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Feeding Patterns Of Growing Pigs At Warm Constant And Cyclic Temperatures

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Abstract

Feeding behavior of *ad libitum*-fed, 39-kg, crossbred gilts was investigated under mean ambient temperatures of 30.8° C with 0, 7, and 16.6° C cycles. Average meal size, 160 to 170 g/pig; meal duration, 13.3 to 14.3 min; and ingestion rate, 12.2 g/min·pig did not appear to be influenced by the temperature conditions. However, meal frequency, 9 to 11 per day, tended to be reduced by elevated hours of exposure to high temperatures. Consequently daily feed intake of the pigs was significantly less in the 16.6° C cycle treatment than in the 0 or 7° C cycle treatments ($P<0.01$). Feed consumed during the lighting period (0600 h to 2100 h) accounted for 75%, 61%, and 37% of daily feed intake for the 0, 7, and 16.6° C cycle treatments, respectively. Pigs under the 0° C cycle had most feeding activities in the afternoon and evening (55% of daily feed intake). In contrast, pigs under the 16.6° C cycle had most feeding events at night and early morning (91% of daily feed intake).

Keywords. Feed intake, Temperatures, Swine.

Introduction

Daily feed intake is a driving force for swine growth. Feed intake is also a dynamic response which can be influenced by thermal environmental conditions. A cyclic temperature of 33±7° C compared to a constant temperature of 33° C has been shown to cause different feeding profiles for growing swine (Feddes et al., 1989). Thus feeding behavior of pigs needs to be investigated for different natural and man-made cyclic temperature conditions for potentially improved animal performance.

Bigelow and Houpt (1988) reported feeding patterns of young pigs under constant air temperature of 22 to 23° C. As the pigs grew from 10 to 130 kg, daily feed intake increased threefold, while meal frequency declined from 14 to 7 per day. Consequently both meal size and meal interval increased. However, meal duration did not appear to be dependent upon age or weight. They also reported that 64% of daily feed intake was during the 12-h light period. Nocturnal meals were less frequent but larger.

Feddes et al. (1989) reported feeding behavior of growing pigs (36 kg) maintained in groups of four at a constant temperature of 33° C versus an equal-mean cyclic temperature of 33±7° C. The cyclic temperature followed a sine wave with a maximum of 40° C at 1400 h and a minimum of 26° C at 530 h. These authors indicated that the periods of highest feed intake in the cyclic treatment occurred earlier in the morning and later at night than those in the constant temperature treatment. Feed consumption rate in both treatments was less than 25 g/min·pig 74% of the time. Mean ingestion rates for both treatments were similar at 15 g/min·pig.

Nienaber et al. (1990) studied feeding behavior of growing-finishing gilts (28 to 103 kg) exposed to cyclic temperatures at lower critical temperature (LCT)±4° C and LCT−12° C. The average eating rate of the pigs ranged from 1.25 to 0.74 g/min·kg$^{.75}$ of live body mass and decreased with age (7 to 23 wk). Eating rate also decreased at LCT−12° C. About 75% of eating activity and feed consumption occurred in the light period (0700-1900 h). Eating activity was reported greatest in the early morning and afternoon.

Feeding parameters also affect digestive patterns of pigs and the data are necessary for development and validation of real time swine physiological growth models such as the one that was being developed by the former NC-179 regional swine research group. As part of the NC-179 regional research project, this experiment was designed to delineate the dynamic feeding characteristics of growing pigs as influenced by warm constant temperature and equal-mean cyclic temperatures with different cycle ranges. Results from this study would provide input data for the development and validation of the logic used to simulate real time swine digestive processes in the NC-179 physiological swine growth model.

Materials and Methods

The experiments were conducted in three indirect animal calorimeters (1.0w×1.51×1.2h m each) equipped with PC-based environmental control and data acquisition apparatus in the Bioenergetics Research Laboratory at the University of Nebraska. The system allowed for continuous monitoring, control, and measurement of the

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Equipment or company names are cited for clarity of the presentation and do not imply endorsement of the equipment by the authors or the University.

