EFFECT OF FLUCTUATING TEMPERATURES ON PERFORMANCE AND IMMUNITY IN FINISHING SWINE

by

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Introduction

The practice of confinement rearing of swine has posed the added dilema of environmental control on the producer. This in turn prompts the question of how much effect adverse environmental conditions have on animal performance. Previous studies (Heitman *et al.* 1958) have identified a relationship between temperature and maximum weight gain in swine. As weight changes there appears to be a corresponding change in the temperature where maximum performance occurs. This temperature is not a specific point but rather a zone. This approximation of an ideal temperature range for growth is known as the thermal neutral zone (TNZ). However, the optimization of temperature conditions can rarely be applied in modern swine finishing facilities. This is limited by physical facilities and utility cost versus performance compromise. Most of the research that has been conducted is in constant environmental conditions. Constant environmental conditions are very rare and thus results based on these models may be of less importance than in a fluctuating environment. The purpose of this research project was to evaluate the compensatory effect of diurnal cooling on performance and immune function.

Review of Literature

The amount of research on environmental factors affecting livestock has been relatively limited despite the important role of environment on livestock performance. The study of fluctuating environments has been evaluated even less.

Concept of Thermoneutrality

Effective ambient temperature (EAT) has been used in describing the relationship between animals and their thermal environments. Effective temperature is a combination of factors including temperature, humidity, air movement and distribution of radiant energy (Monteith 1974). The EAT is the basis with which Mount (1974) described the formation of the thermoneutral zone. It includes the range of EAT in which metabolic heat production remains basal, body temperature remains normal, sensation of comfort is at its maximum, the animal is in it's preferred thermal environment and the optimum thermal environment for maximum performance. The amount of heat loss must equal heat load and production or the animal enters a thermal stress condition. Thus, the ability to withstand heat load is related to the amount of heat loss. The ability to dissipate heat decreases with an increase in weight. This is also dependent upon the level of feeding. Holmes et al. (1967) found that heat loss was proportional to body weight when intake was constant. Close et al. (1971) noted at 12, 20 and 30C that the rates of heat loss from groups of pigs were related to the level of feeding. The social habits of pigs may have an effect on heat loss. Studies of individual pigs by Close (1971) showed no difference in heat loss between 20 and 30C.

Maximum gain as related to temperature is weight dependent with a decrease in temperature as body weight increases. Correlation of average daily gain (Heitman _et al_. 1958) and mean body weight resulted in a significant positive correlation at 10 and 16C and a significant negative correlation at 27, 32, 38 and 43C. Optimum gain for 68 to 91kg pigs was at 21C. Others (Stahly _et al_. 1978, Verstegan _et al_. 1978) found gain and efficiency at its peak at 22.5 and 25C respectively. Nichols _et al_. (1982) predicted a temperature of 19 to 20C as the optimum temperature for maximum gain for 72kg pigs.

These results show that it is difficult to accurately pick a temperature based on performance or physiological responses as being the optimum. Thus the concept of a thermoneutral zone is used to describe a range in which the animal can best maintain homeostasis.

Effect of Heat Stress

As the effective ambient temperature nears the upper critical limit for a pig, physiological adaptation occurs. Respiration and body temperature increase and pulse rate decreases (Heitman _et al_. 1949). Holmes _et al_. (1967) noted an increase in respiration at 30C compared to 20C. As the upper critical limit is approached there is a marked decrease in feed intake (Nichols *et al*. 1982). Lowered intake results in a lower heat increment but also a decrease in performance. Pigs may also adopt different postures to maximize the amount of heat loss (Heitman *et al*. 1949).

Stress and Immune Function

A review by Kelley (1980) showed immune responses may increase or decrease depending on the stressor and the challenge. The effect of stress on immunological function does not have a constant correlation. Blecha *et al*. (1981) reported elevated antibody titers due to cold stress and decreased titers due to weaning. Heat stress produced similar conflicting responses (Kelley 1980) dependent on the variable and the investigation. Intermittent heat stress of chickens had no effect on synthesis of antibodies to sheep erythrocytes, but exposure for five days resulted in a breed dependent increase. Investigations of cell mediated responses in calves and chickens suggest that heat exposure causes a suppression of mitogenic responses. This same test caused an opposite effect in mice (Kelley 1982).

