (RH) and fan-speed sensors were installed in each room to monitor thermal parameters while electrochemical gas sensors were used for monitoring gas levels (ammonia, hydrogen sulphide, carbon dioxide and carbon monoxide) in the room.

Weaner pigs weighing around 20-35 kg were used in the experiment. The animals were weighed, sorted by gender and distributed equally to the two rooms. Each trial is 12 weeks long with the first week allotted for animal and room preparation and the remaining eleven weeks for continuous monitoring and data collection. The average daily gain (ADG), average daily feed intake (ADFI), and mortality rate in both rooms were monitored.

RESULTS
Gas and electrical energy consumption
Figure 1 shows the weekly average gas consumption in both rooms during the trials. Both heaters were barely in operation after Week 7 since pigs at this growth stage were al

ready large enough to generate their own heat and sustain the required setpoint temperature, thus supplemental heat was no longer needed. For all three trials, total gas consumption over the course of a trial was higher in the radiant heater room ($p=0.04$) compared to the forced-air convection heater room by an average of 12.1 m^3.

Figure 2 shows the weekly average electrical energy consumption in both rooms over 3 trials. Throughout the 13-week test period, average weekly electrical consumption was relatively similar in both rooms, with the operation of the ventilation fans in response to prevailing ambient conditions mainly influencing the week to week variation in electricity consumption. Total electricity use over the course of a trial was slightly higher ($p=0.86$) in the forced-air convection heater room than in the infrared radiant heater room by about 1.9 kWh. This difference could be attributed to the additional electrical energy use by a recirculation fan in the forced-air convection heater room, which is an integral part of the heating and ventilation system necessary to distribute heat more uniformly throughout the room.

Temperature, relative humidity and ventilation

Figure 3 shows the average air temperature readings at different locations within the two rooms. Despite the same setpoints used for both rooms for all trials, the overall mean temperature from all locations in each room was higher ($p<0.05$) in the forced-air convection heater room (19.2 °C) than in the radiant heater room (18.4 °C). Within each room, temperatures near the middle of the room were slightly higher than those at the peripheral locations of the room, particularly near the wall with the exhaust fan (outside wall).

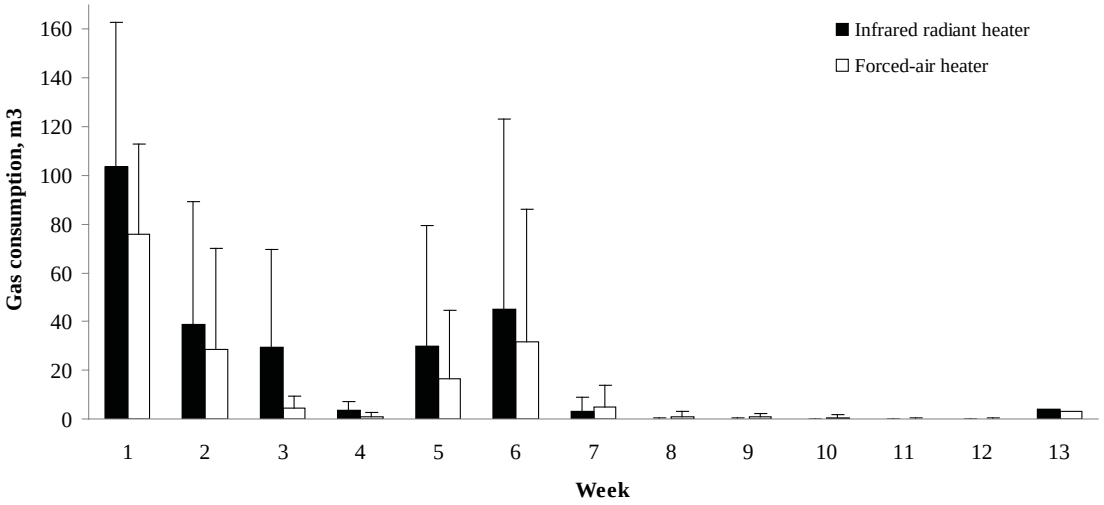


Figure 1. Average weekly gas consumption in the two rooms over 3 trials. Error bars represent standard deviation of weekly gas consumption for the 3 trials.

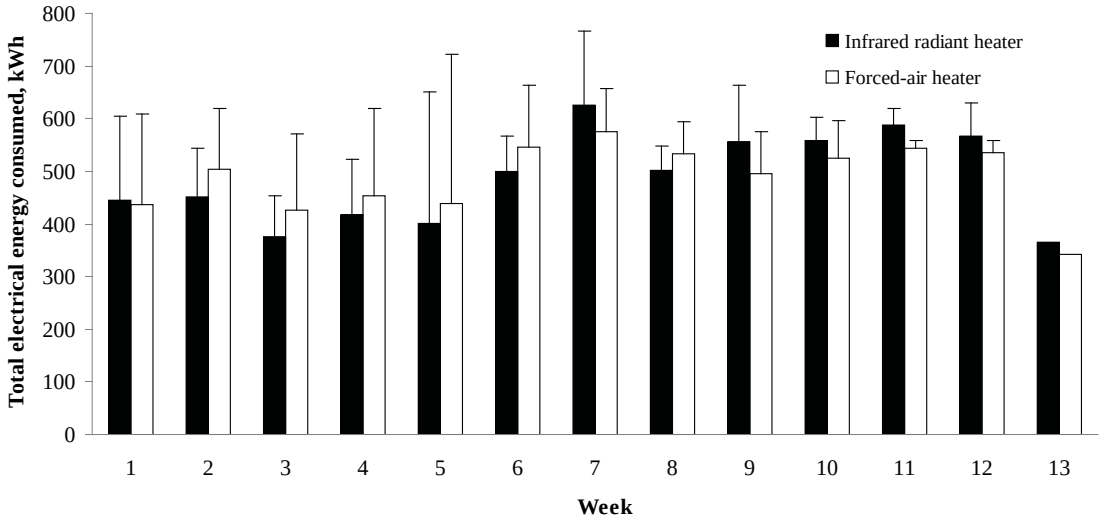
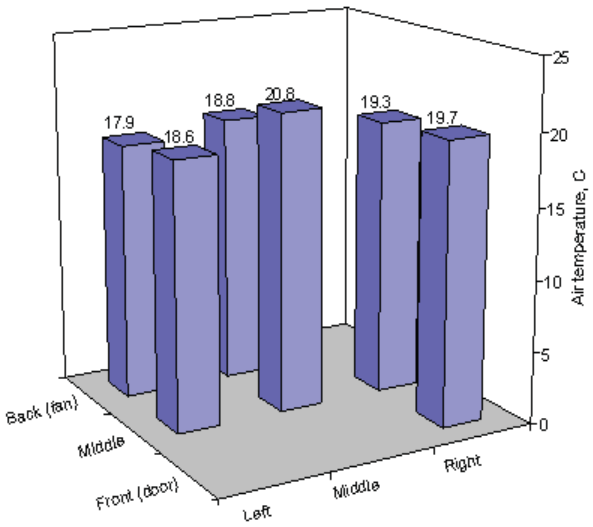


