A FIELD SURVEY AND EXPERIMENTS TO DETERMINE THE EFFECT OF HIGH TEMPERATURE ON THE BIOLOGICAL PERFORMANCE OF PIGS

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SUMMARY

Data were provided by producers in three climatic zones in Eastern Australia on the effects of temperature on the performance of growing pigs housed indoors. In some cases it was inappropriate to combine the data from the different zones because of differences in trends. Growth rate was generally lowest in January (545 g/d) and December (571 g/d) and highest in July (594 g/d). Over the average maximum temperature range from 12 to 34°C, growth rate declined by 10 g/d/°C increment in temperature. When growth rate was regressed against maximum temperatures at teinperatures about 27°C for data from zone 2, growth rate declined on average by 43.5 g/d/°C.

Feed conversion ratio (FCR) was minimum at 22°C, and increased in both the cool and the warmth. Although backfat (P_2) declined linearly when regressed against both mean maximum and mean temperature, between 20 and 25°C mean maximum temperature, backfat increased significantly,. but above 25°C backfat declined, When data from all sources are combined mean growth rate was 590 g/d, FCR 3.03 and backfat (P_2) 17.3 mm.

Data from field experiments carried out at seven pig production units in central New South Wales at different times of the year were analysed. The responses to temperature by pigs were usually similar to those found in the survey.

INTRODUCTION

The effects of high temperature on the biological performance of growing pigs were reviewed by Farrell (1978) and measurements made on pigs in a climate laboratory were reported by Vajrabukka et al. (1981). The adverse effects of high temperature on reproduction in the pig in Australia have also been discussed (Pett 1982, 1983; Stone 1982; Greer 1983a) but this paper will consider only high temperature and its effects on the performance of growing pigs kept indoors and under commercial conditions. Much of the data on effects of high temperature has in the past resulted from studies on pigs under laboratory conditions and field data are limited particularly in Australia. Here climatic zones occur and the problem becomes more complex. For example in the subtropics pigsusually experience environments that are warm to hot, while in areas of New South Wales and Victoria temperatures range from cold to hot and sometimes during a short space of time. Under these conditions acclimating by pigs to warmth may be incomplete.

The purpose of this paper is to report the results of a field survey undertaken in Eastern Australia of pig-performance under commercial conditions. Additional data were obtained and analysed from field experiments designed to examine effects of different feeding regimens and dietarysupplementationduring warm and cool periods of the year (Greer 1983b).

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MATERIALS AND METHODS

Field Survey

To determine the effects of environment on the biological performance of pigs, it is first necessary to classify the various climaticzones, and secondly to gather data for analysis from piggeries situated in the different zones. In the present study the zones were defined objectively using the method of Bonsma et al. (1953) whereby mean air temperature is plotted against mean relative humidity on a monthly basis to form a climograph.

Each producer was asked to provide the following data for each month of the year on:

the sex and type of pig produced (i.e. porker or baconer),
daily rate of gain (DRG),
feed efficiency (FCR),
backfat depth (P2),
meteorological data, preferably from within the grower shed.

Parameters were regressed against month and maximum, minimum and mean temperatures using multiple regression analysis (Steel and Torrie 1980) where,

$$\text{mean temperature} = \frac{(\text{max. temp.} + \text{min. temp.})}{2}$$

The linear, quadratic and cubic coefficients in the polynomial regression were tested for homogeneity, initially within the pooled data for DRG, FCR and P2. As significant heterogeneity was observed, further tests for homogeneity were undertaken. In the first instance data within zones were pooled and between-zone tests were conducted. This was followed by between-farm tests within each of the zones. With respect to the subsequent statistical analyses of the relationships between climate and pig performance, data for each of the biological parameters were pooled whenever homogeneity was established. In the absence of homogeneity, separate analyses were conducted for each farm.

Multivariate correlation analysis using the canonical technique (Bofinger and Wheeler 1975) was also applied to the parameters in order to establish the relative importance of the independent variables (i.e., meteorological data). Since the mean temperature was derived frommaximum and minimum temperatures, the canonical analyses were applied to the parameters with month, maximum and minimum temperatures only.

Twenty six commercial producers were approached to provide pig performance and climatic data on a month by month basis. The producers concerned varied in location from Kingaroy in Queensland (latitude 26°S) to Victoria (latitude 37°S), and in climate from coastal (e.g. Brisbane, Queensland) to dry inland (e.g. Grong Grong, N.S.W.).