Effect of Cyclic Temperatures

It has been found that cyclic temperatures have approximately the same effect on performance and physiological traits as the mean of the cycle (NRC 1981). In a lamb trial with the mean at 15C and fluctuations of 5, 10 and 15C deviations from the mean, performance was unaffected (Giacomini 1979). Bond *et al*. (1963) suggested that constant temperature within the TNZ is more conducive to performance than cyclic temperatures. However a small diurnal variation did not greatly reduce performance. Morrison et al. (1975) also observed comparable performance if the mean of the cycle was in the TNZ but showed a decline in performance when the mean was elevated to 6C above optimum. The possibility of a compensatory growth period after heat stress was studied by Morrison et al. (1982). The post heat stress pigs showed a small but significant increase in gain and feed conversion. This resulted in an overall balancing of efficiency but with a net decrease in gain.

Material and Methods

Eighty Yorkshire x Duroc crossbred barrows with an initial weight of approximately 72 kg were used. Two trials were conducted over a four month period from March to June. Trial 1 consisted of two constant and three diurnal temperature patterns:

1. Constant 20C (0h at 35C)
2. 16h at 20C, 8h at 35C
3. 8h at 20C, 16h at 35C
4. 4h at 20C, 20h at 35C
5. Constant 35C (24h at 35C)

The animals were housed two pigs per pen with four replications, for a total of eight pigs per treatment. The diet was a pelleted sorghum grain-soybean meal, 16% crude protein diet (Table 1) offered ad libitum. Water was supplied ad libitum via nipple waterers. The heat stress and fluctuating temperature treatments were housed in two Forma Scientific Walk-in Rooms (3.6m x 4.6m x 2.4 m) with a temperature and relative humidity sensitivity of +.5C and +.5% respectively. Relative humidity was maintained at approximately 50%. A third area of the same floor dimensions was utilized for the TNZ control treatments. Temperature chart recorders measured temperature patterns in the chambers and TNZ area. TNZ temperatures were in the range of 19 to 21C. Pens were 1.5m wide and 2.1m long. Pigs were given a 3 day acclimation period at 20C before the start of each 28 day trial. Pigs were observed twice daily with emphasis on activity and behavior. Performance data was collected weekly measuring gain, feed intake and pen feed efficiency. Immunological parameters were evaluated weekly. Cellular immunity (In Vivo) was evaluated from the change induced by phytohemagglutinin injections (Blecha et al. 1983). Preliminary skin-fold thicknesses were obtained with a constant tension dial micrometer. A 1ml interdermal injection of phytohemagglutinin (PHA) was given in a rear flank fold and 1ml of physiological saline was injected in the opposite flank. Twenty-four hours post-injection the injection sites were remeasured and the data expressed as the change in flank thickness.

A 5ml, 40% suspension of sheep erythrocytes (SRBC) were injected intraperitoneally at day 0 and day 14 of the trial. Five milliliters of heperanized blood were obtained weekly for determination of total and differential leukocyte numbers and SRBC antibodies. Total leukocyte counts were determined on an electronic particle counter calibrated for porcine leukocytes. Differential leukocyte counts were based on standard 100 cell counts from stained blood films. Determination of SRBC antibody titers were by a microtiter hemagglutination assay (Blecha et al. 1981).

Trial 2 was a duplicate of Trial 1. Data from the trials were pooled and differences in performance, PHA response, blood samples and SRBC titers were analyzed by least-squares analysis of variance of the Statistical Analysis System (Barr *et al.* 1979).

