EFFECTS OF TEMPERATURE ON THE PERFORMANCE OF FINISHING SWINE: I. EFFECTS OF A HOT, DIURNAL TEMPERATURE ON AVERAGE DAILY GAIN, FEED INTAKE, AND FEED EFFICIENCY1

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ABSTRACT

Ninety-six crossbred barrows and gilts weighing 90 ± .67 kg were used during a 21-d study to determine the effects of a hot, diurnal temperature (H; 22.5 to 35°C) compared with a constant, thermoneutral temperature (TN; 20°C) and the effects of sex (barrows vs gilts) on performance. A secondary objective included the determination of weight loss as a result of a 24-h fast immediately after the 21-d feeding study of commingled vs not commingled hogs of both environmental treatments (TN and H). Pigs housed in the hot, diurnal temperature gained 16.3% more slowly (P < .001; -77 vs .92 kg/d) than those in the constant, thermoneutral environment. Feed intake (m) for the H pigs was 10.9% less (P < .001; 3.01 vs 3.38 kg/d) than that for the TN pigs. The H pigs gained 17.6 g/d less and consumed 43.5 g/d less feed for every °C above 20°C; however, no differences were observed for feed efficiency (F/G; 3.86 vs 4.19 kg for the TN and H pigs, respectively). Average daily gain and feed/gain (F/G) were not affected by sex. Likewise, no significant interactions of temperature x sex were observed for ADG, FI, or F/G. Weight loss (shrinkage) during the 24-h fast was not affected by commingling; however, the H pigs lost 17.5% more weight (P < .05) than the TN pigs (3.82 vs 3.25%, respectively).

Key Words: Pigs, Diurnal Temperature, Performance, Shrinkage

Introduction

High ambient temperatures cause swine to decrease voluntary feed intake while their maintenance requirement is increased, resulting in a decrease in growth rate (Close, 1978; NRC, 1987). According to Morrison et al. (1975), much of our present knowledge regarding the physiological responses and quantitative effects of a given environment on swine performance is based on investigations with constant temperatures. Generally speaking, livestock are not raised under constant temperatures. Swine raised in confinement may be subjected to variations in air temperature caused by inadequate mechanisms for temperature control, building design, fluctuating animal heat losses, or even changes of outside temperatures (Bond et al., 1967). Bond et al. (1963) and DeShazer (1982) concluded that additional research on the influence of varying temperatures is needed to understand the animal/environment interactions and to accurately predict the performance level of animals exposed to fluctuating environmental temperatures and thereby help producers in decision-making processes.

The primary objective of this research was to determine the effects of a hot, diurnal temperature on growth rate, feed intake, and feed efficiency of finishing hogs (barrows and gilts). Another objective included determining

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1Contribution from the Missouri Agric. Exp. Sta., Journal Series No. 11248. Approved by the director.
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4Agric. Exp. Sta. Statistician.
Received July 20, 1990.
Accepted November 21, 1990.
the effect of a hot, diurnal temperature on 24-h shrink of pigs fasted vs pigs fasted and commingled.

Experimental Procedures

Ninety-six crossbred barrows and gilts of Duroc, Landrace, and Yorkshire descent, weighing 90 ± 6.7 kg, were used during two trials to determine the effect of a hot, diurnal temperature on performance. The independent variables of temperature (thermoneutral; 20°C vs hot, diurnal; 22.5 to 35°C), sex (barrows vs gilts), and trial were studied as a 2 x 2 x 2 factorial arrangement with six pens per treatment (temperature x sex x trial). Trial 1 was conducted from June 29 to July 21, and Trial 2 was conducted from October 5 to October 27, 1987.

Facilities. The facilities for this experiment consisted of two environmentally controlled chambers at the University of Missouri Samuel Brody Climatology Laboratory in the Animal Sciences Research Center. The control chamber, hereafter referred to as the thermoneutral treatment (TN), was kept at 20°C with an average relative humidity of 55%. The other chamber used for the hot, diurnal treatment (H) cycled from a low of 22.5°C between 2400 to 0600 to a high of 35°C between 1600 to 1800 (an increase of 1.25°C/h). The relative humidity in this chamber fluctuated between 35 and 70%; the temperature and humidity pattern were inversely related. The 24-h temperature-humidity environment for the H chamber, as shown in Figure 1, is representative of a July day in Central Missouri.

