EFFECT OF FAT THICKNESS AND TEMPERATURE ON AVERAGE DAILY GAIN AND FEED TO GAIN RATIO IN FINISHING SWINE

by

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INTRODUCTION

Energy costs for heating and cooling swine buildings have caused producers to search for alternative ways to produce swine with a minimum of supplemental energy. Justification for modifying the environment requires economic benefit in terms of increased gain and feed efficiency.

Heitman *et al*. (1958) developed a formula relating size of pig and air temperature for optimum growth. This formula is:

$$T = -.06W + 26$$

where, T = air temperature (C); and W = hot weight (kg). This formula predicts optimum temperature for 50 kg pigs as 23 C, and for 100 kg pigs as 20 C. To achieve these temperatures environmental modification is generally required.

One major factor not considered in Heitman's formula is fat thickness. Since fat serves as insulation against conductive heat loss, temperature for optimum growth should vary with degree of fatness. With the selection of leaner swine, producers may have lowered the pig's tolerance to cold temperatures.

Two measures of the effect of cold on pigs of varying backfat thickness are feed to gain ratio and average daily gain. By examining the effect of varying degrees of cold, it may be possible to determine the relationship between backfat thickness and the optimum temperature for growth and efficiency as well as the most economically feasible temperature for modern swine production.

LITERATURE REVIEW

Air temperature effects on swine performance have been studied for many years. Temperature is one of the easiest environmental factors to control and according to Bond (1974), in a review of environmental factors affecting production, it may be the most important single factor to consider.

Concepts of Thermal Stress

Graham et al. (1959) defined the thermal neutral zone (TNZ) for domestic animals as the range of temperatures in which heat production is constant. According to Mount (1974), the TNZ may be defined as the range of temperatures in which animal production is maximized. Graham et al. (1959) termed the lower limit of the TNZ the critical temperature. Below the critical temperature (cold stress) or above the upper limit of the TNZ (heat stress) homeotherms undergo chemical and physical changes to acclimate to the environment and to maintain their body temperature (Brody, 1945; Holmes and Close, 1977). This adjustment to stress lowers total efficiency and performance (Johnson, 1978; Whittow, 1971).

Heat Production and Heat Loss

Although animals continually gain and lose heat, heat production equals heat loss. This relationship is necessary to maintain constant body temperature (Holmes and Close, 1977; Graham et al., 1959).

Fuller and Boyne (1972) found heat production increased with increases in body weight and intake with a decline in ambient temperature. Verstegen et al. (1973) concluded that rate of heat loss was determined primarily by two factors: (1) plane of nutrition and (2) environmental temperature. Below the TNZ heat loss was dependent on ambient temperature and not affected by plane of nutrition.

Graham et al. (1959) found different amounts of feed caused a change in heat production at temperatures above 25 C; whereas, below 25 C heat production was dependent on environmental temperature and not feeding level. Close et al. (1971) reported heat production was independent of plane of nutrition above 7 C.

Mount (1976), working with 90 kg pigs observed an increased rate of metabolism from 50 to 78 ($kcal/m^2/hr$) when temperatures were lowered from 20 C to 5 C.

Animals maintain energy balance with the environment by conduction, convection, radiation and evaporation (Brody, 1945). The relative importance of these avenues of heat exchange varies with the ambient temperature.

Conduction, convection, and radiation are generally termed sensible avenues of heat exchange, while evaporation is referred to as insensible (Brody, 1945). Bond et al. (1959), Close (1971) and Holmes and Mount (1967), all reported a decline in insensible heat loss with a decline in temperature. A 14% increase in the sensible component of total heat loss was observed by Bond <u>et al</u>. (1952) when temperatures dropped from 20 to 5 C.

The major factor in rate of conductive heat loss is insulation. Total body insulation consists of three layers: (1) a thin layer of still air on the coat surface, (2) the hair coat and (3) tissue. Brody (1945) developed the formula:

$$I = \frac{I}{\text{heat flow}}$$

where, I = insulation, and T = temperature gradient. Increases in air, external and tissue insulation decrease conductive heat loss (Blaxter, 1972). In pigs fat tissue is the primary insulation against heat flow. Increased body fatness in young pigs and sows has been shown (Ingram, 1964; Holmes and McLean, 1974) to increase tissue insulation.

In comparing fat versus lean pigs weighing 140 kg, Close (1971) observed a significantly lower rate of heat loss for the fat pigs.

<u>Effects of Temperature on Feed Intake</u>

Heitman and Hughes (1949) Ingram and Legge (1973), and Sugahara <u>et al</u>. (1970) found intake decreased at temperatures above the TNZ and significantly increased below the critical temperature. Hale and Johnson (1970) found pigs consumed 6% more feed in winter trials than in summer. Increases in appetite and total calorie intake were observed by Johnson (1978). In young pigs, Fuller (1965), measured intake at 5, 13 and 23 C and reported feed consumptions (g/W kg$^{.75}$/24 hr) were 140, 120 and 100, respectively.

Feed Efficiency During Cold

In early trials, Shelton (1883) reported pigs fed in open barns in winter required 25% more feed per pound of gain than their littermates housed in the basement of a warm barn. Close *et al*. (1971) determined that for each 1 degree drop below 12 C an additional 1.3 g of feed/kg of body weight was needed to maintain a level of energy retention equivalent to that which occurs in the thermal neutral zone.

By use of models and comparisons to field trials, DeShazer and Teter (1974) predicted feed to gain ratios increased below 13 C for the 68 to 91 kg pig. Heitman and Hughes (1949) reported reduced feed efficiency below 15 C for pigs weighing 75 to 118 kg. In experiments with 23 kg pigs to market weight, Mangold *et al*. (1960) found the feed to gain ratios to be .80 higher at -1 C compared to 15 C.

Growth Rate During Cold

DeShazer and Teter (1974) predicted maximum growth of the finishing pig occurred at approximately 13 C with a 25% decline in gain as temperatures were lowered to -1 C. In close agreement, Heitman and Hughes (1949) found 15 C as the point of optimum growth.

Holmes and Coey (1967) observed significantly higher growth rate for finishing pigs at 22 C compared to 12 C. Mangold (1960) reported daily gains at -1 C were .14 kg less than at 15 C.