Table 1. Composition of Diet Fed to Finishing Pigs[a]

Ingredient	International Reference Number	Percent
Grain sorghum	4-04-444	76.35
Soybean meal	5-04-604	20.00
Dicalcium phosphate	6-01-080	1.40
Ground limestone	6-02-632	1.00
Salt		.50
Vitamin premix[b]		.50
Trace mineral premix[c]		.10
Antibiotic[d]		.15

[a] Calculated analysis: 15.97% protein, .75% lysine, .75% calcium, .65% phosphorus, digestible energy 3270 kcal/kg.

[b] Amounts per kg: Vitamin A, 880,000 U.S.P.: Vitamin D_3, 66,000 U.S.P; riboflavin, 990 mgs; d-pantothenic acid, 2640 mgs; choline, 65.9 mgs; niacin, 5500 mgs; Vitamin E, 5500 I.U.; Vitamin B_{12}, 4.84 mgs; Vitamin K, 550 mgs; ethoxyquin, 6270 mgs.

[c] Containing 5.5% manganese, 10% iron, 1.1% copper, 20%zinc, .15% iodine and .1% cobalt.

[d] Supplied as 55 mg tylosin per kg of diet.

Results and Discussion

Average daily gains (Table 3) were depressed (P<.04) for pigs in the 24h at 35C treatment. In all other temperature treatments gain remained similar with a trend towards reduction. Cooling the environment to the TNZ from heat stress for only 4 hours a day resulted in more than a twofold increase in daily gain when compared to pigs exposed to constant 35C.

Average daily feed intake differed (P<.04) between the 0h at 35C and the 24h at 35C treatment animals. As hours at 35C increased there was a trend towards a reduction in feed intake (Table 3). This is consistent with other data (Nichols *et al*. 1982) that showed a decrease in intake with increasing temperatures.

Pigs housed at 35C for 24h had a reduced (P<.04) gain/feed ratio (Table 3). All other treatments were similar.

Pig adaptation to heat stress over the 28 day trial occured. Pigs exposed to 24h at 35C had an increase (P<.04) in gain (Figure 1) and an improvement (P<.04) in feed efficiency (Figure 3). Average daily intake (Figure 2) of pigs at 35C for 24h increased the second week followed by a decline the third week, resulting in no change over the trial.

PHA skin-test responses were decreased (P<.02) for pigs in the 20h at 35C and the 24h at 35C (Table 4) treatments. Lymphocyte numbers (Figure 4) also tended ($P<.10$) to decrease over the 4 week trial in the two hottest temperature treatments (20h at 35C and 24h at 35C). There were no differences in total or differential leukocyte counts (Table 2). Red blood cell counts were similar across all temperature patterns (Table 2). There were no treatment differences in antibody titers to SRBC immunization (Table 2).

The mean temperatures of the treatments were constant 20C, cyclic means of 25, 30, and 32.5C; and constant 35C respectively. Finishing pigs cooled to the TNZ for only four hours (mean 32.5) had similar performance to those at constant TNZ (20C). This differs from data reported by Morrison et al. (1975) that showed a decreased performance when the mean temperature was above the TNZ. These results indicate that there can be a compensatory effect which allows continued performance if a period of relief from heat stress is available. The pigs observed during the heat stress period were usually in a spread posture with little or no movement. When the cooling cycle began they became more active with the majority of their activity being during the cooler period. Data from weaning pig studies (Nichols et al. 1984) showed that pigs may adapt to temperatures outside their TNZ if allowed a diurnal return to the TNZ. In conclusion, these data suggest that pigs in all but the most severe heat stress conditions can compensate for the heat stress and maintain their performance if given only a 4 hour period of cooling. Heat-induced immunosuppression was offset by 8 or more hours of daily cooling (20C).

Table 2. Performance Data[a]

Daily Hours at 35C	Average[b] Daily Gain (kg)	S.E.	Average[c] Daily Intake (kg)	S.E.	G/F[c]	S.E.
0	.87[d]	.04	3.07[d]	.06	.28[d]	.01
8	.84[d]	.04	2.72[d,e]	.06	.31[d]	.01
16	.64[d]	.04	2.27[d,e]	.06	.28[d]	.01
20	.73[d]	.04	2.45[d,e]	.06	.29[d]	.01
24	.31[e]	.04	1.89[e]	.06	.18[e]	.01

[a]Data are least-square means pooled from trials 1 and 2.