Each environmental chamber (room) was 6.1 x 9.1 m and contained 12, 1.2-m² pens used to accommodate two barrows or two gilts; hence, each chamber contained six pens of barrows and six pens of gilts. The 12 pens in each chamber were arranged as two rows of six. All pen fencing material was vertical pipe, with the exception of the divider between

![Figure 1. Temperature (---) and relative humidity (---) cycle for the hot (H) and thermoneutral (TN) chambers.](image-url)
adjacent pens of different rows, which consisted of welded wire panels. The floor in each chamber was coated with an epoxy paint containing sand to prevent slippage. Approximately 60% of the floor in each pen was epoxy-coated metal and the remainder epoxy-coated concrete. The epoxy-coated metal portion of the floor covered a slotted area over a flush gutter.

All pens were equipped with one watering cup and a one-hole, stainless steel self-feeder. Each chamber contained six water meters, which enabled the recording of water disappearance (WD) for two adjacent pens within different columns of pens. A hygrothermograph was placed in each chamber to continuously record temperature and humidity throughout each trial.

**Procedures.** The official test period (excluding the 1-d, posttest shrink study) was 21 d in duration; however, a 7-d acclimation period preceded the official test. Initially, the temperature of both the TN and H chambers was set at 20°C. The temperature of the H chamber was increased 2.5°C/d to enable the appropriate diurnal temperature to be reached during the 7-d acclimation period. Both chambers received 12 h of light from 0700 to 1900. The floor in each room was washed twice daily, once during the morning and again in the afternoon.

All pigs were given ad libitum access to a 13% CP corn-soybean meal diet (meal form) without additives that was formulated to meet NRC (1973) recommendations (Table 1). Dietary metabolizable energy (ME) was calculated to be 3,182 kcal/kg.

Pigs were randomly assigned, within sex, to either the TN or H chamber. Next, two barrows and two gilts were randomly assigned, within sex, to each of six pairs of adjacent pens (one pen from each of two columns). However, pigs were switched, if necessary, to avoid having any littermates in the same pen. The two adjacent pens nearest the entrance in each chamber were designated as row one and those farthest from the entrance row six. Therefore, each row of two pens within each chamber contained two barrows and two gilts.

Average daily gain and pen feed intake (FI) were determined on d 7, 14, and 21. In addition, all pigs were weighed on d 22 following a 24-h shrink. Water meters were read daily at 0800 to determine WD for two adjacent pens. Respiration rate (RR) and rectal temperature (RT) were measured in an effort to determine the extent of stress experienced by the H pigs. These variables (RR and RT) were measured twice daily on Monday, Wednesday, and Friday starting at 0800 and 1500, with one exception. Respiration rate and RT for the TN pigs of Trial 1 were only determined in the morning, rather than morning and afternoon. Respiration rate was determined by counting the number of flank movements per minute. Rectal temperature was determined by inserting an electronic digital probe thermometer5 approximately 10 cm into the rectum.

**Posttest Shrink.** On d 21, after the pigs were weighed off test, access to feed and water was restricted for a 24-h period. In addition, the welded wire panels that divided the adjacent pens of rows 1, 3, and 5 in each chamber were removed to allow commingling of two barrows and two gilts. This was done to compare 24-h shrinkage of market-weight hogs that are fasted vs those that are fasted and commingled under TN and H temperatures.

**Statistical Analysis.** The data were compared by ANOVA according to a split plot in time (Gill and Hafs, 1971) with the data of

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Trials 1 and 2 pooled, except for respiration rate and rectal temperature. Pen mean was the experimental unit for all dependent variables. The linear statistical model contained the effects of trial, temperature, and sex in a $2 \times 2 \times 2$ factorial arrangement. The error term for the main plot effects was pen within trial, temperature, and sex. The subplot contained the effect of period (0 to 7 vs 7 to 14 vs 14 to 21 d) and all possible interactions of period with the main plot effects. Means were separated according to Fisher’s LSD test protected by a significant F-value (Steel and Torrie, 1980).