Carcass Composition

There is some disagreement on the effect of temperature on carcass composition. Sorenson (1962) reported a greater effect of cold temperatures on nitrogen retention than on growth rate, suggesting that pigs in colder climates would produce fatter carcasses than those in the thermal neutral zone. Since less energy is available for deposition of fat at temperatures below the critical temperature, it would be expected that maximum carcass fatness would occur within the TNZ. Fuller (1969) found pigs kept at temperatures within the TNZ were significantly fatter than those subjected to cold or heat stress. Holmes and Coey (1967) found no differences in backfat depth of pigs at 12 C and 22 C. However, pigs at 22 C produced longer carcasses. In agreement, Sugahara *et al*. (1970) found carcasses of pigs kept at 7 C were significantly shorter than those at either 23 C or 33 C. Hale and Johnson (1970) reported that pigs in summer trials probed 6% more backfat than those fed in winter trials. Studying the effect of feeding level and temperature, Fuller and Boyne (1971), fed pigs at 5, 13 and 23 C. When all pigs were fed at levels which yielded equal growth, carcasses from the 5 C group were significantly fatter than those at 23 C. When the pigs were fed equal amounts of feed, no differences in carcass composition were observed. Hacker et al. (1973) found pigs raised at 2 C were leaner than littermates raised at 20 C.

Behavioral Effects

An interesting, but subjective effect of thermal stress is behavior. Close (1971) observed pigs at 7 C were much more excitable and developed a crouching position compared to pigs housed at 20 and 30 C. Close et al. (1971) found huddling of pigs occurred at 7 C and pens were kept considerably cleaner than those housed at 30 C. Heitman and Hughes (1949) also observed huddling at 5 C and termed this action "community heating." Sugahara et al. (1970) reported pigs housed at 7 C had longer hair coats and a reduction in the amount of surface area exposed to the cold compared to pigs fed at 23 and 33 C.

Huddling or community heating reduces surface area exposed and sensible heat loss from the pig. In comparing heat losses of finishing pigs kept at 7, 20 and 30 C, Close (1971) found heat losses were 19 to 23% less for groups of pigs compared to those fed individually. This demonstrates the pig's ability to lower heat loss with behavioral changes.

MATERIALS AND METHODS

The experiment was divided into five 28-day trials. Temperatures of 0, 5, 10, 15 and 20 C were studied. All temperatures were controlled in two Forma Scientific Walk-In Rooms (3.6 m X 4.6 m X 2.4 m) with a temperature sensitivity of $\pm$ .5 C. All temperatures were randomly assigned prior to the start of the experiment and replicated once.

Eighty crossbred barrows of similar genetic background were obtained for the study. All pigs weighed approximately 72 kg at the start of each trial. Barrows were selected for a lean and fat population by use of a Scanoprobe ultrasonic backfat measuring device. Measurements were taken at the first rib, last rib and last lumbar vertebrae and averaged. Starting backfat thickness for the lean and fat groups were 1.5 and 2.8 cm, respectively.

Prior to the start of each trial pigs were allotted and fed for five days at 15 C. After the five-day adjustment period pigs were reweighed, proved and fed the next four weeks at the assigned temperature.

Each chamber was divided into four equal sized pens 1.5 m wide and 2.1 m long. Two pigs of the same fat thickness group were placed in each pen. Floors of the pens were totally slatted with concrete slats. Relative humidity was held constant at fifty percent. Air movement was minimized to eliminate drafts and wind chill effects.

Feed and water were supplied *ad libitum*. All pigs were fed the same sorghum-soy diet in meal form. Composition and proximate analysis of the ration are reported in table 1.

Pigs were weighed and probed weekly. Feed consumption was also measured weekly. Average daily gain, average daily feed intake, feed to gain ratio and average backfat were calculated and analyzed.

The least square analysis of variance Kemp (1972) was used to statistically analyze the data. Regression equations and R-square values were calculated. Plots of the data were established with the IBM 370 plotting routine.

RESULTS AND DISCUSSION

In comparing fat and lean groups combined average daily gain (table 4) was linearly ($P<.01$) affected by ambient temperature. Maximum gain was observed at 20 C, but no significant improvement in gain was observed when temperatures were raised above 10 C.

Feed to gain ratio for the fat and lean groups combined is reported in table 4. Temperature affected feed to gain ratio quadratically ($P<.01$) for the pooled data. The lowest feed to gain ratios observed occurred at 20 C. However, as reported for average daily gain, no significant improvement in feed to gain ratio was observed above temperatures of 10 C.

Feed intake of pigs housed at 0 C was significantly higher than at any of the warmer temperatures ($P<.01$). Pigs fed at 0 C consumed 5.1 kg feed daily compared to intake of 3.8 kg for pigs housed at 5 C.

Less variation in response to temperature was observed for feed intake than for either average daily gain or feed to gain ratio. Regression analysis of average daily feed showed a very low R-square value. Average daily feed values are reported in table 4.

Regression equations (figures 1 and 2) were calculated based on the observations. Predicted ADG (kg) is described as:

$$ADG = .4732 + .0214 \text{ (temp C)}.$$

The quadratic equation for feed to gain ratio is:

$$F/G = 9.657 - .6819 \text{ (temp C)} + .019 \text{ (temp C)}^2.$$

Predicted performance from these equations at 0 C is .47 kg ADG and F/G, 9.66. At 20 C, predicted performance is .90 kg ADG and F/G, 3.62.

Based on the observations of this study, the critical temperature defined previously is 10 C or lower and optimum temperature of performance is approximately 10 to 15 C for pigs weighing 65 to 95 kg. This range is slightly lower than proposed by Heitman et al. (1958).

In comparing fat versus lean pigs, no significant differences in performance were observed at any of the temperatures studied. Mean values of average daily gain and feed to gain ratio are listed in table 3.

Regression equations were calculated for predicting the performance of the fat and lean pigs. Plots of observed values and regression equations of average daily gain are given in figures 3, 4 and 5 and feed to gain plots appear in figures 6, 7 and 8.

The fat group showed no significant advantage in performance or apparent lowered heat loss compared to the lean pigs. Close (1971) observed lower rates of heat loss for fat versus lean pigs weighing 140 kg.

As temperature increased from 0 to 20 C, lean pigs tended to outgain fat pigs housed at the same temperature.

