RESEARCHREPORT

Title: Zone Heating for Wean-to-Finish Facilities: A Performance Comparison - **NPB #02-194**

Investigator: Richard R. Stowell

Institution: University of Nebraska – Lincoln

Date Received: May 3, 2004

Abstract: Farm research trials were conducted in 2003 and 2004 to assess the effects of the type of zone heater and floor mat used in a wean-to-finish building on the thermal environment created for newly weaned pigs and resulting pig performance. Modulated LP gas-fired brooder heaters were compared to electric heat lamps, and floor mats made from farm-cut wood sheathing (3/8" oriented-strand board, OSB) were compared to commercial [unheated] rubber mats in a replicated 2x2 factorial experiment. No consistent differences in air temperature near the heating zone were found between either of the treatments, with treatment means within 1 °F of each other in both trials. In pens having modulated gas-fired heaters, black-globe temperatures just outside the heating zone were consistently warmer (+2-2.5 °F, $P<0.05$) than in pens with heat lamps. Black-globe temperatures were also warmer in pens with OSB mats (+0.5-2 °F) than in pens with rubber floor mats. Conversely, the temperature of exposed mat surface area was warmer (93.9 °F vs. 86.3 °F on average, $P<0.001$) under the heat lamps than under the brooders. However, no significant difference was found in pig dorsal surface temperature. There was some evidence ($P<0.10$) that the temperatures of exposed mat surface areas were slightly warmer with rubber mats than with OSB sheathing (91.4 °F vs. 88.9 °F), but no corresponding difference in pig surface temperatures was found.

Overall, no statistically significant treatment differences in pig performance were found at the end of the zone-heating periods. Slightly higher rates of gain during the first week were found in pens using modulated gas-fired brooders than with heat lamps, but this advantage was not sustained. Time-lapse video footage helped document pig activity, but any differences that may have existed in pig activity did not noticeably influence performance. Daily energy consumption rates averaged 0.025 gal/pig/d for the LP gas-fired brooders and 0.40 kWh/pig/d for the electric heat lamps. For electricity prices ranging from 6 to 12 ¢/kWh and LP gas prices of $0.70-1.40/gal, annualized equipment & operating costs varied from $1.26 to $2.26 per pig place for electric heat lamps and $2.26 to $3.00 for the gas-fired brooders. Unless gas prices are low relative to electric rates, or some other financial benefit is obtained by using gas-fired brooders, heat lamps would appear to have an economic advantage for producers due to their lower unit fixed cost in equipment.

These research results were submitted in fulfillment of checkoff funded research projects. This report is published directly as submitted by the project's principal investigator. This report has not been peer reviewed

For more information contact:
National Pork Board, P.O. Box 9114, Des Moines, Iowa USA
800-456-7675, **Fax:** 515-223-2646, **E-Mail:** porkboard@porkboard.org, **Web:** http://www.porkboard.org/

Introduction: While wean-to-finish systems are rapidly gaining in use, the development of useful information on the appropriate selection of zone-heating components has not kept pace. The advantages of wean-to-finish production systems lie mainly in moving pigs one less time during production, which results in less stress on the pigs and reduced labor associated with moving pigs from a nursery unit to the grow-finish facility. Improved profit potential depends largely on performance soon after pigs are placed in the wean-to-finish facility - when the newly weaned pigs are placed in a facility designed to accommodate much larger market-weight hogs. Thermal stress is a major potential source of stress on young pigs, especially in a wean-to-finish setting. This experiment investigated a couple of available options to see which provided a comfortable thermal environment at minimal cost.

Objectives: Specific objectives of this research were to:

i) Determine the effects of using electric heat lamps vs. gas-fired brooder heaters as the heating source and rubber vs. wood sheathing for floor mats on the thermal environment created for newly weaned pigs, the energy requirement for zone heating, and pig performance in terms of rate of gain and feeding efficiency; and

ii) Determine which of the combinations above are the most cost-effective for various costs / market prices.

