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Performance of finishing pigs in hoop structures and confinement during winter and summer

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Abstract

Performance of finishing pigs in hoop structures or confinement during winter and summer was evaluated in Iowa. Hoops are large, tent-like shelters with cornstalks or straw for bedding. During summer and winter seasons for 3 yr (1998 to 2001), six trials were conducted using three hoop barns (designed for 150 pigs per pen, one pen per hoop) or a mechanically ventilated confinement barn with slatted floors (designed for 22 pigs per pen, six pens in the barn). A total of 3,518 pigs started the trials. Summer trials were June through October, and winter trials were December through April. Target stocking density was 1.11 m^2/pig in hoops and 0.74 m^2/pig in confinement. Identical corn-based diets were fed ad libitum from 16 to 118 kg for 127 d. Pigs were scanned before harvest for backfat and loin muscle area. When seasons were merged (season × housing interaction, $P \geq 0.05$), hoop-fed pigs had more backfat (21.8 ± 0.3 vs 20.8 ± 0.2 mm; $P < 0.001$), smaller loin muscle area (41.3 ± 0.3 vs 43.0 ± 0.2 cm^2; $P < 0.001$), less lean percentage (51.1 ± 0.2 vs 52.1 ± 0.1%;$P < 0.001$), and less yield (74.9 vs 75.8 ± 0.1%; $P < 0.001$) than confinement-fed pigs. When season × housing type interactions were observed ($P < 0.004$), summer hoop-fed pigs had greater ADG (834 ± 5 vs 802 ± 3 g/d; $P < 0.001$), required fewer days to 113 kg (174.9 ± 0.9 vs 178.5 ± 0.6 d; $P < 0.01$), had similar ADFI (2.40 ± 0.03 vs 2.35 ± 0.02 kg/d, as-fed basis) and gain:feed (G:F; 348 ± 4 vs 342 ± 3 g/kg) compared with confinement-fed pigs. Lean gain/day and efficiency of lean gain did not differ between housing systems. During winter, hoop-fed pigs had similar ADG (794 ± 5 vs 801 ± 3 g/d), required more days to 113 kg (176.7 ± 0.9 vs 172.9 ± 0.6 d; $P < 0.01$), had greater ADFI (2.54 ± 0.03 vs 2.35 ± 0.02; $P < 0.001$), less G:F (313 ± 4 vs 341 ± 3; $P < 0.001$), less lean gain/day (312 ± 2 vs 322 ± 1 g/d; $P < 0.01$), and less efficiency of lean gain (130 ± 2 vs 144 ± 1 g lean gain/kg feed; $P < 0.01$) than confinement-fed pigs. Percentage of mortalities and culls did not differ between housing systems. During summer, there was a trend for fewer light pigs at marketing (< 100 kg) from hoops (0.8 vs 1.7%; $P = 0.10$). During winter, there were more light pigs at marketing from hoops (3.9 vs 1.3%; $P = 0.01$) than from confinement. Bedding use in hoops was 92 and 122 kg/pig for summer and winter, respectively. Performance of finishing pigs in bedded hoop structures depends in part on thermal environment.

Keywords

Deep Litter Housing, Finishing, Pigs, Swine Housing

Disciplines

Agriculture | Animal Sciences | Bioresource and Agricultural Engineering

Comments

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Performance of finishing pigs in hoop structures and confinement during winter and summer[1]