Field Experiments

Details of the experiments undertaken on seven properties incentral N.S.W. during winter and spring (1979) and repeated during summer and autumn of 1979 and 1980 were described by Greer (1983b). The diet comprised (g/kg) of barley (800), meat and bone meal (150) and soybean meal

(50). Additional lysine was added to some dietary treatments. Diets were offered in four different feeding systems to pigs grown from 20 to 95 kg.

RESULTS

Field Survey

Twenty-five out of the 26 producers responded and supplied some of the data requested, although only 14 of these provided records for more than 7 consecutive calendar months (the minimum considered necessary for statistical analysis). Out of the 14 sources only 2 supplied shed temperatures and it was necessary to discard this information and substitute meteorological data from the recording station (Division of Land Use and Research, CSIRO) closest to each pig unit. The locations of the 14 units, their closest meteorological stations and climatic zone are given in Table 1.

Monthly records of backfat depth of pigs in Tasmania (Zone 3) were made available by Mr. A.C. Hughson of the Department of Agriculture. Abattoir killing sheets provided data from six commercial producers, each of whom had pigs slaughtered in at least 7 of the 12 months studied. From these records the data from 720 pigs were randomly selected for analysis.

TABLE 1 Location of data sources, their closest meteorological stations, and zone classification

	Data source	Meteorological station	Zone
1	Kingaroy, Queensland	Kingaroy, Queensland	1
2	Toowoomba, Queensland	Toowoomba, Queensland	1
3	Warwick, Queensland	Warwick, Queensland	1
4	Gatton, Queensland	Gatton, Queensland	1
5	Brisbane, Queensland	Brisbane, Queensland	1
6	Murwillumbah 1, N.S.W.	Lismore, N.S.W.	1
7	Murwillumbah 2, N.S.W.	Lismore, N.S.W.	1
8	Pine Ridge, N.S.W.	Gunnedah, N.S.W.	2
9	Temora, N.S.W.	Temora, N.S.W.	2
10	Grong Grong, N.S.W.	Wagga Wagga, N.S.W.	2
11	Corowa 1, N.S.W.	Albury, N.S.W.	2
12	Corowa 2, N.S.W.	Albury, N.S.W.	2
13	Corowa 3, N.S.W.	Albury, N.S.W.	2
14	Bendigo, Victoria	Bendigo, Victoria	2

Homogeneity Tests

Since data from Brisbane were for pork pigs only and the pig unit at Temora was fitted with sprinklers which would modify shed temperature, these two sources of data were excluded. from the homogeneity tests, the results (Table 2) of which revealed significant heterogeneity between producers in the pooled data. However, homogeneity was achieved when zones were treated as sources and data within zones were pooled. The results which follow are thus presented on an overall, zone or farm basis depending on the level of homogeneity recorded for each parameter.

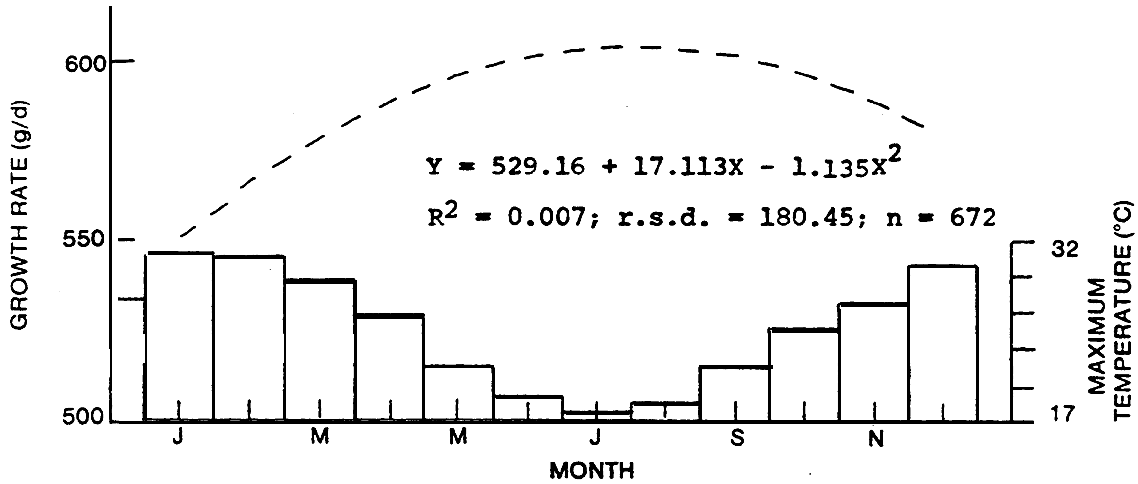

Figure 1 Mean growth rate of pigs (zones 1 + 2) over a 12 month period.