Materials and Methods: A 2x2 factorial randomized design was used with heat source being one treatment factor and type of floor mat being the other. The 4 treatment combinations were replicated four times in the sixteen 8'x14' fully slatted pens within the wean-to-finish facility at Haskell Agricultural Laboratory, Concord, NE. Modulated LP gas-fired brooder heaters were installed and operated in 8 of the 16 pens while electric (250-Watt) heat lamps were used in the remaining 8 pens. Within each of these treatment groups, pens were randomly selected to use either commercial rubber floor mats or mats made of OSB (oriented-strand board) sheathing.

A few adjustments were made to the methods specified in the original proposal. The primary adjustment made in this experiment was that two trials were conducted, rather than one as originally proposed. An outbreak of PRRS developed during the second week of Trial 1 (March 2003), which almost certainly affected pig performance during the trial. Therefore, a second trial was conducted with the zone-heating portion ending in February 2004.

In each trial, newly weaned pigs were placed within pens at a stocking rate of 15 pigs per pen (7.5 sq ft/pig). Each pen had one FarmWeld wean-to-finish feeder and one wean-to-finish cup drinker. Pigs were weighed weekly for the first four weeks post-weaning. Biweekly weights continue to be made through slaughter weight for Trial 2.

Air temperatures within the pig space of each pen were measured (Type-T thermocouples) at 1-minute intervals and hourly average temperatures were recorded via a data logger (Campbell Scientific 21X). Temperatures were monitored above the floor mat (i.e. near the zone heater) and at a consistent interior location away from the zone heater. Weather data for the research station was retrieved to help qualify the observed heating needs. Black-globe temperature sensors were added to better detect heating effects of the two types of heaters. A handheld IR (infrared) temperature sensor was used to measure pig and pen surface temperatures on a regular basis.

Four video cameras were installed within the facility to monitor pig activity within one set of four pens having each of the replicated treatment combinations. Having access to visual data without accessing the facility enabled monitoring of pig activity levels in a non-intrusive manner.

Gas and electric meters recorded energy use for the building throughout the study. A separate gas meter was installed to differentiate the fuel consumption of the zone heaters from the primary heating system for the room. Energy consumption and costs were analyzed and a partial budget was developed, including a sensitivity analysis on energy prices.

Results: Due to the PRRS outbreak in Trial 1, the trial was terminated once zone heating was discontinued, and the pigs were weighed one final time 26 days into the trial. The following winter (January 2004), the wean-to-finish facility was again stocked with newly weaned pigs – from a 'PRRS-negative' operation - for a second trial. At the time this report was written, these pigs continued to be raised in the wean-to-finish facility to market weight. Data used in this report is only for the zone-heating periods of the two trials.

Comparison of Thermal Environments:

A statistical analysis of temperature data from Trial 1 showed that there was no difference between treatments in terms of the air temperature maintained near the zone heating area (1 ft off floor on aisle side of mat). Air temperatures were less than 1 ^{o}F warmer for modulated gas-fired brooders compared to heat lamps and for OSB (oriented-strand board) sheathing compared to rubber mats. Results for Trial 2 again showed no significant differences in air temperature; mean air temperatures of treatment groups were within 0.5 ^{o}F of each other.

Conclusion drawn: *The radiant heaters and floor mats considered have a similar net influence on the air temperature near the edge of the zone-heating area.*

During Trial 1, black-globe temperatures near the edge of the zone heating area within pens having modulated gas-fired heaters or wood mats were higher (about 2 ^{o}F warmer on average) than within their counterpart pens with electric heat lamps or rubber mats. Statistically significant differences ($P<0.05$) in black-globe temperatures existed between both treatments. Results from Trial 2 confirmed the directions of the advantages found in Trial 1, but to different extents. The difference between heater types was nearly 2.5 ^{o}F in Trial 2, again favoring the modulated gas-fired brooders, whereas the advantage for the OSB mats was only 0.5 ^{o}F, which is within the level of error in the measurement and monitoring system.