[b]Data from 16 observations per treatment.

[c]Data from 8 observations per treatment.

[d,e]Means with different superscripts in the same column differ ($P<.04$).

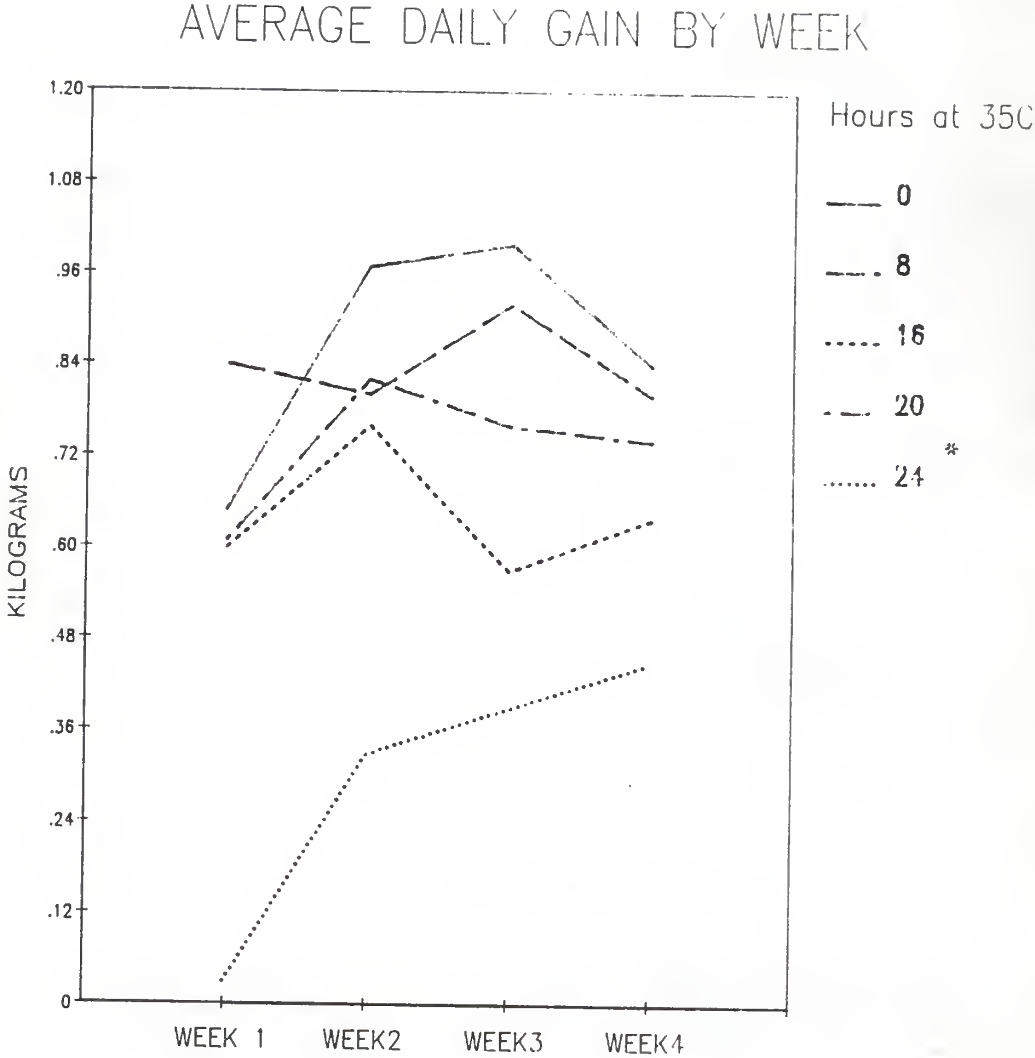

Figure 1. Data are least-square means by week for trial 1 and trial 2.

*Indicates a change (P<.04) between initial and ending weekly gains.