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environmental conditions inside the calorimeters. It also monitored and recorded the dynamic feeding activities of the animal. Detailed information on design and operation of the indirect calorimetry system is described elsewhere (Xin, 1989).

TEMPERATURE REGIMENS

Selection of the air temperature regimens was based on a typical Southeast Nebraska July and August cyclic temperature condition of 33±7° C with maximum and minimum temperature occurring at 1400 h and 0600 h, respectively (AGNET, 1984). This natural diurnal temperature cycle was first modified to reduce all temperatures higher than 33° C (occurring between 1000 h and 2200 h) to 33° C with the remaining cycle unchanged (fig. 1). This modified temperature pattern, cycling from 26° to 33° C with a mean of 30.8° C, was designated as reduced daytime peak temperature (RPK). Another modification, cooling the same amount of degree hours as in RPK, was the reduction of all temperatures lower than 33° C (occurring from 2200 h to 1000 h) to 23.4° C except for the hours of 2200 h to 2300 h and 0900 h to 1000 h. From 2200 h to 2300 h, temperature was linearly decreased from 33° to 23.4° C and from 0900 h to 1000 h, temperature was linearly increased from 23.4° to 33° C. This modified temperature pattern, cycling from 23.4° to 40° C with a mean of 30.8° C, was thus designated as a reduced nocturnal temperature (RNT). The cooling schemes were selected to represent possible production management practices and thus could have an impact on the on-farm load management. Since both cyclic temperatures had the same mean of 30.8° C, a constant temperature treatment (CON) of 30.8° C was identified. Dewpoint temperature of the incoming air to the animal area was maintained at 10° to 12° C to result in a relative humidity of 45% at the dry-bulb temperature of 31° C. The relative humidity was allowed to vary as a function of air temperature. Fluorescent lighting with an intensity of 800 to 1100 L/m/m^2 was provided from 0600 h to 2100 h.

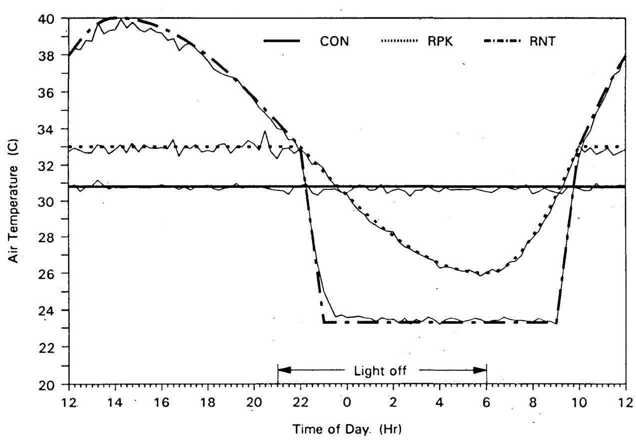

Figure 1–Air temperature treatment regimens: constant temperature of 30.8° C (CON); reduced peak temperature cycling from 26° to 33° C with mean of 30.8° C (RPK); and reduced nocturnal temperature cycling from 23.4° to 40° C with mean of 30.8° C (RNT). Intended regimens are designated by the smooth lines in the legend; actual temperatures are shown as the solid lighter lines above each smooth line.

EXPERIMENTAL PIGS AND PROCEDURE

A total of 18 randomly selected crossbred gilts at an initial body mass of 31(±2) kg were obtained for this study from the University of Nebraska Energy Integrated Farm located near Mead, Nebraska. A randomized complete block design was used, with six replicates, each involving three pigs, one for each treatment. The pigs were transported from the farm (60 km away) to the Bioenergetics Research Laboratory. The pigs were then randomly assigned to the temperature-controlled calorimeters. Individual penning of the pigs was used to eliminate possible masking effects on the dynamic responses caused by social interactions of group penned pigs. The pigs, however, could view each other through the transparent walls of the calorimeters and thus potential isolation stress was reduced. Feed and water were available during all trials. The corn-soybean diet used at the farm and during the experiment contained 88.76% dry matter, 17.7% protein, 1.0% calcium, 0.9% potassium, 1.27% lysine, and 16.04 kJ/g gross energy.