This difference in gain increased as temperature increased. However, in comparing feed efficiencies of the two groups (figure 8), the fat pigs became progressively less efficient than the lean pigs as temperatures were lowered from 20 to 0 C.

Average daily gain, feed to gain ratio and average daily feed were measured weekly.

No significant differences by week were observed for feed to gain ratio or average daily feed. Week of trial did show a significant effect on average daily gain ($P<.05$). Pigs housed at 0, 10 and 15 C appeared to show an acclimation response and average daily gains improved significantly after one week on trial.

Although difficult to measure, behavioral effects were also observed. No behavioral differences were observed between the fat and lean groups. All pigs shivered intensely at 0 and 5 C. Pigs housed at the lower temperatures appeared to show increased excitability and restlessness. As temperatures declined the pigs developed a crouching position and increased huddling with pen mates was observed. This posture was an apparent attempt to lower body surface area exposed to the cold environment.

The results of this study indicate temperature does effect performance of finishing pigs. Temperatures below 10 C have a severe, detrimental effect on pig performance. Above 10 C costs of environmental modification may be difficult to justify since no significant improvement in performance was observed when temperatures were raised to 15 or 20 C.

In comparing fat versus lean pigs, no significant differences were observed at any of the temperatures studied. This may indicate that within the usual range of temperatures of swine production in the finishing phase, reduction of backfat thickness will not depress performance.

TABLE 1. COMPOSITION OF RATION FED TO PIGS[a]

Ingredient	International reference number	Percent
Grain sorghum	4-04-444	76.45
Soybean meal (44%)	5-04-604	20.00
Dicalcium phosphate	6-01-080	1.40
Ground limestone	6-02-632	1.00
Salt		0.50
Vitamin premix[b]		0.50
Trace mineral premix[c]		0.05
Antibiotic[d]		0.10
		100.00

[a]17.2% protein, .78% lysine, .74% calcium, .62% phosphorus, digestible energy 3270 cal/gm.

[b]Amounts per kg: Vitamin A, 881,000 U.S.P.; Vitamin D_3, 66,000 U.S.P.; riboflavin, 991 mgs; d-pantothenic acid, 2,650 mgs; choline, 66 mgs; niacin, 5,500 mgs; Vitamin E, 4,400 I.U.; Vitamin B_{12}, 4.8 mgs; Vitamin K, 550 mgs; antioxidant, 6.3 mgs.

[c]Containing 0.1% cobalt, 1.0% copper, 0.3% iodine, 10% iron, 10% manganese and 10% zinc.

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

TABLE 2. EFFECT OF TEMPERATURE ON AVERAGE DAILY GAIN BY WEEK

Temperature (C)	Average daily gain (kg)[a]			
	Week 1	Week 2	Week 3	Week 4
0	.29[b]	.48[c]	.59[c]	.54[c]
5	.56[b]	.54[b]	.58[b]	.46[b]
10	.63[b]	.78[c]	.80[c]	.81[c]
15	.93[c]	.81[b]	.74[b]	.84[bc]
20	.95[b]	.88[b]	.86[b]	.80[b]

[a]Values are means of 16 observations.

[bc]Values within the same row with the same superscript are not significantly different ($P<.05$).

TABLE 3. EFFECT OF TEMPERATURE ON AVERAGE DAILY GAIN AND FEED TO GAIN RATIO OF FAT VERSUS LEAN PIGS ADJUSTED FOR WEEK EFFECT

Temperature (C)	Average daily gain (kg)[a]		Feed to gain[b]	
	Fat	Lean	Fat	Lean
0	.54	.54	9.12	9.67
5	.54	.51	6.52	7.69
10	.71	.89	4.66	4.07
15	.73	.86	4.36	3.62
20	.82	.88	3.72	3.85

[a]Values are means of 8 observations.

[b]Values are means of 4 observations.

TABLE 4. EFFECT OF TEMPERATURE ON AVERAGE DAILY GAIN, FEED TO GAIN RATIO, AND AVERAGE DAILY FEED OF FAT AND LEAN PIGS COMBINED

Temperature (C)	Average daily gain (kg)[a]	Feed to gain[b]	Average daily feed (kg)[c]
0	.54[d]	9.40[d]	5.07[d]
5	.53[d]	7.10[d]	3.76[e]
10	.80[e]	4.37[e]	3.50[e]
15	.79[e]	3.99[e]	3.15[e]
20	.85[e]	3.79[e]	3.22[e]

[a]Values are means of 16 observations.

[b]Values are means of 8 observations.

[c]Values are means of 8 observations.

[de]Means with same superscript are not significantly different ($P<.05$).