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ABSTRACT: Performance of finishing pigs in hoop structures or confinement during winter and summer was evaluated in Iowa. Hoops are large, tent-like shelters with cornstalks or straw for bedding. During summer and winter seasons for 3 yr (1998 to 2001), six trials were conducted using three hoop barns (designed for 150 pigs per pen, one pen per hoop) or a mechanically ventilated confinement barn with slatted floors (designed for 22 pigs per pen, six pens in the barn). A total of 3,518 pigs started the trials. Summer trials were June through October, and winter trials were December through April. Target stocking density was 1.11 m^2/pig in hoops and 0.74 m^2/pig in confinement. Identical corn-based diets were fed ad libitum from 16 to 118 kg for 127 d. Pigs were scanned before harvest for backfat and loin muscle area. When seasons were merged (season × housing interaction, $P \geq 0.05$), hoop-fed pigs had more backfat (21.8 ± 0.3 vs 20.8 ± 0.2 mm; $P < 0.001$), smaller loin muscle area (41.3 ± 0.3 vs 43.0 ± 0.2 cm^2; $P < 0.001$), less lean percentage (51.1 ± 0.2 vs 52.1 ± 0.1%; $P < 0.001$), and less yield (74.9 vs 75.8 ± 0.1%; $P < 0.001$) than confinement-fed pigs. When season × housing type interactions were observed ($P < 0.004$), summer hoop-fed pigs had greater ADG (834 ± 5 vs 802 ± 3 g/d; $P < 0.001$), required fewer days to 113 kg (174.9 ± 0.9 vs 178.5 ± 0.6 d; $P < 0.01$), had similar ADFI (2.40 ± 0.03 vs 2.35 ± 0.02 kg/d, as-fed basis) and gain:feed (G:F; 348 ± 4 vs 342 ± 3 g/kg) compared with confinement-fed pigs. Lean gain/day and efficiency of lean gain did not differ between housing systems. During winter, hoop-fed pigs had similar ADG (794 ± 5 vs 801 ± 3 g/d), required more days to 113 kg (176.7 ± 0.9 vs 172.9 ± 0.6 d; $P < 0.01$), had greater ADFI (2.54 ± 0.03 vs 2.35 ± 0.02; $P < 0.001$), less G:F (313 ± 4 vs 341 ± 3; $P < 0.001$), less lean gain/day (312 ± 2 vs 322 ± 1 g/d; $P < 0.01$), and less efficiency of lean gain (130 ± 2 vs 144 ± 1 g lean gain/kg feed; $P < 0.01$) than confinement-fed pigs. Percentage of mortalities and culls did not differ between housing systems. During summer, there was a trend for fewer light pigs at marketing (< 100 kg) from hoops (0.8 vs 1.7%; $P = 0.10$). During winter, there were more light pigs at marketing from hoops (3.9 vs 1.3%; $P = 0.01$) than from confinement. Bedding use in hoops was 92 and 122 kg/pig for summer and winter, respectively. Performance of finishing pigs in bedded hoop structures depends in part on thermal environment.

Key Words: Deep Litter Housing, Finishing, Pigs, Swine Housing

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Introduction

Alternative swine production systems have attracted interest recently for a variety of reasons, including low capital costs, versatility, niche market access, and the perception of positive environmental and animal welfare attributes (Honeyman, 1996). One alternative system for finishing pigs utilizes deep-bedded hoop structures (also referred to as hoop barns or simply hoops).

Hoop barns are tent-like structures consisting of metal pipe arches, or trusses, covered by a polyethylene fabric tarp attached to concrete or wooden sidewalls. The pigs are kept inside the hoop with most of the floor area covered by bedding (e.g., usually straw or cornstalks; Brumm et al., 1997; Honeyman et al., 1999). Feeders and waterers are on a concrete platform.

The hoop structure concept was generally based on a renewed interest in outdoor pig production in Europe (Thornton, 1990; Andersson and Botermans, 1993;

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Arey, 1993), and more specifically on Japan's tunnel housing (Gadd, 1993). The Japanese perfected the use of sawdust bedding in polyvinyl-covered tunnels for market pig production. The concept was transferred to Manitoba, Canada about 1990, where the current hoop structures were developed (Connor, 1993). They were introduced to the United States by the mid-1990s and rapidly adopted. By 2001, approximately 2,100 hoop barns had been built in Iowa by 760 swine producers, with 90% of them used for finishing pigs (Honeyman et al., 2001b). Assuming 200 pigs per hoop barn and 2.5 turns per year, the Iowa hoop barns could produce one million market pigs annually.

Connor (1993, 1994) and Matte (1993) documented market pig performance in hoops in Canada. Hoop pig performance in Iowa was recorded from 1995 to 1997 (Honeyman et al., 2001a). This long-term comparative study was started in 1998 with objectives to document the performance of finishing pigs in hoops during summer and winter in Iowa, and to evaluate pig performance in bedded hoops compared with a confinement housing system.