Acclimation of the experimental pigs was based on the mean housing air temperature recorded at the swine farm during the previous week. The mean temperature ranged between 20° to 24° C. Air temperature inside the calorimeters was linearly increased by 2.5° C per day from 0600 h to 1400 h until the constant level of 30.8° C was reached. The experimental temperature regimens were then initiated at 1000 h the following day. The pigs were kept in the calorimeters for 14 to 18 days. Response data during the last five days were used and analysis of variance and Duncan's multiple mean comparison were performed to evaluate the treatment effects.

MEASUREMENT OF FEEDING EVENTS

The mass of Smidley modified finishing feeders with 13 kg capacity (Marting MFG, Inc., Britt, Iowa) was scanned approximately every 20 s with off-center load cells which had the capacity of 50 kg and sensitivity of 10 g (model 1010F, Tedea, Inc., 8606 Wilbur Ave., Northridge, California). Output signals from the load cells were processed by a strain gage signal conditioning unit (model 10K4 DataPac with 10A70-2 strain gage cards, Daytronic Corporation, 2589 Corporate ModelPlace, Miamisburg, Ohio), which was interfaced to the data acquisition PC.

The start and end of each feeding event were detected as follows (Nienaber, 1988). Four consecutive mass readings of a feeder were compared to detect a feeding event. The first reading was used as the reference value. If the absolute differences between the reference reading and the following three readings were all equal to or greater than 20 g, then a feeding event was considered to have begun at the time of the reference reading. If at least one of the absolute differences was less than 20 g, the subsequent point became the reference reading and the process was repeated. The feeding event was considered to have ended when the feeder mass was below the starting value and three consecutive differences were within the tolerance range of ±10 g. The first of these readings was taken as the end reading of the feeding event. Addition of feed to the feeders was detected and excluded from comparison by defining 5000 g as the upper threshold for the absolute difference. Data were scanned but not recorded when the feeder mass was within ±10 g of variation. An examination of the dynamic feeding records indicated that the feeding events could be well separated by clustering the activities that took place within three minutes. Thus, feeding events occurring in three minutes were combined as one meal. In addition, feeder mass was recorded every five minutes to check against the hourly feed intakes as determined by the 20 s feeding event scanning. Both measurements yielded identical hourly feed intakes.

RESULTS AND DISCUSSION

Feeding behavior characteristics of the pigs are summarized in Table 1. It appeared that meal size and meal duration were not affected by the simulated temperature patterns. However, meal frequency tended to be reduced by the large temperature cycle (16.6° C) in the RNT treatment. Consequently the RNT pigs consumed significantly less amount of feed (1.53 kg/day) and had a slower growth rate (0.70 kg/day) than the RPK pigs (1.76 kg and 0.84 kg) or the CON pigs (1.70 kg and 0.81 kg) ($P<0.01$). Feed reduction of the RNT pigs was caused by the high temperatures in the late morning and afternoon of the diurnal cycle. This result differed from the findings of Brumm and Shelton (1988). These authors indicated that a reduced nocturnal temperature of 6° C lower than the daytime thermal neutral constant temperature (30° C and lowered 2° C/wk) had no effect on subsequent performance of weaned pigs. They also reported that the weaned pigs ate more feed and gained faster with the reduced nocturnal temperature and there were no carry-over effects during the growing-finishing phase. However, air temperature in the current RNT treatment reached a maximum daytime level of 40° C.

Feeding characteristics found in this study, i.e., meal size of 160 to 170 g, meal duration of 13.3 to 14.3 min and meal frequency of 9 to 11 per day, were similar to those reported by Bigelow and Houpt (1988) for 30 to 40 kg female pigs at air temperature of 22° to 23° C, i.e., meal size of 166 g, meal duration of 17.7 min, and meal frequency of 10.2 per day. These results were also in agreement with the eating behavior characterized by Nienaber et al. (1990) for pigs of similar weight at air temperature of LCT±4° C. The calculated mean ingestion rates were similar among RPK, CON, and RNT treatments and averaged 12.2 g/min pig. This value was somewhat lower than 15 g/min pig as reported by Feddes et al. (1989) for 36-kg pigs in groups of four at 33° C and 33±7°C. The slower ingestion rate for the individually penned pigs could have resulted from less competition for feed.