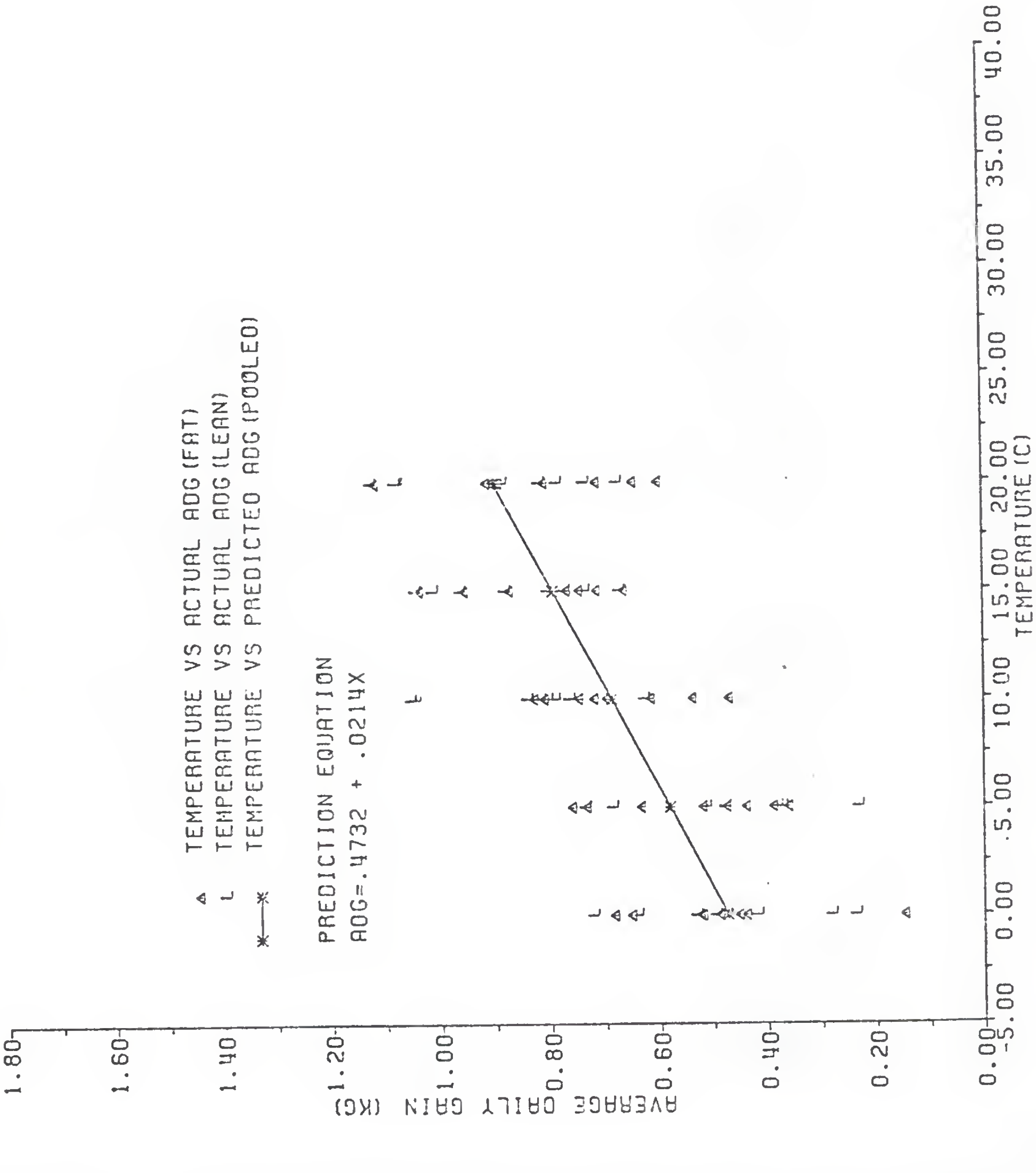

Figure 1. Average daily gain versus temperature for fat and lean pigs combined.

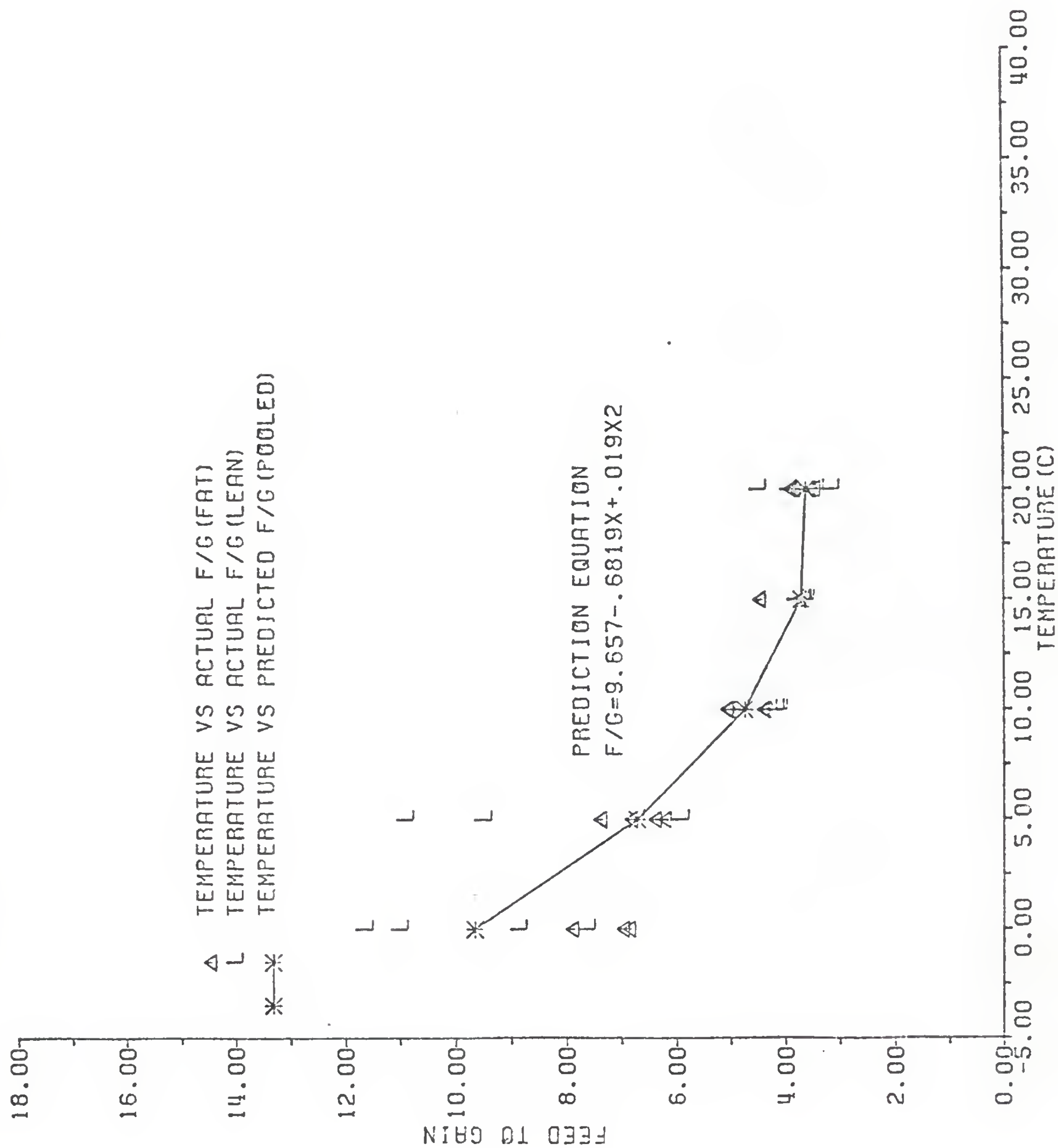

Figure 2. Feed to gain ratio versus temperature for fat and lean pigs combined.