Materials and Methods

The Hoop Research Complex was developed in 1997 at the ISU Rhodes Research Farm, Rhodes, IA, to conduct research and demonstrations related to feeding pigs in hoop structures. The farm is about 40 km northeast of Des Moines (latitude 41° 53′ N; longitude 93° 25′ W; elevation 313 m). The mean annual precipitation is 93.3 cm. Between 1998 and 2001, six trials were conducted there: three in winter (December through April) and three in summer (June through October).

For each trial, pigs were placed in three (9.1 × 18.3 m) bedded hoop structures (American Shelters, Audubon, IA) with 1.8-m sidewalls (150 pigs per pen, one pen per hoop). A fourth group was placed in a mechanically ventilated modular confinement building (Double L, Garnavillo, IA) with slatted floors and six pens (22 pigs per pen). Pigs were placed in the three hoops and confinement over a 3-wk period. Each pen was filled with pigs that were weaned at the same time. The pigs were injected with ivermectin (Merial Ltd., Iselin, NJ) and vaccinated for erysipelas (Grand Laboratories, Larchwood, IA) at the beginning of the trials. The pigs were wormed with senbendazole (Intervet, Millsboro, DE) in the feed at approximately 55 kg of BW. A total of 3,518 pigs started the trials. The pigs weighed approximately 16 kg each at the beginning of the trials.

Stocking densities for finishing pigs was 1.11 m^2/pig in hoop structures (Brumm et al., 1997) and 0.74 m^2/pig (MWPS, 1983) in confinement. With 1.11 m^2/pig, each hoop structure was designed to hold 150 pigs. The confinement pens (4.11 × 3.96 m) were designed to hold 22 pigs per pen. In the trials, a hoop is defined as a pen. There were three pens of hoop-fed pigs and six pens of confinement-fed pigs for each of the six trials.

The hoop structures were operated as unheated facilities with baled cornstalks for bedding. The north end was kept closed, except for a vent at the top, during the winter, and the south was left open. This allowed air to be exchanged at a sufficient rate to prevent condensation on the underside of the tarp. Bedding was added to maintain a relatively dry bedding pack. During summer, both ends were left open, and a sprinkler system with a temperature-activated (32°C) cycle timer (on 2 min, off 8 min) was used during hot weather. Each hoop had 5.5 × 9.1 m (full width) of concrete across the south end for feeders and waterers.

Large, round bales of cornstalks were used as bedding. Bales were unrolled in the hoops about 22 cm thick, and several more were placed on end in the bedded area. The pigs were then placed in the hoops. Additional bedding was not needed during the first 6 to 8 wk and then was added as needed. All bedding used was weighed and recorded. Bedding per pig was calculated by dividing the total of bedding used by the number of pigs at the beginning of the trial.

The confinement facility used a variable-speed fan to maintain a sufficient minimum negative ventilation rate during winter. A propane makeup air heater (L. B. White, Onalaska, WI) was used to maintain temperature. Minimum temperature setting started at 24°C for the small pigs and was reduced 2°C per week until a setting of 16°C was reached. The facility used a mechanical negative ventilation system during the summer along with circulating fans and a sprinkler system controlled by a temperature-activated (32°C) cycle timer (on 2 min, off 8 min) to reduce heat stress.

Animal housing and care was conducted under the supervision of the Iowa State University Committee on Animal Care log no. 1-8-3774-1-S, and in accordance with the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 1999).

All pigs were from terminal Duroc boars crossed with predominantly white sows and were porcine reproductive and respiratory syndrome (PRRS)-negative and high health status. The groups were approximately half barrows and half gilts. Weaning groups were randomly assigned to housing systems.

All pigs were fed the same five diets in phase ad libitum during the trials according to published nutrient guidelines (NRC, 1998). All diets were corn- and soybean meal-based and were fed in meal form (650 to 750 microns; Table 1). The diets were dispensed in each hoop by two round feeders with 12 feeding spaces each (Pride of the Farm, Hawkeye Mfg., Houghton, IA). The confinement pens contained a single round feeder with eight spaces (Osborne Industries, Osborne, KS). The hoops contained two waterers with two drinking spaces each (Ritchie Industries, Conrad, IA), and the confinement contained four nipple waterers per pen.