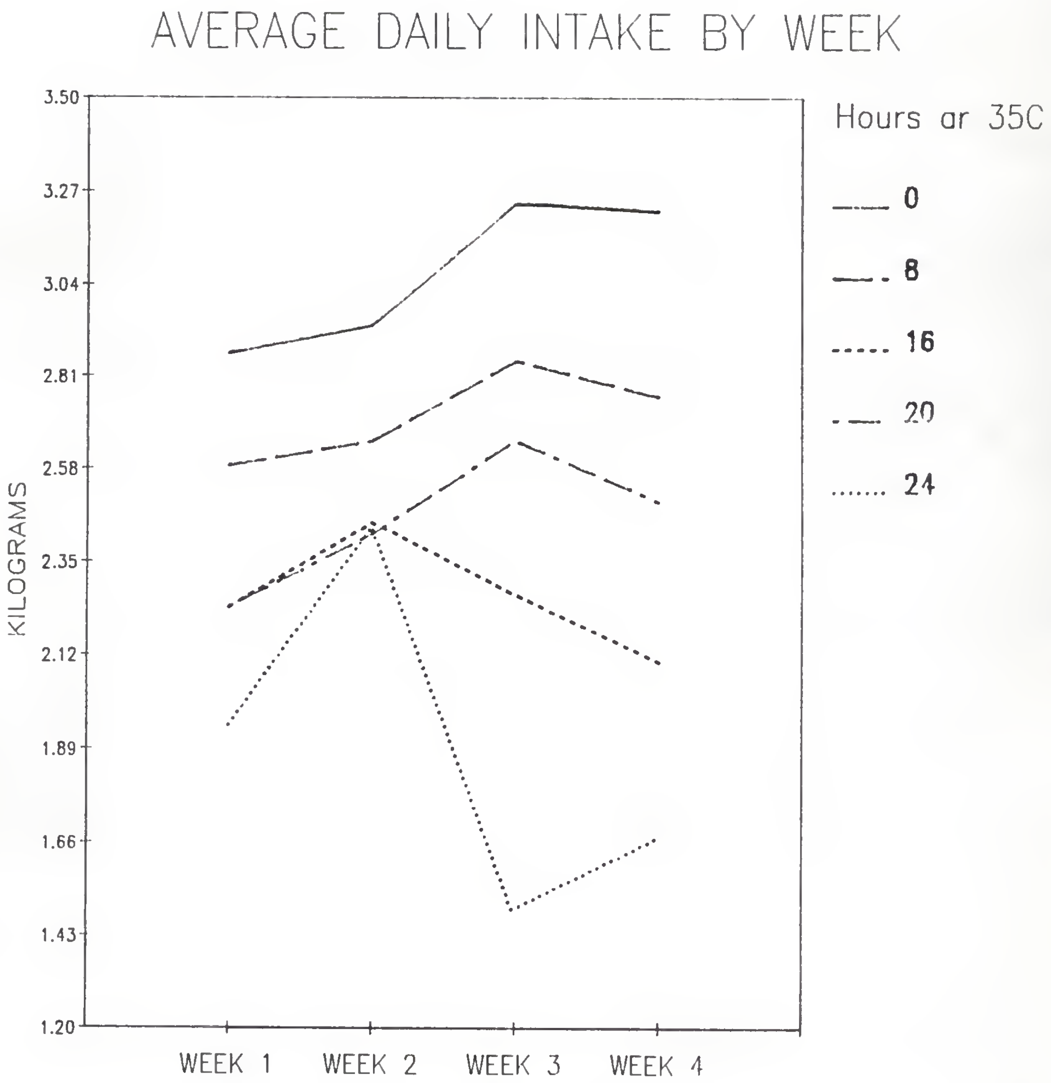

Figure 2. Data are least-square means by week for trial 1 and trial 2.