The 24-h dynamic feeding profiles as influenced by the simulated temperature regimens are illustrated in figures 2a, 2b, and 2c. The profiles are pooled hourly feed intakes over the six replicates and five days of period. The CON pigs had most feeding activities in the afternoon and evening (between 1500 h and 2100 h), consuming 55% of their daily feed intake. These pigs showed a gradual increase in their feeding activity till darkness. This result paralleled those reported by Ingram et al. (1980) and Fraser et al. (1991) for pigs held under a moderate constant temperature with 12 hours of lighting. In contrast, the RNT pigs had most feeding events at the cooler night and early morning (between 2100 h and 900 h), with 91% of their daily feed intake. In spite of the increased feed intake by the RNT pigs during the cooler period, it was not enough to fully compensate for the feed intake depression from the high temperatures. It appeared, however, if the cooler temperature in the RNT cycle had been extended another two hours into the afternoon or early morning, these pigs might have had more compatible daily feed intake to those by the CON and RPK pigs. By comparison, hourly feeding profile of the RPK pigs was featured by two peaks of

TABLE 1. Feeding characteristics of pigs at the constant and cyclic temperatures

TRT	Body Mass (kg)	Meal Size (g)	Meal Duration (min)	Meal Frequency (meals/day)	FI_{light} (% total)
CON	40 (1.3)	170 (30)	13.3 (1.9)	10 (2)	75
RPK	39 (1.8)	160 (20)	14.3 (2.3)	11 (1)	61
RNT	38 (1.7)	170 (15)	13.5 (1.1)	9 (1)	37

Values in parentheses are standard errors of the means.
TRT - Treatment.
CON - Constant temperature of 30.8° C.
RPK - Reduced daytime peak temperature with a diurnal cycle of 26° to 33° C and mean of 30.8° C.
RNT - Reduced nocturnal temperature with a diurnal cycle of 23.4° to 40° C and mean of 30.8° C.
FI_{light} - Percent of daily feed intake during the lighting period.

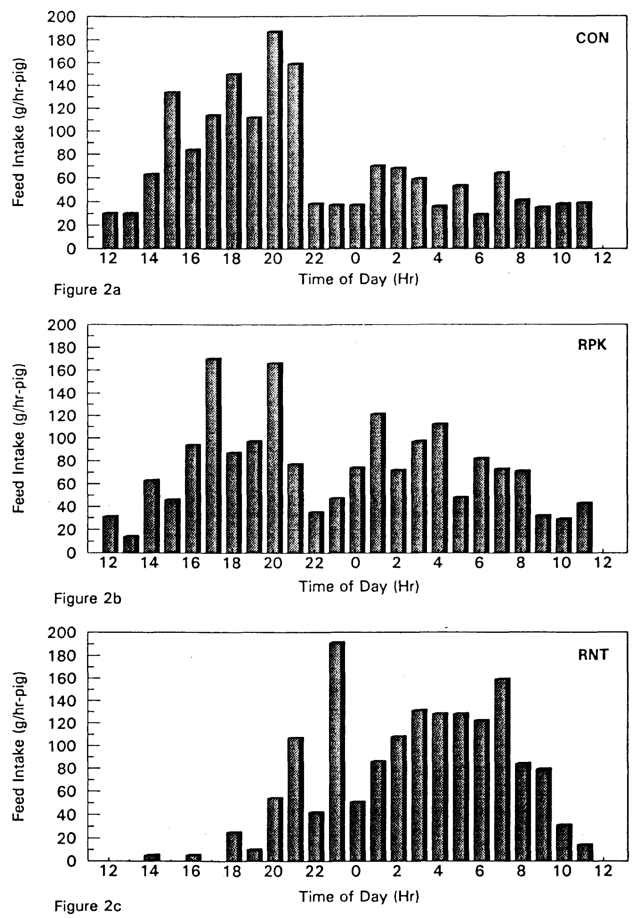

Figure 2–Hourly feed intake of growing swine under the simulated constant temperature (CON) of 30.8° C; reduced daytime peak temperature (RPK) cycling from 26° to 33° C with mean of 30.8° C; and reduced nocturnal temperature (RNT) cycling from 23.4° to 40° C with mean of 30.8° C.

feeding activity. One peak was in the evening and the other was from late night to early morning (fig. 2b). The first peak was believed to be stimulated by lighting while the environment was still warm. The second peak presumably resulted from the lower temperature stimulation.