Feed was weighed when placed in the feeders. Every 28 d when pigs were weighed, the feeders were emptied

Table 1. Diet composition and calculated analysis by phases, as-fed basis

	Pig weight, kg				
Item	16 to 29[a]	29 to 44[b]	44 to 63[b]	63 to 86[b]	86 to 118[b]
Ingredient, %					
Ground corn	61.70	67.00	73.20	77.40	81.60
Soybean meal, dehulled	35.00	30.00	24.00	20.00	16.00
Dicalcium phosphate	1.70	1.40	1.10	0.90	0.75
Calcium carbonate	0.80	0.80	0.90	0.90	0.90
Salt	0.42	0.41	0.40	0.40	0.35
Trace mineral and vitamin premix[c]	0.38	0.39	0.40	0.40	0.40
Calculated analysis					
CP, %	21.60	19.60	17.30	15.70	14.10
Lysine, %	1.22	1.08	0.92	0.80	0.69
Ca, %	0.79	0.72	0.67	0.61	0.57
P, %	0.73	0.65	0.57	0.52	0.48
ME, kcal/kg	3,290	3,300	3,310	3,320	3,330

[a]Contained carbadox 55 mg/kg (Phibro Animal Health, Fairfield, NJ).
[b]Contained bacitracin methylene disalicylate 33 mg/kg (Alpharma, Fort Lee, NJ).
[c]Premix supplied vitamins and trace minerals to meet or exceed NRC (1998) requirements for finishing pigs.

and feed disappearance was recorded. Feed wastage was minimized by feeder adjustment, but not measured or estimated. Feed disappearance divided by the number of pigs marketed and then divided by the days on feed equaled ADFI. Feed efficiency or gain:feed (G:F) was calculated by dividing ADG by ADFI.

Marketed pig weights at the farm less starting weights divided by the number of days on feed equaled ADG. Only pigs marketed to the packer were considered marketed pigs. Mortalities (i.e., pigs that died during the trial—natural or euthanized) and cull pigs were excluded from the marketed pig weights. Pigs were euthanized using a captive bolt if illness or injury was major (i.e., if the pig was not expected to recover). Pigs were culled and sold alternatively if lameness, umbilical hernia, rectal prolapse, or other detrimental conditions made them unacceptable at the packing plant. Light pigs were marketed at the packing plant but weighed less than 100 kg liveweight. The percentage of mortalities, culls, and lights was equal to the number of pigs of each category divided by the number of pigs at the start of the trial.

Pigs were weighed at 28-d intervals. Weighing occurred in the morning after feed was removed from the pigs for approximately 12 h. Marketing began when a pen attained an average weight of 109 kg. There were two marketings for each pen. On the first marketing, all pigs weighing 109 kg or more were marketed. At this time, all pigs were individually weighed and scanned by a National Swine Improvement Federation certified technician with an Aloka 500-V SSD ultrasound machine fitted with a 3.5-MHz, 12.5-cm linear-array transducer (Corometrics Medical Systems, Inc., Wallingford, CT). Off-midline backfat and loin muscle area were measured from a cross-sectional image taken at the 10th rib. A sound-transmitting guide (Superflab, Mick Radio Nuclear Instruments, Inc., Bronx, NY) conforming to the pig's back was attached to the ultrasound probe, and vegetable oil was used as conducting material between the probe and skin. Backfat and loin muscle area values were used to calculate lean weight (kg) and percentage of lean for each pig using published formulas (NPB, 2000). The pigs weighing less than 109 kg were returned to their respective pens and fed until the next marketing. When the remaining pigs in a pen averaged at least 107 kg, the second marketing occurred. All remaining pigs were marketed at this time. All pigs were transported to a commercial packing plant (Excel Corp., Ottumwa, IA) for processing. Yield values were taken from slaughter data sheets from the packing plant.

Temperature data were collected at the farm using an automated weather station (Campbell Scientific, Logan, UT). Long-term (30 yr) and trial period temperature averages for the farm are shown in Table 2. Temperatures during the trial were recorded and averaged.