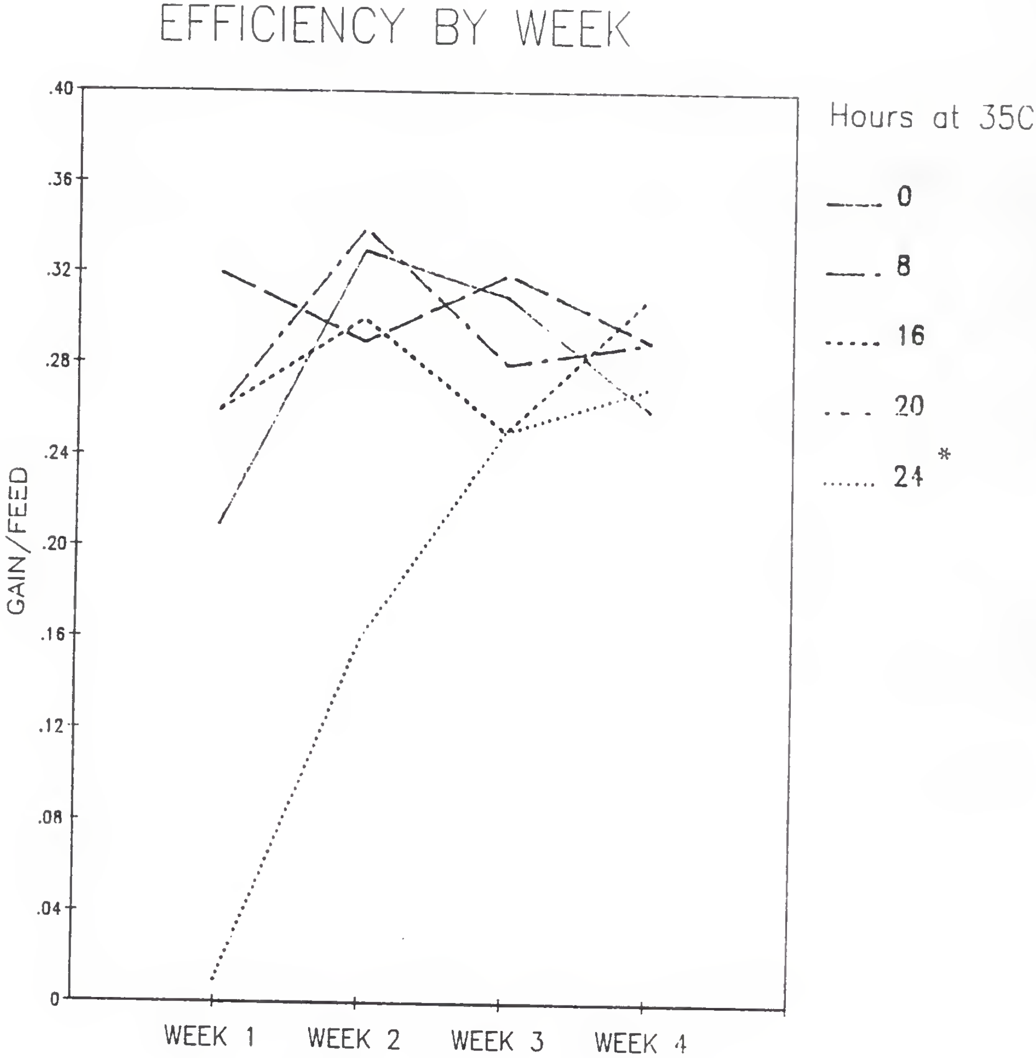

Figure 3. Data are least-square means by week for trial 1 and trial 2.

*Indicates a change (P<.04) between initial and ending weekly efficiencies.