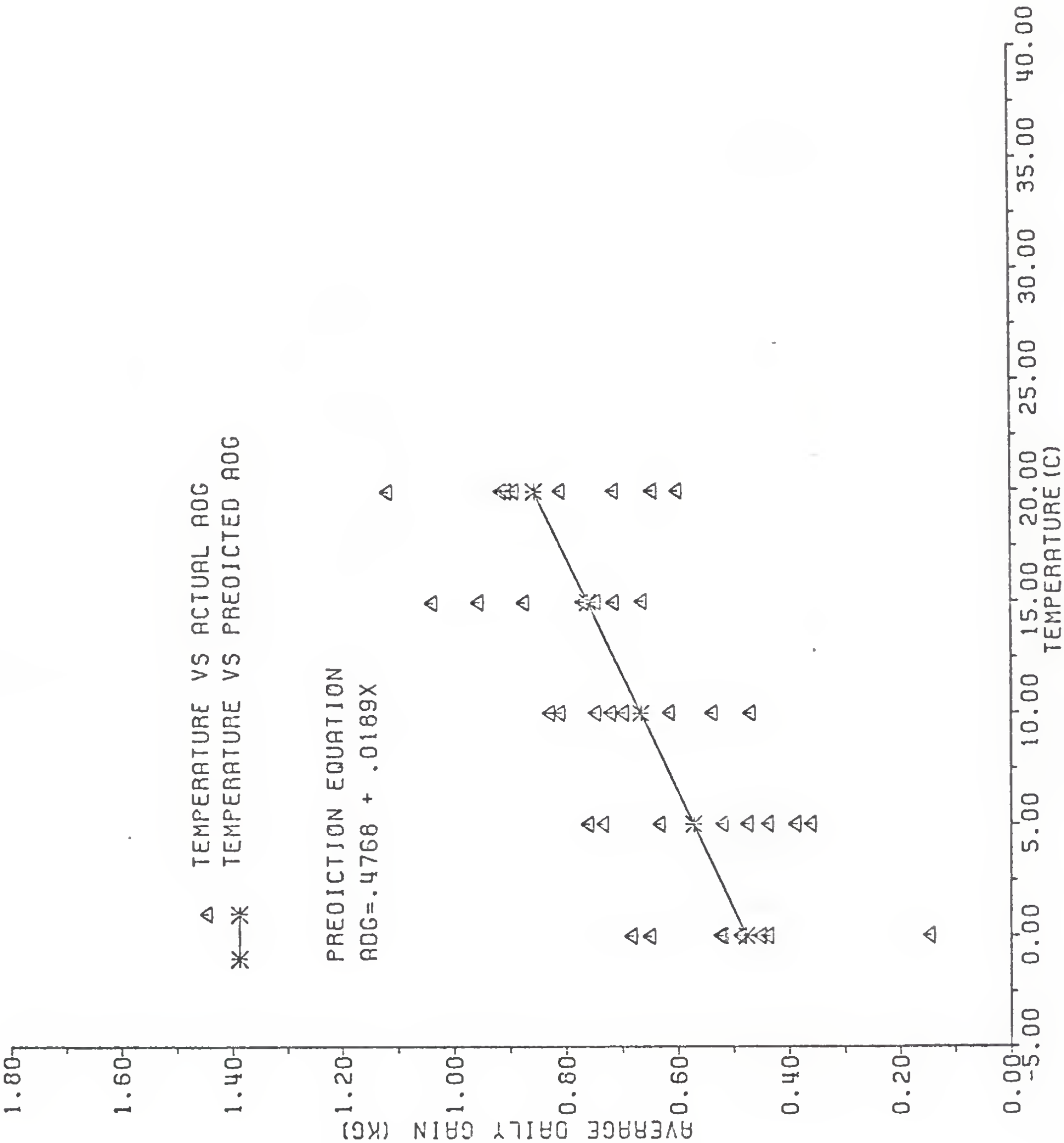

Figure 3. Average daily gain versus temperature for fat pigs only.