Conclusion drawn: *Modulated gas-fired brooder heaters may produce slightly warmer black-globe temperatures at a location 2 feet above the edge of the mat, but it is less likely that the type of mat chosen influences the black-globe temperature at that location.*

Surface temperatures of the mats and of the pigs resting on the mats were measured and recorded several days a week during the zone-heating periods of the trials. During Trial 2, there was very strong evidence ($P<0.001$) that the temperature of exposed mat surface area was several degrees warmer using electric heat lamps than with modulated gas-fired brooders (93.9 ^{o}F vs. 86.3 ^{o}F, on average). A difference of 1.2 ^{o}F in pig dorsal surface temperature (97.5 ^{o}F vs. 96.3 ^{o}F, on average, for heat lamps and brooders, respectively) was not supported statistically. There was some evidence

(P<0.10) that the temperatures of exposed mat surface areas were slightly warmer (91.4 °F vs. 88.9 °F, on average) using rubber mats than with OSB sheathing. A corresponding 1.5 °F difference in pig surface temperatures (97.5 °F vs. 96.0 °F, on average, for rubber and OSB mats, respectively) was not supported statistically.

Conclusions drawn: *Electric heat lamps may warm the exposed surfaces of floor mats more than modulated gas-fired brooders, but no significant thermal advantage was supported for radiant warming of pigs when resting in the zone heating area. Rubber mats might be warmed slightly more than mats made of OSB sheathing, but any advantage in terms of warming of pigs within the heating zone is likely small and difficult to substantiate.*

Comparison of Pig Performance and Activity Levels:

In both trials, rates of gain during the first week in the wean-to-finish facility were slightly higher in pens using modulated gas-fired brooders than with heat lamps. Pig weights were up 3% (7.2 vs. 7.0 kg) through Day 6 (P<0.01) after starting out equal at 5.7 kg, and ADG was 14% higher (0.226 vs. 0.198 kg/day) through Day 6 (P<0.05). Near the end of the zone-heating period (Day 20), however, the advantages with gas-fired brooders were only 2% for pig weight and 3% for ADG, and the differences were no longer statistically significant (P>0.10). No differences in other performance measures for the heaters were observed.

Conclusion drawn: *No difference in pig performance, based upon selection of common electric heat lamps or modulated gas-fired brooders, is expected for wean-to-finish pigs.*

No statistically significant differences in pig performance were observed overall between the two types of floor mats. The two trials produced conflicting information on the effects of mat type on rates of gain. In Trial 1, there was strong support (P<0.05) of slightly improved rates of gain with OSB mats compared to rubber mats toward the end of the zone-heating period (Day 20). Pig weights were 3% heavier (mean of 9.6 vs. 9.3 kg) and ADG was 8% greater (0.234 vs. 0.217 kg/day) for pigs on the wood sheathing. However, no statistically significant differences in performance existed in Trial 2 at Day 6 or Day 20, and the performance values were generally better for rubber mats.

Conclusion drawn: *No difference in pig performance, based upon selection of commercially available rubber mats or OSB [wood] sheathing, is expected for wean-to-finish pigs.*

Four contiguous pens representing each of the four treatment combinations (no replication) were monitored via videotape throughout most of the zone-heating period. Fifteen minutes of sequential footage were recorded every 3 hours. An employee then viewed the tapes and documented pig activity in each of the pens. Based upon 62 viewing periods where activity could be observed for each of the pens, comparisons of pig activity were made for the overall zone-heating period of Trial 1 and the first 7 days of footage (starting Day 4).

During the first week of videotaping, the shares of pigs observed using the mats were very similar for all four pens (84.6-84.7%). Greater proportions of the pigs on the mats were lying down on the mats with modulated gas-fired brooders (94.3 vs. 85.5% for heat lamps) and rubber mats (91.9 vs. 87.8% for OSB mats). Over the full taping period, mat usage was higher when heat lamps were used than with brooders (84.9% vs. 79.6%) and with OSB mats (83.8% vs. 80.7% with rubber). Again, greater proportions of the pigs on the mats were lying down in the pens having gas-fired brooders

(94.8 vs. 92.4% for heat lamps) and rubber mats (94.8 vs. 92.3% for OSB mats), although the differences were smaller.