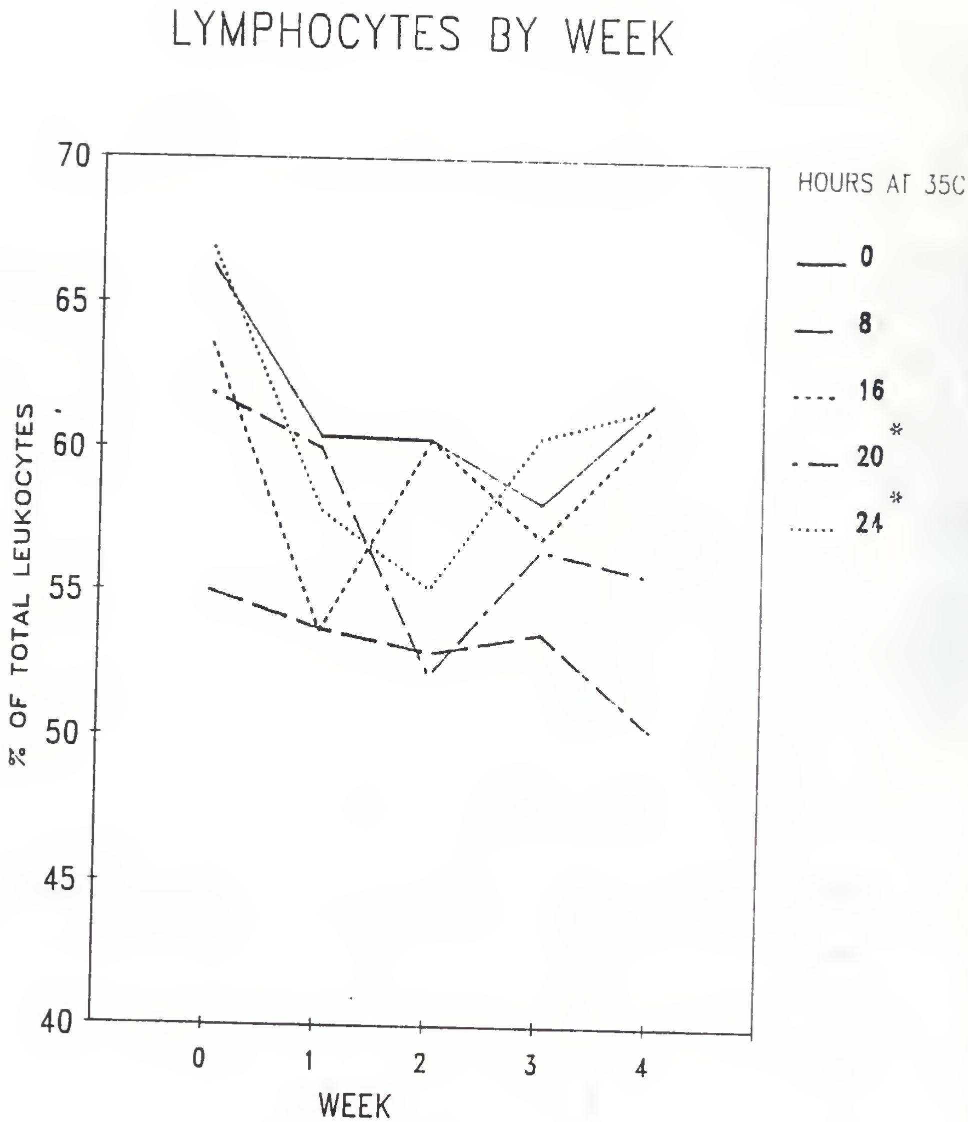

Figure 4. Data are least-square means of weekly lymphocyte counts for trials 1 and 2.

*Indicates a change (P<.10) between initial and ending weekly lymphocyte counts.

Table 3. Total and Differential Leukocyte Counts, RBC Counts and SRBC Titers.[a]

Hours at 35C	WBC $10^3.ml^{-1}$	S.E.	RBC $10^6.ml^{-1}$	S.E.	Poly %	S.E.	Lymph %	S.E.
24	20.36	.54	8.00	.16	26.20	.89	60.35	1.06
20	20.98	.53	7.51	.16	28.24	.87	57.25	1.04
16	21.78	.55	8.26	.16	24.30	.89	59.07	1.06
8	22.32	.53	7.74	.16	26.72	.87	53.08	1.04
0	21.97	.54	8.66	.16	26.34	.89	61.36	1.05
	EOSU %	S.E.	Mono%	S.E.	Baso%	S.E.	SRBC log_2	S.E.
24	6.09	.48	3.01	.26	.44	.09	4.00	.09
20	6.40	.47	3.57	.25	.70	.09	3.94	.09
16	8.04	.48	4.90	.26	.49	.09	3.89	.09
8	11.04	.47	5.72	.26	.70	.09	4.19	.09
0	5.88	.48	2.99	.26	.68	.09	4.36	.09

[a]Data are least-square means of pooled values from all weekly determinations+.