A sample of the dynamic feeding profile for an individual pig (RNT-pig #3) is presented in figure 3. The instantaneous feeding events were represented by the duration-width of a vertical bar and the feed intake-height of the vertical bar for each feeding event. An individual pig did not eat every hour in spite of the feed consumption shown in the pooled hourly feed intake profiles.

The stimulating effects of lighting on feed intake were shown by the 61% and 75% of daily feed intake that occurred during the 15-h lighting period for the RPK and CON pigs, respectively. These results were in agreement with those reported by Bigelow and Houpt (1988) and Nienaber et al. (1990). However, for the RNT pigs, feed intake was greatest during the dark but cooler period (63% of the daily feed intake). The effect of lighting was overwhelmed by the concurrent high temperature and thus normal feeding rhythm was disrupted in this RNT case. It was hypothesized that had light been provided around the clock for the RNT pigs, a greater amount of feed intake might have occurred during this normally dark but cool period. Consequently, the RNT pigs might have been able to overcome their feed loss caused by the high temperatures. This hypothesis needs supporting evidence and may be further investigated.

Frequency distributions of meal size under each temperature regimen are presented in figures 4a, 4b, and 4c. Meal sizes of 35 to 55 g and 85 to 105 g occurred most often for the CON pigs (25% of all meal sizes) (fig. 4a). For the RPK pigs, the most frequently occurring meal sizes were 65 to 95 g (16%), although there was a wide spread in meal size ranging from 20 to 300 g. Finally, the most frequently occurring meal sizes for the RNT pigs were 125 to 145 g and 170±5 g (18%). Thus the meal size distributions indicated that the RNT pigs were likely to eat larger meals compared to the RPK and CON pigs. The larger meal sizes were expected for the RNT pigs as they had reduced feeding activity for approximately 10 hours due to high temperatures. However, meal size and thus compensatory feed intake were limited by the stomach capacity of the animal.

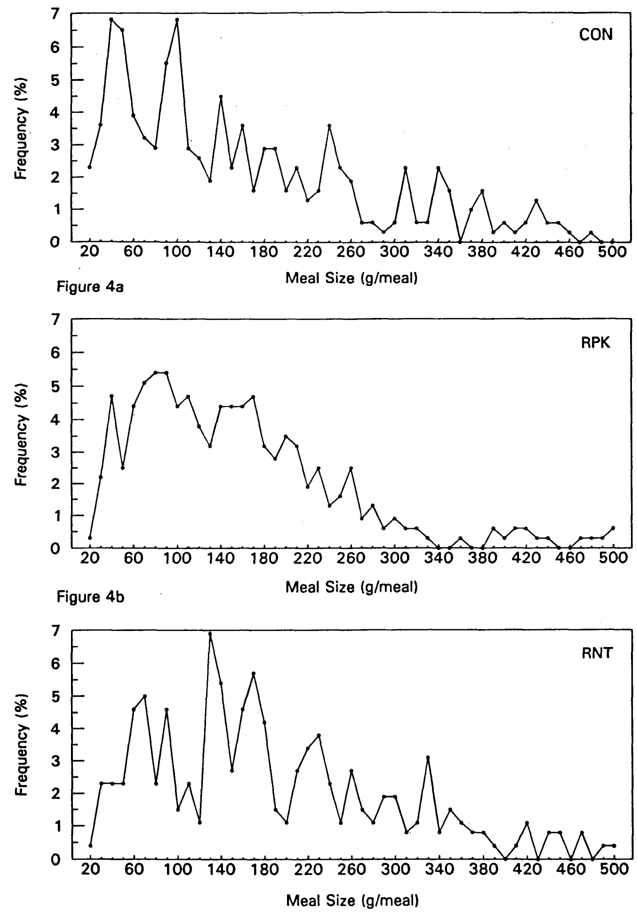

Figure 4–Frequency distribution of meal sizes of growing swine under the simulated constant temperature (CON) of 30.8° C; reduced daytime peak temperature (RPK) cycling from 26° to 33° C with mean of 30.8° C; and reduced nocturnal temperature (RNT) cycling from 23.4° to 40° C with mean of 30.8° C.