Results and Discussion

Performance. Three-week growth rates for the TN and H pigs were .87 vs .81 kg/d and .97 vs .74 kg/d for Trials 1 and 2, respectively, resulting in a significant ($P < .05$) trial x temperature interaction. Although the cause of this interaction is unknown, a possible explanation is a pretest season effect. Means for the main effects of temperature and sex on performance during the 21-d finishing period are shown in Table 2. Pigs housed in the hot, diurnal temperature (H) gained 16.3% more slowly ($P < .001$; .77 vs .92 kg/d) than those in the constant, thermoneutral environment (TN). These values are similar to those of Nienaber et al. (1987), who reported that finishing swine gained .76 kg/d during the first 4 wk of a 7-wk study when subjected to a temperature fluctuation of 8 to 32°C, compared with .93 kg/d at a constant temperature of 20°C. Morrison et al. (1975) also observed a 16% difference in growth rate of finishing pigs that were kept at a thermoneutral temperature (21.5°C) vs a high temperature (27.5°C); however, ADG was poorer (.72 and .60 kg/d, respectively) than for this study. Pigs in the H chamber had a 17.6-g decrease in ADG for every 1°C above 20°C (based on a mean value of 28.5°C for the H treatment), which is considerably less than values of 57 and 60 g reported by Heitman and Hughes (1949) and Heitman et al. (1958), respectively, comparing constant temperatures of 21 vs 32°C and 19 vs 27°C. Hazen and Mangold (1960) reported a 7-g decrease in ADG per 1°C increase in environmental temperature from 18 to 32°C for pigs weighing 20 to 100 kg. Our observed

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Values were computed from pen means. Beginning and ending test weights for the TN, H, B, and G pigs were 90.4 and 109.7 vs 91.2 and 107.5 vs 91.2 and 109.4 vs 90.4 and 107.8 kg, respectively.

*TN = thermoneutral; H = hot; B = barrows; G = gilts.

*Pooled standard error with 78 df associated with the subplot error mean square.

*Pooled standard error with 39 df associated with the main plot error mean square.

*Average daily gain, feed intake, and feed/gain means in a column by temperature or sex with different superscripts differ ($P < .05$).

*Means in a row by temperature or sex with different superscripts differ ($P < .05$).
decrease in ADG of 17.6 g per C° increase in environmental temperature above 20°C is within the 10- to 20-g range as estimated by NRC (1981). This estimate was derived from the average of data reported by Hazan and Mangold (1960), Mangold et al. (1967), and Heitman et al. (1958). This extreme variability in reported values should be expected because of numerous differences in independent variables (i.e., pig weight, degree of fatness, breed, diet, temperatures compared, etc.). Average daily gain, expressed as grams per kilogram \(^{75}\), decreased .55 g per C° increase in environmental temperature above 20°C, which is considerably lower than the .77 g reported by Close et al. (1978) for 38-kg pigs.

Average daily gain favored the TN pigs during the first and third periods (P < .05). During the first period the relatively high ADG of the TN pigs (1.02 kg) may be partially due to the fact that the environmental temperature during the adjustment period and during Period 1 was more favorable than the pigs' previous environmental temperature at the farm. Therefore, this performance may be reflective of compensatory gain. During Period 3 the H pigs were less able to cope with the high temperatures, which probably reflects an increasing stress at heavier weights as the pigs increased in body fat. Mean ADG by period for all pigs was .92, .82, and .79 kg for Periods 1, 2, and 3, respectively.

Period × temperature resulted in a significant interaction (P < .001) for FI. Mean FI for all pigs was 3.05, 3.20, and 3.33 kg/d for Periods 1, 2, and 3, respectively (P < .001). Similar to ADG, FI for the H pigs was less than that for the TN pigs (P < .001) for the entire 21-d study (3.01 vs 3.38 kg/d) and during the first and third 7-d periods. The H pigs consumed 10.9% less feed during the 21-d test period, which represented 15.3, 1.8, and 15.1% less than the controls (TN) for the first, second, and third periods, respectively. These results agree with those of Stahly and Cromwell (1979), who stated that initial heat stress causes pigs to decrease their feed intake in an effort to reduce the burden of heat increment. Expressed as a percentage of feed intake at a constant 15°C, Heitman and Hughes (1949) observed an intake of 43% and 37°C, which represents a 2.0% decrease per C° increase in temperature. Nichols et al. (1980) reported FI at 35°C to be 48.1% of the FI at 15°C. This represents a 2.4% decrease per C° increase in temperature above 15°C. Our mean diurnal temperature for the H treatment was 28.5°C, and the H pigs reduced their FI 1.28% (43.5 g) for every C° above 20°C. This suggests that the relationship of FI to environmental temperatures above the animal's thermoneutral zone is probably curvilinear. Ames (1982) stated that in diurnal, fluctuating conditions, night cooling may relieve an animal of the severity of hot, daytime temperatures, resulting in a voluntary feed intake that is higher than predicted intake from the mean daily or weekly temperature. A significant increase in FI for the H pigs during Period 2 suggests that these pigs were able to adjust to the high temperatures. Bond et al. (1963) found that a ± 5.5°C variation in temperature from 21.1°C caused no difference in swine performance; however, variations of ± 11.1°C from 21.1°C did result in reduced performance. Our results of a 1.28% decrease in FI per C° above 20°C are lower than the figures reported by Heitman and Hughes (1949) and Nichols et al. (1980) for constant temperatures of 37 and 35°C, respectively. The authors of NRC (1981) estimated daily feed intake to decrease about 40 g/C° of heat stress. Our observed decrease in FI was 43.5 g/°C above 20°C. Daily feed intake expressed as grams per kilogram \(^{75}\) was 95.6 and 107.0 for the H and TN treatments (28.5 and 20°C, respectively), compared with 103.9 for 30°C reported by Close and Mount (1978). Calculated daily ME intake for our study was 1,423 and 1,268 kJ/kg/°C at 20 and 28.5°C, respectively, compared with 1,655, 1,406, and 1,202 kJ/kg/°C for 20, 25, and 30°C, respectively, reported by Close and Mount (1978).