Table 4. PHA and Saline data represented are induced changes in initial and 24h post-injection skin-fold thicknesses.[c]

Daily Hours at 35 C	PHA (mm)	S.E.	Saline (mm)	S.E.
0	9.87[a]	.23	.38	.11
8	9.43[a]	.23	.76	.11
16	8.89[a]	.23	1.18	.11
20	7.20[b]	.23	.85	.11
24	7.21[b]	.23	1.19	.11

[a,b]Means with different superscripts in the same column differ (P<.02).

[c]Data are least-square means for trial 1 and 2 with 16 observations per temperature treatment.

Summary

Eighty crossbred barrows were used to evaluate the effect of diurnal fluctuations of heat stress to thermal neutral temperatures on the performance parmeters of average daily gain, feed intake, and efficiency of finishing pigs. Immunological responses evaluated were phytohemagglutinin (PHA) skin test reaction, antibody response to sheep erythrocytes (SRBC) and total and differential leukocyte numbers. Five different temperature treatments were used. Two constant dry bulb temperatures of 20C and 35C and three diurnal fluctuations of 16h at 20C, 8h at 35C; 8h at 20C, 16h at 35C; and 4h at 20C, 20h at 35C. After a 3 day acclimation period at 20C the pigs were placed on a 28 day trial. A 16% protein, sorghum grain-soybean meal diet and water were supplied ad-libitum. Feed intake and growth performance were measured weekly. _In vivo_ cellular immunity was evaluated weekly by recording the change in flank skin thickness due to PHA injections. A 5ml, 40% SRBC suspension was injected at day 1 and day 14 of each trial. Determination of SRBC antibody titers and total and differential leukocyte numbers were based on weekly heparnized blood sampling. Average daily gain, average daily feed intake and feed efficiency (gain/feed) were improved (P<.04) for pigs housed in thermal neutral enviornments as compared to the constant heat stress (.87, 3.07 and .28 vs. .31, 1.89 and .18) of 24h at 35C. Pigs housed in environments with daily cooling to 20C for 4,

8 or 16h had improved (P<.04) performance over the those exposed to constant heat stress conditions. Pigs exposed to the two hottest treatment environments (20 and 24hrs at 35C) resulted in a decreased (P<.02) skin-test reaction and lymphopenia tended (P<.10) to occur. The data suggests that daily cooling for as little as a 4h period can result in an improvement in performance parameters and that heat stress conditions for all or most of the day can result in a decrease in cellular immunity in finishing pigs.

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Eighty crossbred barrows of approximately 72kg were used to evaluate the effect of diurnal cyclic temperature treatments on the performance and immunological response of finishing pigs. The experiment consisted of two trials utilizing 4 pens of 2 pigs for each treatment per trial. The environmental treatments were two constant dry bulb temperatures of 20C and 35C and three daily fluctuations of 16h at 20C, 8h at 35C; 8h at 20C, 16h at 35C; and 4h at 20C, 20h at 35C. Average daily gain (kg), feed intake (kg) and efficiency (gain/feed) were improved (P<.04) for pigs housed in thermal neutral environments (20C) as compared to the constant heat stress (.87, 3.07 and .28 vs .31, 1.89 and .18) of 24h at 35. Pigs housed in environments with daily cooling to 20C for 4, 8 or 16h also had improved (P<.04) performance over the constant heat stress conditions. The two hottest treatment environments resulted in a decreased (P<.02) phytohemagglutinin skin-test reaction and lymphopenia tended (P<.10) to occur.