The relationship of ingestion rate to meal duration was similar for all experimental pigs and is plotted in figure 5. Although inconclusive because of the low regression coefficient (0.55), it appeared that the ingestion rate and meal duration were somewhat inversely related. Further

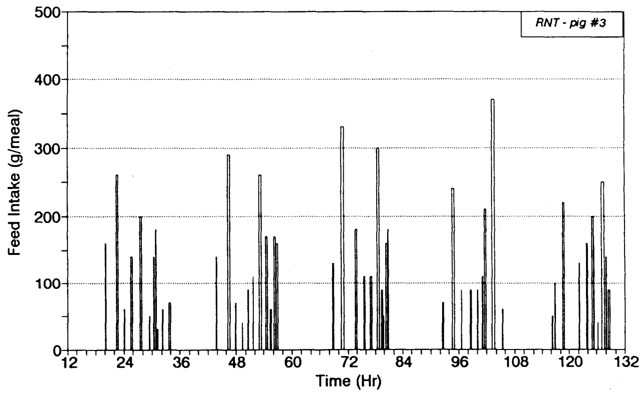

Figure 3–A sample dynamic feeding pattern for a single pig from the reduced nocturnal temperature (RNT) treatment. The width of the vertical bars represents the duration of the feeding events and the height represents the corresponding feed intake.

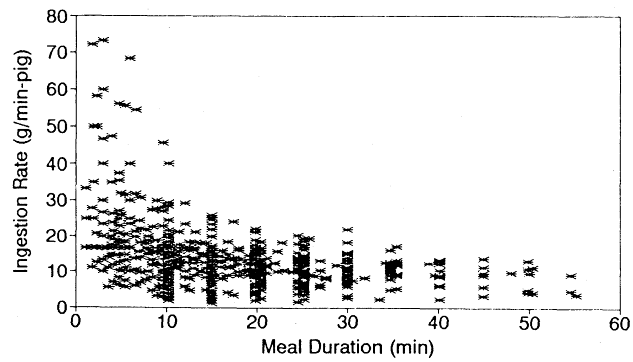

Figure 5–A graphical illustration of relationship between ingestion rate and meal duration for growing pigs under the simulated constant and cyclic temperatures.

verification of the relationship and development of a mathematical expression is recommended.

SUMMARY AND CONCLUSIONS

Feeding behavior of *ad libitum*-fed growing crossbred gilts (39±1.6 kg) as influenced by simulated constant and cyclic temperatures was characterized and compared. The temperature treatments were a) constant temperature of 30.8° C (CON); b) reduced daytime peak temperature cycling from 26° to 33° C with mean of 30.8° C (RPK); and c) reduced nocturnal temperature cycling from 23.4° to 40° C with mean of 30.8° C (RNT). The following conclusions were drawn.

1. Daily feed intake of the pigs was significantly reduced due to the elevated period of exposure to high temperatures in the RNT regimen ($P<0.01$). A 12-h nocturnal cooling did not allow the pigs to fully compensate for their feed intake depression.
2. Average meal size (160 to 170 g), meal duration (13.3 to 14.3 min), and ingestion rate (12.2 g/min pig) did not seem to be influenced by the temperature regimens. However, meal frequency (9 to 11/day) tended to be reduced by the elevated hours of exposure to high temperatures.
3. Dynamic feeding profiles of the pigs were largely influenced by the ambient temperature patterns. Heat stress could disrupt the normal feeding rhythm of the animal. Lighting generally stimulated feeding activity.

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