This study consisted of six trials, each of which had the two building types with pens nested in building type. The experimental unit was a pen of pigs. The trials were a combination of year and season. Data from all trials were combined and analyzed as a mixed linear model using the GLM procedure of SAS, resulting in an ANOVA structure with the following factors: year, season, year × season, housing type, pen (housing type), year × housing, season × housing type, and error. Because there was only one trial during each year/season combination, the year × season interaction was used as the error term for testing the main effects of year and season. The model error was used to test the remaining factors. Those items with significant season × housing type interactions ($P < 0.01$) were reported separately for each season (Table 4). Those items where the season × housing type interaction was

Table 2. Ambient temperature averages for Iowa State University Rhodes Farm, Marshall Co.

	Long-term[a]			Trial period 1998 to 2001	
Item	Annual	Winter[b]	Summer[c]	Winter[b]	Summer[c]
Avg. temperature, °C	8.6	−1.7	18.7	−0.3	18.8
Avg. maximum temperature, °C	14.4	3.8	24.9	5.2	24.9
Avg. minimum temperature, °C	2.7	−7.2	12.3	−5.7	12.7

[a]Long-term refers to 30-yr averages for this location.
[b]Winter = December through April.
[c]Summer = June through October.

not significant were reported as main effects for building type (Table 3). The percentages of pig mortalities, culls, and lights were analyzed by nonparametric procedures (chi square) and reported in Table 5. The number of pigs per pen was inherent to the housing system. Pens were not completely independent because of proximity to one another. Data are reported as least squares means, unless noted otherwise. The study was designed to compare two distinct housing systems therefore variables inherent to systems were not adjusted to make them equal, e.g., floor space, number of pigs/pen, etc.

Results

Average temperatures for the trial period December 1998 through October 2001 did not differ markedly from the long-term (30 yr) averages (Table 2). Earlier work at the site showed that temperatures inside the hoops were 3 to 5°C warmer during the winter and 1 to 2°C warmer during the summer than outside temperatures (Honeyman et al., 2001a). For the trial periods, there were an average of 17 d less than −18°C during the winter trials and 18 d greater than 32°C for the summer trials on a per-trial basis.

Overall Results

For start weight, end weight, scan weight, weight gain, on-feed period (the day from the start of the trial until market), test period (the day from start of trial until scanning), backfat thickness, loin muscle area, lean weight, lean percentage, and yield percentage, no season × housing type interaction was observed ($P \geq 0.05$).

Pigs were started on trial at 15.7 and 15.9 kg, fed for 127.1 and 126.4 d, and marketed at 118.4 and 116.8 kg for the hoops and confinement, respectively (Table

Table 3. Performance and carcass characteristics of pigs fed in hoops and confinement (six trials total over 3 yr)[a]

	Hoops		Confinement		
Item	Mean	SEM	Mean	SEM	*P*-value
No. of pens	18	—	36	—	—
Start weight, kg	15.7	0.2	15.9	0.2	0.52
End weight, kg[b]	118.4	0.5	116.8	0.4	0.03
Weight gain, kg	102.6	0.6	100.9	0.4	0.03
On feed period, d[c]	127.1	0.9	126.4	0.6	0.54
Scan weight, kg[d]	111.3	0.6	112.7	0.5	0.07
Test period, d[e]	118.8	0.9	120.8	0.7	0.08
Backfat, mm[f,g]	21.8	0.3	20.8	0.2	0.002
Loin muscle area, cm^2[f,g]	41.3	0.3	43.0	0.2	0.0001
Lean, kg/pig[h]	41.9	0.2	43.4	0.2	0.0001
Lean, %[h]	51.1	0.2	52.1	0.1	0.0001
Yield, %[i]	74.9	0.1	75.8	0.1	0.0001

[a]No season × housing type interactions for the items listed were observed, except start weight, which was not subjected to treatments ($P \geq 0.05$).
[b]End weight was the live weight at the farm before shipping to the plant.
[c]On feed period was the number of days from the beginning of the trial until market.
[d]Scan weight was the mean weight of the pigs at scanning.
[e]Test period was the number of days from the beginning of the trial until scanning.
[f]Calculated from ultrasound scan data. Note: All pigs in a pen were scanned at the same time, but marketing occurred at two separate times.
[g]Adjusted to 113 kg of live weight.
[h]Includes 0% fat, calculated with NPB formula using scan data (NPB, 2000).
[i]From slaughter data sheets.