In terms of other activities, more pigs were observed at the feeder early on in the two pens with gas-fired heaters compared to heat lamps and with OSB mats compared to rubber mats (5.1 vs. 3.5% in both cases). Observed differences over the full zone-heating period were much smaller (4.0 vs. 3.8% in both cases). Early on, more pigs were lying down off of the mat in pens with heat lamps (2.7 vs. 1.5% for brooders) and rubber mats (2.8 vs. 1.4% for OSB mats). Over the course of the zone-heating period, the share of pigs lying off of the mats increased and varied somewhat, in that the share was higher in the two pens with brooders (8.2 vs. 5.1% for lamps). More pigs were again observed lying off the mat in pens with rubber mats than with OSB mats (8.6 vs. 4.6%).

Analysis of video footage from Trial 2 should offer additional insight into pig activity. Since this part of the study did not involve any replication or allow suitable statistical analysis, no firm conclusions were drawn on pig activity. However, one can conclude that any differences that may have existed in pig activity did not noticeably influence performance.

Comparison of Energy Requirements and Economics

Daily energy consumption rates averaged 0.38 gal/pen/d (32,100 Btu/pen/d) for the modulated LP gas-fired brooders and 6.0 kWh/pen/d (20,500 Btu/pen/d) for the electric heat lamps. The rates were very similar for both trials despite there being noticeably different weather conditions (Trial 1 began in March with an average outdoor temperature during the zone-heating period of 45 ^{o}F, compared to Trial 2, which began in January with an average temperature of 11 ^{o}F). The room heaters consumed an average of 407 and 516 gallons of LP gas per day during the same periods of Trial 1 and 2, respectively. The zone-heating period in Trial 1 was longer than in Trial 2 (26 d vs. 21 d) due to pigs being less healthy and slower growing. Consequently, total zone-heating energy use was greater during Trial 1. At 15 pigs per pen (slightly smaller-than-standard pens), daily energy consumption rates averaged 0.025 gal/pig/d for the LP gas-fired brooders and 0.40 kWh/pig/d for the electric heat lamps.

Conclusions drawn: *More fuel energy will be consumed with gas-fired heaters due primarily to expected differences in heating efficiencies of the fuels. The impact of weather on zone-heating fuel usage is relatively small compared to weather's effect on fuel usage by the primary heating system for the room, resulting in more consistent rates of energy usage.*

An economic analysis was performed which considered annualized costs of purchased zone-heating equipment and readily definable annual operating costs (bulb replacement and energy/fuel costs). The following table presents key values from this analysis, based upon currently prevailing equipment and energy costs in Nebraska, and two zone-heating periods a year, each 21 days in length.

The gas-fired heaters had roughly 30% lower operating costs than the electric heat lamps, but higher fixed costs of equipment resulted in nearly 80% higher annualized total cost. For electricity prices ranging from 6 to 12 ¢/kWh and LP gas prices of $0.70-1.40/gal, total annual costs varied from $1.26 to $2.26 per pig place for electric heat lamps and $2.26 to $3.00 for the gas-fired brooders (divide by 2 to obtain approximate cost per finished pig).

Summary table of zone-heating costs

Heating system	Unit fixed cost ($/pen)	System fixed cost ($/pen)	Annualized fixed cost[b] ($/yr/pig[c])	Fuel cost	Operating cost ($/yr/pig[c])	Total cost ($/yr/pig[c])
Brooders	110	[a]118	1.51	$0.875/gal.	0.93	2.44
Lamps	10	10	0.13	$0.066/kWh	1.23	1.36

[a] Based upon use of controls (gas modulating valve and regulators) in a 1,000-head facility.
[b] Based upon 7-year expected useful life of heating equipment and 8% interest rate.
[c] "Per pig" here represents room capacity or "per pig place".