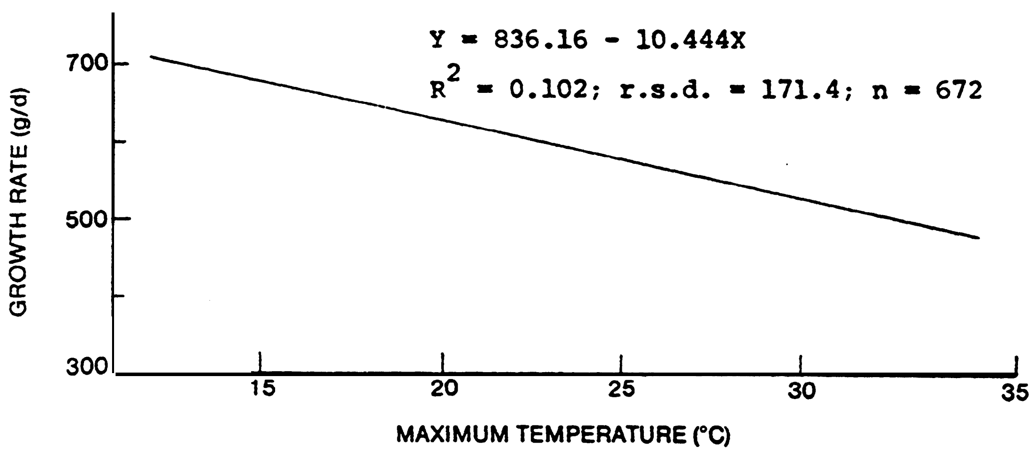

Figure 2 Growth rate of pigs (zones 1 + 2) as related to mean monthly maximum temperature.

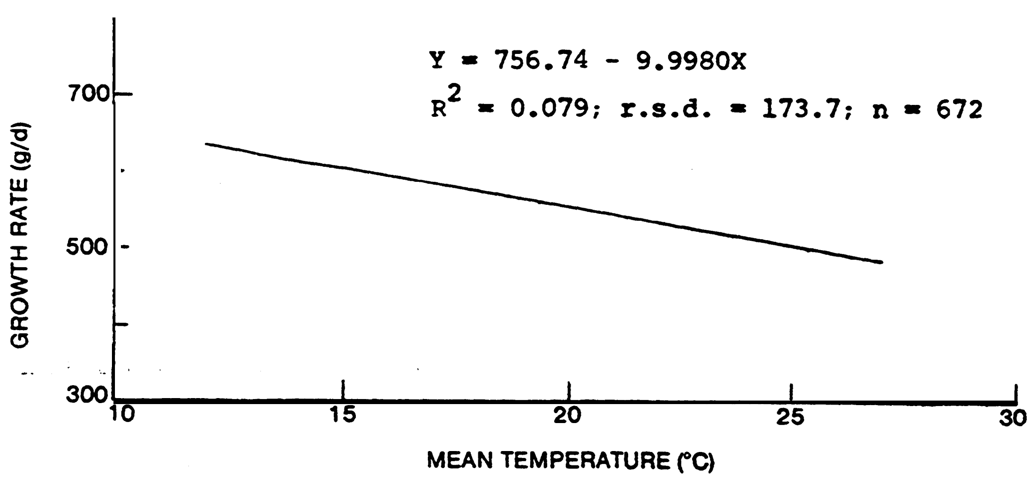

Figure 3 Growth rate of pigs (zones 1 + 2) as related to the mean monthly temperature.