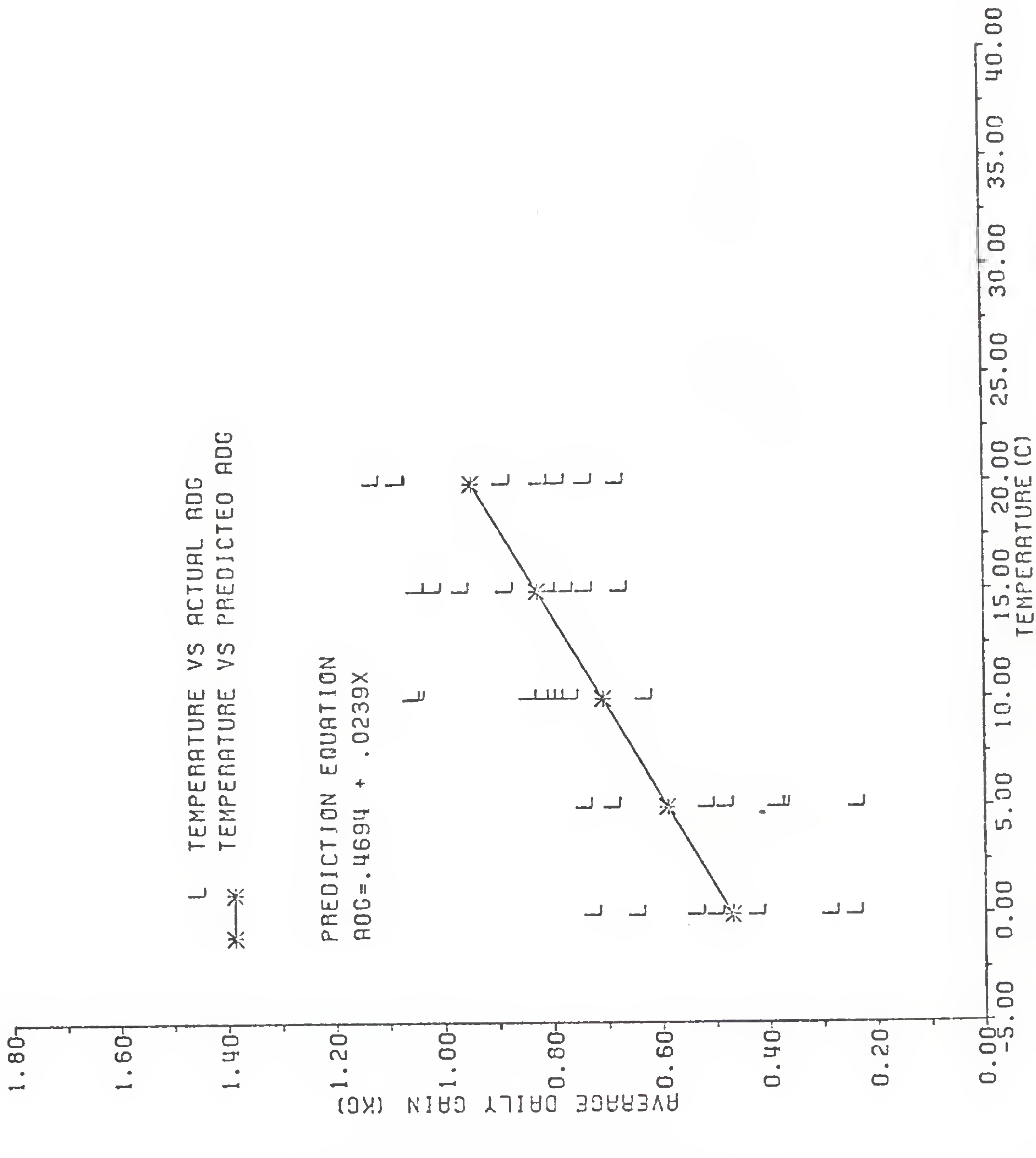

Figure 4. Average daily gain versus temperature for lean pigs only.

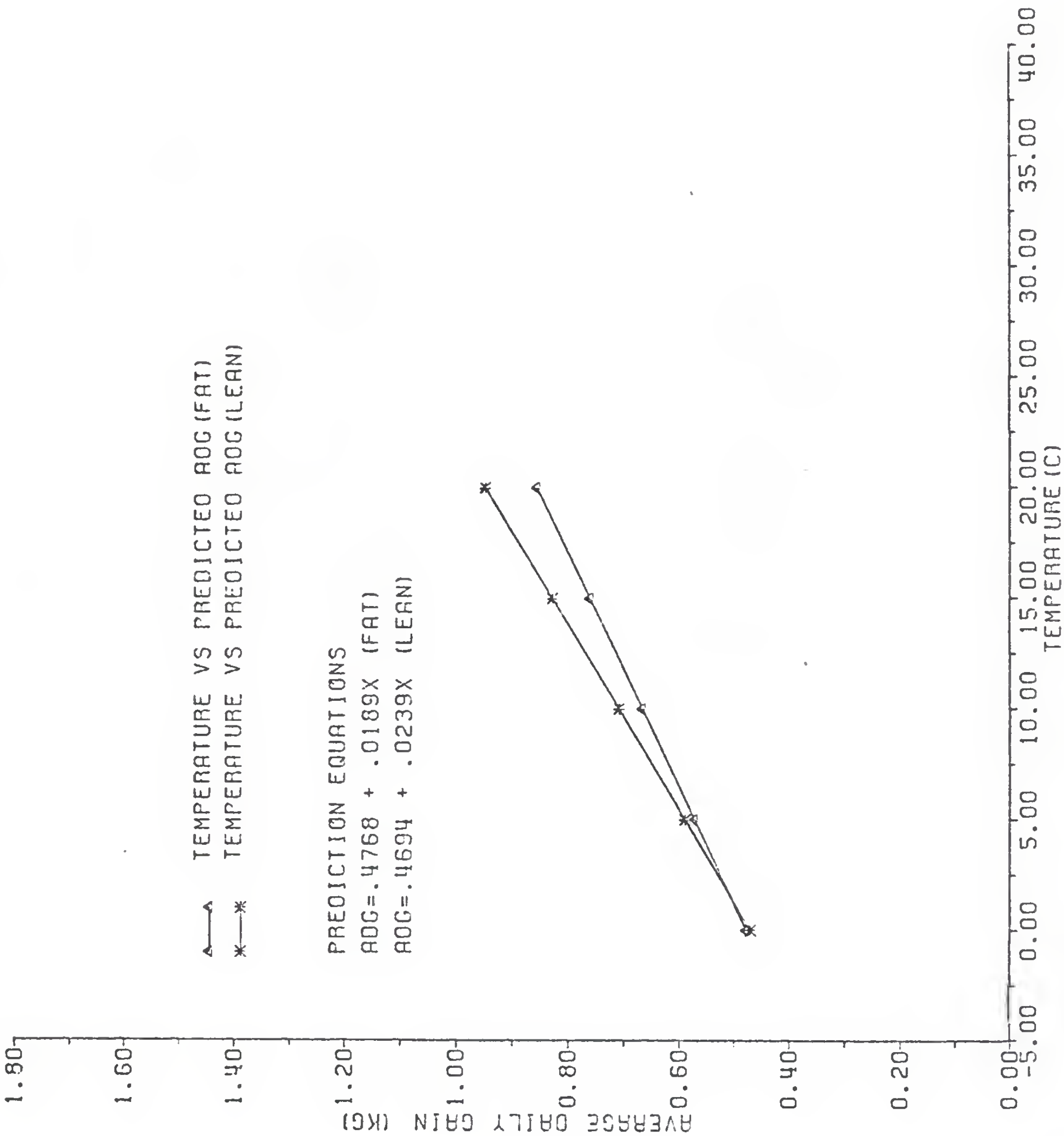

Figure 5. Predicted average daily gain (fat) versus predicted average daily gain (lean).