Table 4. Performance of pigs fed in hoops and confinement during summer and winter (six trials total over 3 yr with two seasons)[a]

	Summer		Winter		SEM	
Item	Hoop	Conf	Hoop	Conf	Hoop	Conf
No. of pens	9	18	9	18	—	—
Age, d[b]	174.9[v,w]	178.5[x]	176.7[w,x]	172.9[v]	0.9	0.6
Bedding, kg/pig[c]	92[y]	—	122[z]	—	3	—
ADFI, kg/d[d]	2.40[y]	2.35[y]	2.54[z]	2.35[y]	0.03	0.02
ADG, g/d	834[y]	802[z]	794[z]	801[z]	5	3
Gain:feed, g/kg[e]	348[y]	342[y]	313[z]	341[y]	4	3
Lean gain, g/d on test[f]	314[w]	313[w]	312[w]	322[v]	2	1
Efficiency of lean gain, g of lean gain/kg feed[f]	136[w]	139[w]	130[x]	144[v]	2	1

[a]Season × housing interactions for the items listed were observed ($P < 0.004$).
[b]Adjusted to 113 kg of live weight. The values were the calculated number of days from birth to 113 kg of live weight.
[c]Bedding use = total bedding ÷ number of pigs at start of trial.
[d]ADFI, as-fed basis = (feed disappearance ÷ number of pigs marketed) ÷ days on feed.
[e]Gain:feed = ADG/ADFI.
[f]Includes 0% fat, calculated with a NPB formula using scan data (NPB, 2000).
[v,w,x]Within a row, means that do not have a common superscript differ ($P < 0.01$).
[y,z]Within a row, means that do not have a common superscript differ ($P < 0.001$).

3). Hoop-fed pigs were heavier at marketing and gained more weight than confinement-fed pigs ($P < 0.05$). There was a trend for hoop-fed pigs to be lighter at scanning and to be on test for fewer days than confinement-fed pigs ($P < 0.10$; Table 3). When scan data was adjusted to a standard liveweight (113 kg), hoop-fed pigs had slightly more backfat ($P < 0.01$) and a slightly smaller loin muscle area ($P < 0.001$) than confinement-fed pigs. These values resulted in hoop-fed pigs having less calculated lean weight and one percentage unit less calculated carcass lean than confinement-fed pigs ($P < 0.001$). Also, yield or dressing percentage was lower for hoop-fed pigs ($P < 0.001$; Table 3).

Seasonal Results

For calculated pig age at 113 kg, bedding used, ADFI, ADG, G:F, calculated lean gain, and efficiency of lean gain, a season × housing type interaction was observed ($P < 0.004$). Items with season × housing type interactions for performance of pigs fed in hoops and confinement during summer and winter are shown in Table 4. Each season has three trials, one for each year. Hoop-fed pigs reached 113 kg, 3.6 d sooner than confinement-fed pigs in summer, but 3.8 d later than confinement-fed pigs in winter ($P < 0.01$; Table 4). Bedding use was 92 kg/pig in summer and 32% more or 122 kg/pig in winter ($P < 0.001$).

There was no difference in ADFI during the summer between pigs fed in the two housing systems, but during winter hoop-fed pigs ate 8% more feed than confinement-fed pigs due to colder environment ($P < 0.001$; Table 4).