Although weekly and 21-d differences were found for ADG and FI, no differences (P > .05) were observed for feed efficiency (feed/gain; F/G) by temperature or sex. However, there was a significant (P < .01) period effect with mean F/G values of 3.47, 4.11, and 4.49 for Periods 1, 2, and 3, respectively. These differences were expected because efficiency of feed conversion decreases as hogs increase in BW. Feed conversion for the 21-d study was 3.86 and 4.19 for the TN and H groups, respectively. These results are in agreement with those of Morrison et al. (1975), who found no significant differences in feed efficiency when treatments were a diurnal variation in air temperature of ±10°C or ±20°C from 20°C or a constant 20°C (3.31 and 3.51
Responses. Hence, they were not technically mixed, respectively.

24-h fast without any observed difference in the TN pigs compared with the H pigs. The lack of a significant effect on weight loss could be because commingled pigs within the chamber for the TN pigs averaged 27.8 liters/d for four pigs (two adjacent pens) compared with 40.0 liters for the H pigs. Daily water disappearance was essentially constant for the TN pigs compared with a weekly increase (P < .001) for the H pigs (37.0 vs 40.7 vs 42.4 liters for Periods 1, 2, and 3, respectively). Johnson and Yeck (1964) observed that heat-stressed animals increased daily water intake in amount per day and amount per unit of feed intake compared with animals in a thermoneutral or cold environment. The average water disappearance expressed as a ratio to feed intake was 2.1:1.0 and 3.6:1.0 for the TN and H treatments, respectively, which is another indication of the increased daily water requirement of the H pigs. Mount et al. (1971) reported that pigs at a constant 20 vs 33°C had water to feed ratios of 2:1 and 5:1, respectively. Using these water:feed intake ratios, the 33°C pigs had a 250% greater water usage (5.2/2.0 × 100) than the 20°C controls. This difference is 19.2% when expressed as a percentage per C° difference between the high temperature and control pigs (250%/13 degrees). Likewise, considering our H treatment to be an average of 28.5°C, our increased water disappearance of 171% (3.6/2.1 × 100) expressed per C° difference between the TN and H pigs was 20.1% (171%/8.5 degrees).

Respiration rate (RR) of the H pigs was higher (P < .001) than that of the TN pigs; morning counts for Trials 1 and 2 averaged 41.0 vs 28.6 and afternoon counts for Trial 2 averaged 69.3 vs 37.6, respectively. These RR values represent a 69.0 and 31.5% increase in respiration rate for the H and TN pigs from morning to afternoon, accounting for an increase in metabolism and activity for both groups and a response to the increase in room temperature for the H pigs. According to Ames (1982), evaporation of moisture from the respiratory tract is the primary mechanism used by animals to lose excess body heat in a hot environment.

During Trial 1, morning rectal temperatures (RT) were not different by treatment (P > .05); however, during Trial 2 the H pigs' 3-wk average RT values for both morning and afternoon observations were higher (P < .001) than those of the TN pigs (39.27 vs 39.08°C and 39.45 vs 39.00°C, respectively). Likewise, morning vs afternoon RT values of the H pigs were different (P < .001), which is to be
expected due to the diurnal temperature. Robinson and Ames (1982) noted that rate of heat production increased as heat stress became more severe.

Implications
Finishing hogs consumed less feed and grew more slowly when housed in a hot, diurnal temperature than pigs kept in a constant, thermoneutral environment; however, feed efficiency was not affected. Average daily gain and feed conversion of barrows vs gilts was not different. Commingling did not affect weight loss during a 24-h fast; however, pigs in the hot environment did shrink more than those in the thermoneutral chamber.

Literature Cited