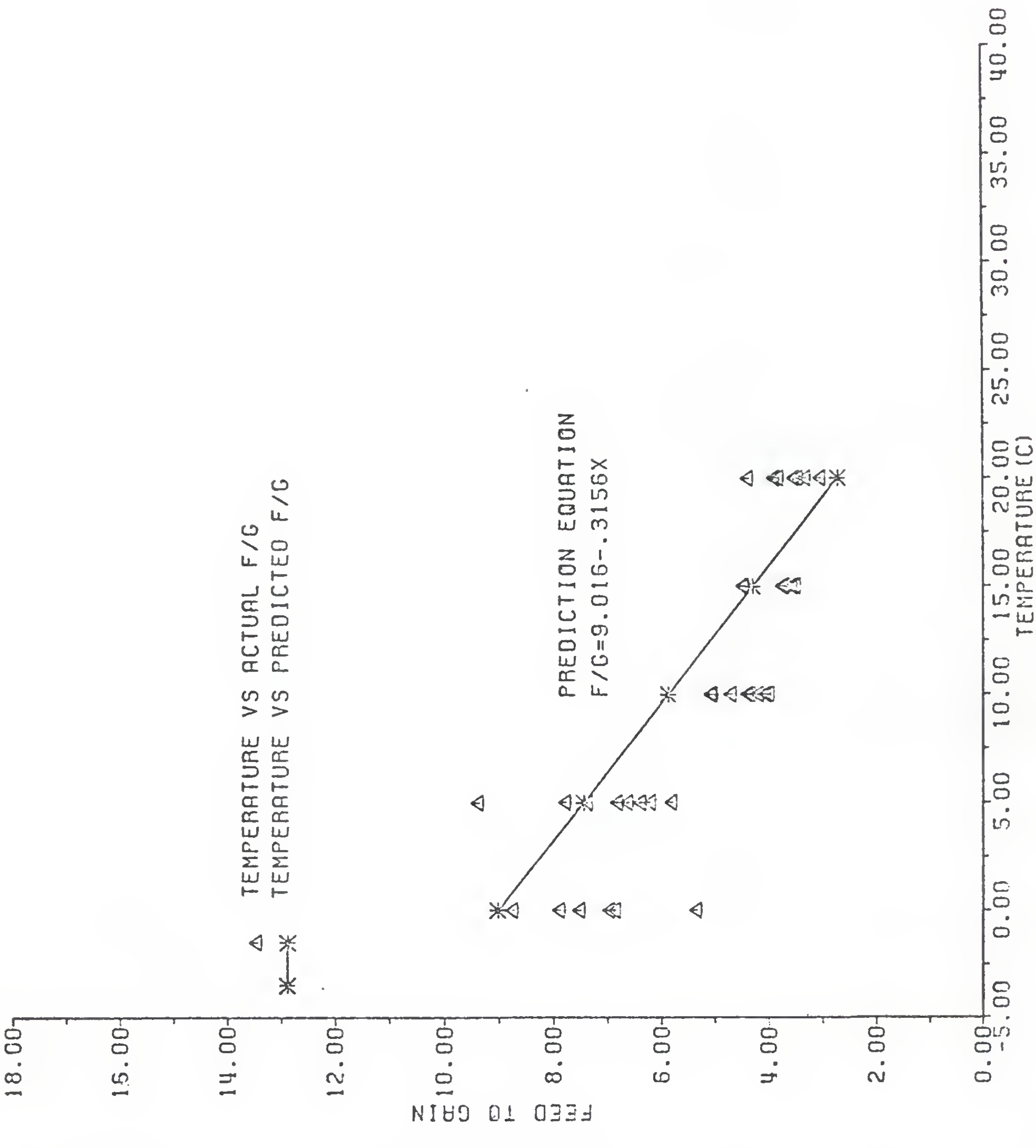

Figure 6. Feed to gain ratio versus temperature for fat pigs only.

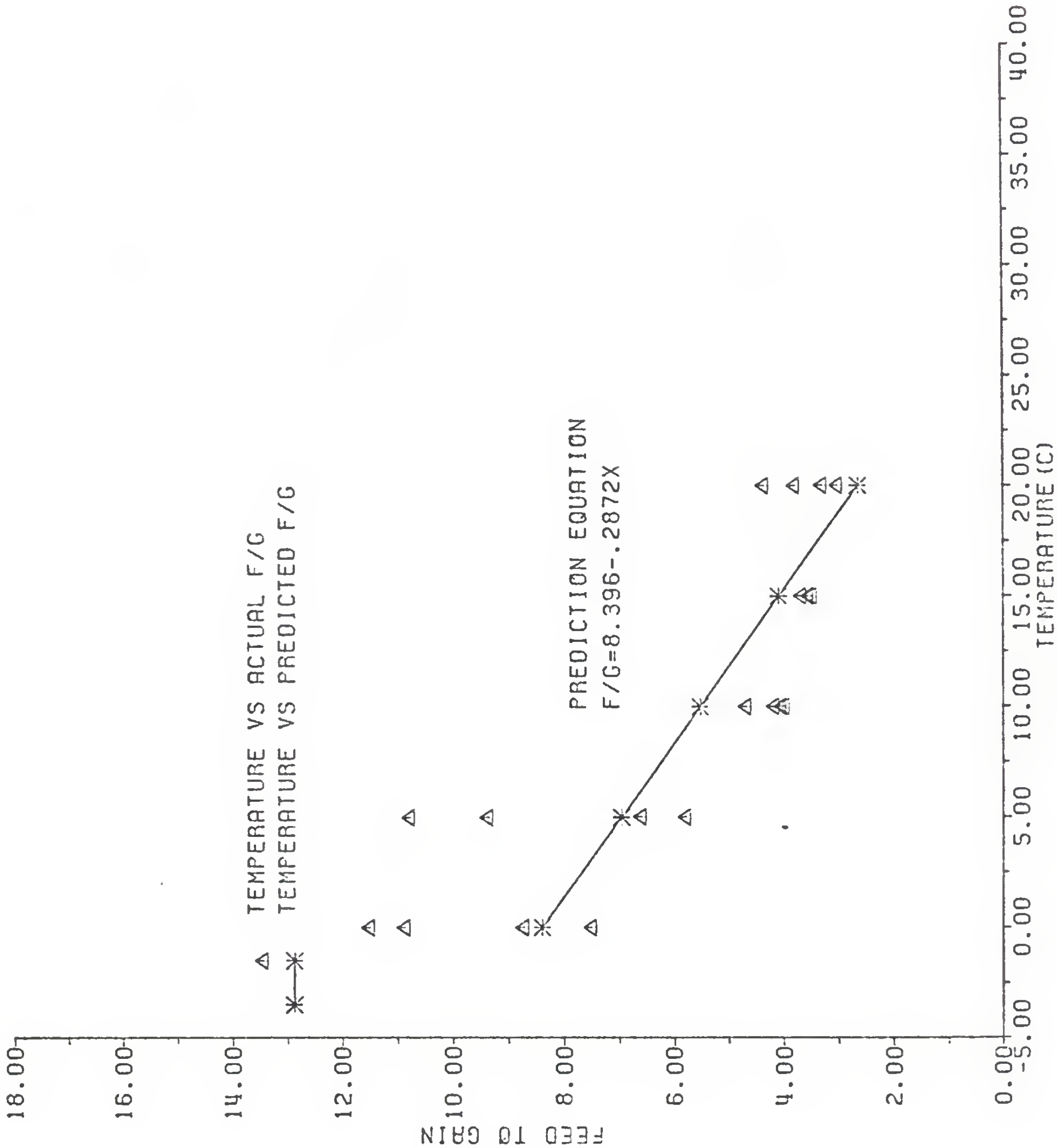

Figure 7. Feed to gain ratio versus temperature for lean pigs only.