Pigs in hoops grew 4% faster in summer than confinement-fed pigs ($P < 0.001$), but there was no difference in winter. During summer, feed efficiency was similar when comparing pigs fed in hoops and confinement (Table 4). Feed efficiency of hoop-fed pigs was 8% poorer than confinement-fed pigs in winter ($P <$

Table 5. Percentage of mortalities, cull and light pigs fed in hoops and confinement during summer and winter (six trials total over 3 yr with three seasons)[a]

	Summer			Winter		
	Hoop	Conf	P-value	Hoop	Conf	P-value
No. of pens	9	18	—	9	18	—
Mortalities, %[b]	1.8	2.7	0.21	3.8	2.3	0.14
Culls, %[c]	1.7	1.0	0.32	1.8	1.0	0.29
Lights, %[d]	0.8	1.7	0.10	3.9	1.3	0.01

[a]Simple means and P-values derived from chi-square analyses.
[b]Mortalities were defined as pigs that died or were euthanized at the farm. The number of pigs at the start of the trial was the divisor in calculating the percentage.
[c]Culls were defined as pigs that were marketed alternatively because of their detrimental condition (e.g., lameness, hernia, etc.). The number of pigs at start of trial was the divisor in calculating percentage.
[d]Lights were defined as marketed pigs not weighing 100 kg at marketing. The number of pigs at start of trial was the divisor in calculating percentage.

0.001). The pigs apparently utilized more of the feed nutrients consumed for maintenance (i.e., to maintain body temperature).

Rate of lean gain was similar in summer for pigs in either housing system and hoop-fed pigs in winter, but was about 3% more for confinement-fed pigs during winter ($P < 0.01$). Efficiency of lean gain did not differ in summer, but was 9.7% poorer in winter for hoop-fed pigs than for confinement-fed pigs ($P < 0.01$; Table 4). Again, this was apparently related to a colder thermal environment during the winter in hoops.

Percentage of pig mortality and the percentage of cull pigs did not differ by housing type during summer or winter (Table 5). There was a trend for a lower percentage of light pigs at marketing from the hoops compared with confinement during summer ($P = 0.10$; Table 5), however there was a higher percentage of light hoop-fed pigs compared with confinement during winter ($P = 0.01$; Table 5).

Discussion

Although these two housing systems are markedly distinct, overall pig performance (ADFI, ADG, G:F) and carcass characteristics (backfat, loin muscle area, lean) differed slightly. These results generally concur with the results of Canadian work with finishing pigs in hoop structures bedded with straw (Connor, 1993, 1994; Matte, 1993). Pigs can compensate for wide variations in thermal environment when housed as a group with bedding. Much of this discussion will focus on the differences in pig performance and carcass characteristics between the two housing systems, but generally the pigs performed well with major similarities.

Environment in the confinement was less variable in the winter than in the hoop, because supplemental heat was added when the temperature dropped below 16°C. The winter hoop environment was 3 to 5°C above outdoor temperatures (Honeyman et al., 2001a). Thus temperatures of −10 to −12°C occurred an average of 18 d during the winter trials in the hoops. For groups of 34 kg pigs with straw bedding, a lower critical temperature (LCT) of −20°C was reported by Sällvik and Wejfeldt (1993). Summer temperatures in the two housing systems were similar and only slightly higher than outside temperature (Honeyman et al., 2001a), although the confinement had mechanical ventilation and the hoops relied on natural air movement.

Feed or energy intake is a major factor affecting pig performance. Under ad libitum conditions, pigs adjust feed intake in response to changes in ambient temperatures. Noblet et al. (2001), in a review of work in this area, reported a curvilinear decrease in feed intake as ambient temperature increased with larger feed intake depression at high ambient temperatures for heavier pigs. Our feed intake results are consistent with this analysis (i.e., feed intake in the quasi-thermally regulated confinement barn did not differ seasonally, but in the hoop barn feed intake was higher during winter).

Bedding was an important environmental factor in the hoops. In addition to absorbing urine and feces, the bedding was used by the pigs to modify their environment, particularly during winter. Portions of the bedding pack composted in situ generating temperatures above 40°C at 15- to 30-cm depths and above 30°C over approximately half of the bedded area (Honeyman et al., 2001a). During cold months, the effective temperature experienced by hoop pigs was moderated by the pigs burrowing in the bedding and from heat generated by the bedding pack. During the summer, the pigs sought out the cooler, noncomposting areas of the bedding pack. The bedding also created an enriched environment for hoop pigs that may have contributed to “enhanced welfare” compared with pigs in confinement (Lay et al., 2000). Chewable, non-nutritive materials, e.g. bedding, may be helpful in lessening behavior problems in finishing pigs (Feddes and Fraser, 1993). Pigs in hoops (at this site) had fewer aberrant behaviors, more play behavior, lower plasma cortisol in response to handling, and fewer injuries than the pigs in confinement (Lay et al., 2000). Also, pigs in hoops ingest some bedding, which may affect behavior or growth (Huenke and Honeyman, 2001).