Conclusions drawn: *Based upon prevailing equipment and energy costs in Nebraska, electric heat lamps should have an economic advantage over gas-fired brooders for zone heating in areas having similar prices. The price of electricity relative to LP gas is an important factor to consider when assessing zone-heating equipment, since the operating costs of heat lamps were higher than for gas-fired brooders (with very low electricity prices).*

Discussion: Since zone heaters rely on radiant heating, it makes sense that any thermal differences between treatments would show up in the black-globe and infrared temperatures, rather than air temperatures. It should be noted that, for practical reasons, the black-globe sensors were located outside the direct 'view' of the radiant heaters; therefore, the heating effect on the globe would be due primarily to reflected radiant energy and indirect heating, so heating should have been considerably less than if the globes could have been situated to receive direct radiant heating.

Conflicting trends existed between the surface temperatures measured within the zone heating area (favoring heat lamps and rubber mats) and temperatures of black globes located nearby, but outside the view areas of the radiant heaters (favoring gas-fired heaters and OSB sheathing). One reasonable explanation for this is that more radiant heat from the heat lamps was absorbed by the mats, especially if rubber mats were used, resulting in less heat being reflected away from the heating area (as measured by the black globes) than with gas-fired brooders and OSB mats.

Based upon the two trials, there was no advantage of one heating system or mat type over the other in pig performance. Of the thermal measurements taken, pig surface temperature is probably the most indicative of animal comfort level. Since there was no significant difference in pig surface temperature between the treatments, there is little basis for expecting any resulting difference in thermal comfort or subsequent performance. Differences in mat surface temperatures between treatments were evident, which might influence pig activity (e.g. time spent lying on mats vs. standing on mats). Further investigation of video footage from Trial 2 and more information in general may be required to adequately discuss observations on pig activity.

A number of assumptions were made in the economic analysis. The annual costs presented are probably conservative as it was assumed that two zone-heating periods would occur each year and less zone heat may be required during warm-season production. On the other hand, some may consider a 21-day zone-heating period to be overly aggressive or optimistically short. Costs to install gas and electric lines within the facility were not included since it was assumed that one or both of these lines would often be required to operate room heating, lighting and feeding systems, although installation of the lines could certainly be a sizeable cost. Feed, labor and

other production costs, as well as market hog receipts, were not included since no differences in performance were detected in the experiment during the zone-heating phases and none are expected during the ongoing finishing stage of Trial 2. This experiment did not consider cleaning and maintenance, pig health, or other potentially valuable system amenities, which may factor into the choice of heating system.

Lay Interpretation: The University of Nebraska conducted on-farm research trials in 2003 and 2004 to determine the impacts of zone-heating options for wean-to-finish operations. Modulated LP gas-fired brooders were compared to standard 250 W electric heat lamps, and quartered sheets of 3/8" OSB sheathing were compared to commercially available rubber floor mats in the replicated trials. Farm personnel were able to produce suitable thermal environments with both of the heating systems and mat types evaluated in this study without any extraordinary effort being required. Some minor differences were found in some temperature measurements between systems, but no effect on pig performance existed in the pigs coming out of the zone-heating periods.

Without an advantage in pig performance, the gas-fired brooders are at an economic disadvantage due to higher equipment costs and low electricity prices in Nebraska (about 6.5 cents per kWh) compared to moderate gas prices (around 90 cents per gallon of LP), even though annual operating costs should be lower. Gas-fired heaters may have an advantage in regions where electricity prices are higher relative to natural or LP gas prices.

New OSB sheathing proved to be equally suitable to rubber as a floor mat during these trials in terms of pig performance. Although the wood sheathing is much less expensive initially than are rubber mats, the rubber mats can be readily cleaned and used again. In order to be cost competitive with commercially available rubber mats, the wood mats would probably need to be reused. Questions about the durability and sanitary condition of wood sheathing reused for floor mats remain unanswered at this time.