Figure 2. Average weekly electrical energy consumption in both rooms over 3 trials. Error bars represent standard deviation of electrical energy use for 3 trials.

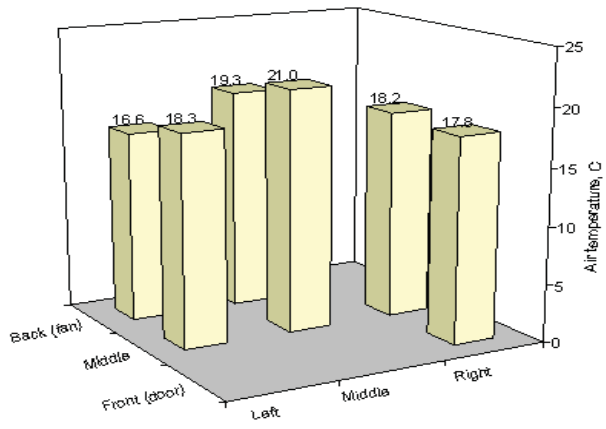
Comparison of the deviation from the mean temperature at the various locations in each room showed no significant differences (p=0.85), indicating similar uniformity in temperature distribution in both rooms.

Relative humidity readings were monitored at the middle and near the exhaust fan in both rooms. Generally, the average RH at the middle of the control room (55.5%) was higher (p<0.05) than in the trreatment room (52.3%). Near the exhaust, the average RH readings were relatively higher (58.9 - 59.2%) than at the middle of the room, but no significant difference (p=0.75) was observed between the two rooms.

The overall mean ventilation rate in the radiant heater room (2,050 L/s) was slightly higher than in the forced-air convection heater room (1,870 L/s), but due to wide variation in ventilation rate values throughout the trials, the differences between the two rooms was not significant (p=0.15).



(a)



(b)

Figure 3. Average air temperature measured at various locations in the (a) forced-convection heater room and the (b) radiant heater room.

Table 1. Weekly average concentrations (in ppm) and standard deviations (SD) of various gases monitored in the two rooms.

	Forced-air heater		Radiant heater		
Gas	**Mean**	**SD**	**Mean**	**SD**	**P-Value**
NH_3 (n=34)	6.38	4.79	5.89	3.85	0.58
CO (n=25)	0.25	0.46	0.26	0.47	0.90
H_2S (n=29)	0.46	0.82	0.29	0.68	0.09
CO_2 (n=20)	2036.97	1059.81	1298.31	498.19	0.01

Gas concentrations

Table 1 shows the mean concentrations of different gases monitored over the course of the trials. Hydrogen sulphide (H_2S) and carbon monoxide (CO) concentrations in both rooms were usually at levels barely detectable by the respective sensors with typical levels below 1 ppm. As expected, concentrations of H_2S were observed to spike to considerably high levels (>90 ppm) during pit pulling events. Ammonia (NH_3) and carbon dioxide (CO_2) levels were similar in both rooms with average concentrations below 10 and 2000 ppm, respectively. Among these various gases, only CO_2 levels were found to differ significantly (p=0.01) between the two rooms, with higher values in the control room compared to the treatment room. This can be attributed to the operation of the forced-air convection heater, which vented combustion gases into the airspace.

Pig performance

Over the course of the trials, the average daily gain (ADG) and average daily feed intake (ADFI) in both control and treatment rooms were relatively similar (p>0.05). Mean ADG values from all trials were 0.97 and 0.98 kg/pig-day while ADFI values were 2.51 and 2.60 kg/pig-day for the control and treatment rooms, respectively. Average mortality rates from all trials were 2.0% and 0.60% for the control and treatment rooms, respectively.

IMPLICATIONS

Trends observed from these trials showed no major differences in the overall energy use (natural gas and electrical energy) between the rooms with infrared radiant heater and forced-air convection heater systems. Both heater types had similar uniformity in air temperature distribution within the room. Gas concentrations (ammonia, hydrogen sulfide, carbon monoxide and carbon dioxide) and animal performance was not affected by the type of heater used.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Alberta Agriculture and Rural Development for the financial support of this research project. The authors also acknowledge the strategic program funding provided to Prairie Swine Centre Inc. by Sask Pork, Alberta Pork, the Manitoba Pork Council and the Saskatchewan Agriculture Development Fund.