Seasonally, G:F was similar in the summer for the two housing systems. During the winter, hoop-finished pigs gained less per unit of feed than the confinement-finished pigs (Table 4). These results generally agree with work from Canada, where feed per unit of liveweight gain was similar during summer but not in winter compared with pigs fed in confinement (Connor, 1993, 1994; Matte, 1993). These results indicate that hoop-fed pigs were using more of the feed nutrients consumed for thermoregulation during the cold months.

Feed efficiency is also related to leanness. Lean gain requires much less energy than fat accretion. Hoop-fed pigs were less lean than the confinement-fed pigs, i.e., more backfat, smaller loin muscle area, and lower lean percentage (Table 3). During the cold months, lean gain per day and efficiency of lean gain was reduced in hoop-fed pigs compared with confinement-fed pigs (Table 4).

Pigs in hoops ate the same or more feed than pigs in confinement depending on the season. Also, during the winter, more of the feed nutrients were required for thermoregulation. The seasonal growth differential resulted in hoop-fed pigs reaching 113 kg liveweight 3.6 d sooner than confinement-fed pigs in the summer, but 3.8 d later in the winter (Table 4). These results also agree with Canadian work, where marketing age tended to be less in summer but more in winter for hoop-fed pigs than confinement-fed pigs (Connor, 1993).

There has been considerable work comparing the performance of outdoor to indoor finishing pigs. Pig performance has been variable due to many factors including climate, genetics, nutrition, health status, management intensity, and housing. In Texas, outdoor-finished pigs had higher ADG than indoor-finished pigs during warm months, but similar ADG during winter months (Gentry et al., 2002). Enfalt et al. (1997) indicated that outdoor-finished pigs in northern Europe had lower ADG than indoor-finished pigs during winter. In Canada, Sather et al. (1997) reported that outdoor-fed pigs had lower ADG in both winter and summer trials. When warmer Texas environment and colder northern European and Canadian environments are considered, results of these studies generally concur with our hoop feeding results. There is also an indication that the hoop environment may be somewhat superior to an outdoor environment in both summer and winter for feeding finishing pigs.

Performance of finishing pigs housed in a converted poultry house with fescue hull bedding in central Missouri was compared to pigs housed in a slatted-floor confinement finishing facility in western Kansas during fall and early winter. Pigs finished on bedding had heavier carcasses and more backfat than confinement-fed pigs (Gentry et al., 2002).

Warriss et al. (1983) and Enfalt et al. (1997) reported that outdoor-fed pigs were leaner than indoor-fed pigs. Gentry et al. (2002) found that pigs fed outdoors in Texas during the summer were fatter than indoor-fed pigs. An enriched environment may improve growth rate and increase backfat (Beattie et al., 2000), although other studies found no differences when the environment was enriched (Pearce and Paterson, 1993; Blackshaw et al., 1997). The enriched bedded environment of hoop structures may have been a factor in increasing ADFI, ADG, and backfat for the hoop-fed pigs in these studies. Lower yields for hoop-fed pigs may be related to increased ADFI and ingestion of bedding. Causes of these trends for finishing pigs in hoops has not been clearly identified.

Implications

Hoop structures with bedding are a viable alternative production system for finishing swine. The hoop-fed pigs were less lean than the confinement-fed pigs. There were seasonal variations in hoop-fed pig performance. In summer, hoop-fed pigs grew faster than confinement-fed pigs. In winter, hoop-fed pigs consumed more feed, were less efficient, and had a greater percentage of light pigs at marketing. These effects may be related to thermal environment, the enriched-bedded environment, or group size. Diets for pigs in hoops with cold environments may need to be altered by adding fiber to increase heat of digestion. More experience in managing finishing pigs in hoop barns is needed particularly in cold environments. Alternative pig production systems are sensitive to climatic and seasonal variations.

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