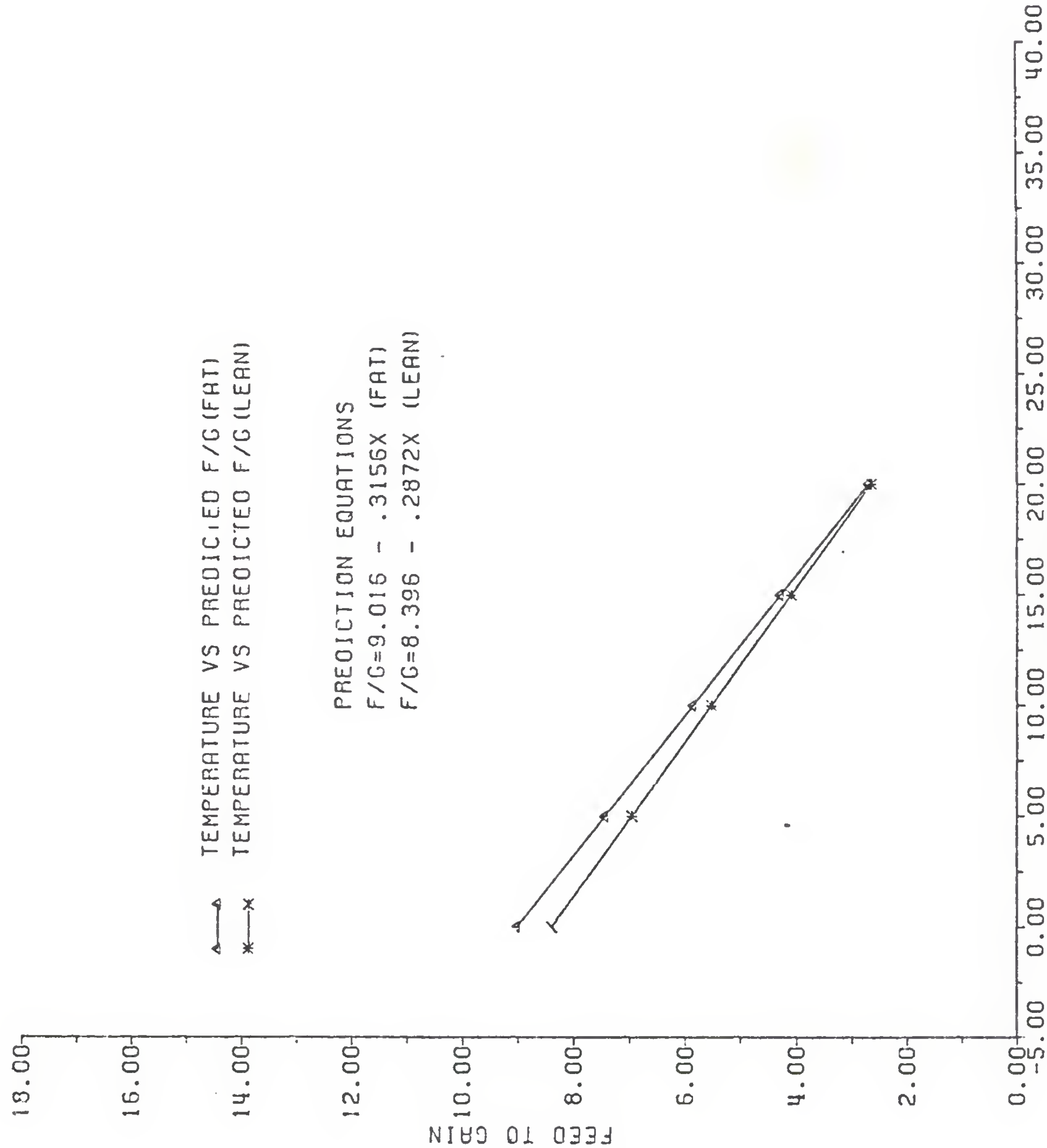

Figure 8. Predicted feed to gain ratio (fat) versus predicted feed to gain ratio (lean).

SUMMARY

Average daily gain, feed to gain ratio, and average daily feed were determined for finishing swine at ambient temperatures of 0, 5, 10, 15 and 20 C. Effects of temperature on fat versus lean pigs were observed as well as on both groups combined. Temperatures below 10 C significantly affected average daily gain, feed to gain, average daily feed and also behavior. No difference in performance was observed between fat and lean groups for any of the parameters measured.

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The experiment was conducted to determine the effect of temperature on performance of fat versus lean pigs. Forty fat and forty lean (2.8 cm and 1.5 cm backfat thickness, respectively) barrows weighing approximately 72 kg were used. Five 28-day trials at temperatures of 0, 5, 10, 15 and 20 C were conducted in two environmentally controlled rooms. Each room was divided into four pens with concrete slatted floors. Two pigs of the same fat thickness group were placed in each pen. All barrows were fed the same sorghum-soy diet. No significant differences in feed to gain ratio or average daily gain were observed between fat and lean pigs at any of the temperatures studied. Observed average daily gain (kg) for the fat and lean groups combined at 0, 5, 10, 15 and 20 C were .54, .53, .80, .80 and .84, respectively. Feed to gain ratios were 9.40, 7.10, 4.37, 3.99 and 3.79, respectively. Pigs housed at 0 and 5 C gained significantly slower ($P<.05$) and less efficiently ($P<.01$) than those housed at 10, 15 or 20 C. No improvement in performance was observed when temperatures were raised above 10 C. Increased huddling, shivering and longer hair coats were observed at the lower temperatures.