TABLE 2 Results of homogeneitytests for daily gain (DRG), feed conversion ratio (FCR), and backfat (P2) from 14 commercial pig units

Parameter	Month of year			Meteorological parameter								
				Maximum temp.			Minimum temp.			Mean temp.		
	Lin.	Qua.	Cub.	Lin.	Qua.	Cub.	Lin.	Qua.	Cub.	Lin.	Qua.	Cub.
DRG:												
farms pooled	***[*]	NS[**]	NS	NS	NS	***	*	NS	NS	NS	NS	NS
Zone 1	**	NS	NS	NS	NS	NA[†]	NS	NS	NS	NS	NS	NS
Zone 2	**	*	*	NS	NS	NS	*	NS	NS	*	NS	NS
zones pooled	NS	NS	NS	NS	NS	**	NS	NS	*	NS	NS	*
FCR:												
farms pooled	***	***	**	*	NS	NA	*	NS	NS	*	NS	NS
Zone 1 only	NS	***	NS	NS	NS	NA	NS	NS	NS	NS	NS	NS
zones pooled	***	*	***	***	NS	NA	*	NS	NS	**	NS	NS
P2:												
farms pooled	***	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zone 1 only	NS	NS	***	NS	NS	NA	NS	NS	NS	NS	NS	NS
zones pooled	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Significant results imply heterogeneity, such data were not subjected to further analysis when pooled.

**NS, not significant, ** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

† NA, not available.

Growth Rate

The pooled data (zones 1 + 2) for daily rate of gain (DRG) when regressed-against month of the year (Figure 1) revealed some indication of a quadratic trend (linear $p < 0.05$; quadratic $p < 0.10$) such that maximum DRG occurred in July (594 g/d) , the month with the lowest maximum temperature. On the other hand, the lowest DRG occurred in January and December (545 and 571 g/d) when maximum temperatures were high.

Because of statistical constraints it was not possible to fit other curves to the combined data shown in Figures 2 and 3. When data were analysed separately for the two zones significant ($p < 0.01$) linear and curvilinear relationships were found, For zone 1 when growth rate was regressed against mean ambient temperature, at temperatures above 20°C, growth rate declined by 45.5 g/d/°C rise; for zone 2 a similar decline occurred above 19°C and growth was reduced by 43.5 g/d/°C rise. Similar calculations for maximum temperature in zone 2 showed that above 27°C growth rate declined by 29.3 g/d/°C rise. Canonical analysis indicated that mean maximum ambient temperature had a greater influence on growth rate than mean minimum temperature, which in turn had a greater influence than month of the year.

The only significant relationships observed for the pooled data were quadratic ones between FCR and mean maximum ($p < 0.05$) and mean ($p < 0.05$) temperatures (Figures 4 and 5 respectively). These results suggest that

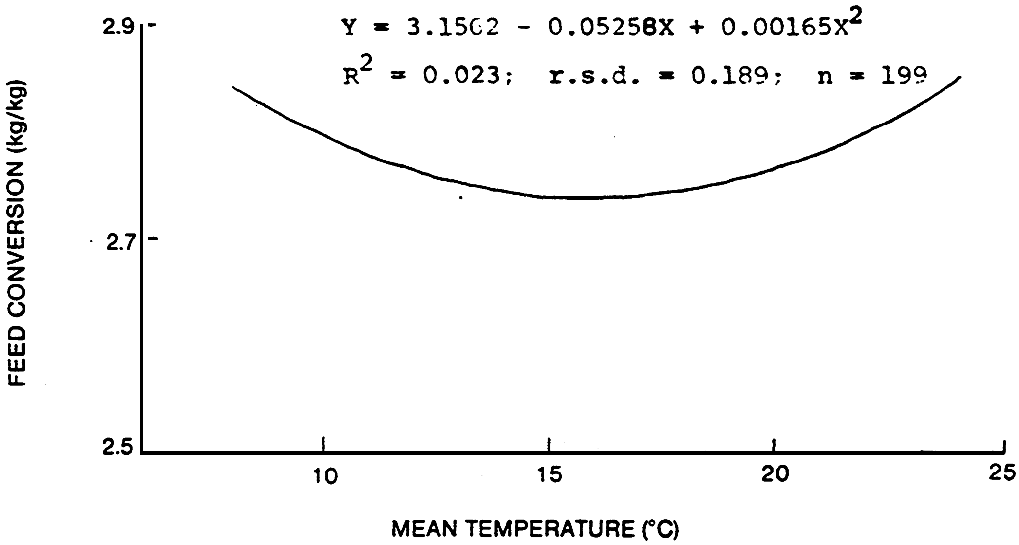

Figure 4 FCR of pigs as related to mean monthly temperature (zones 1 + 2).

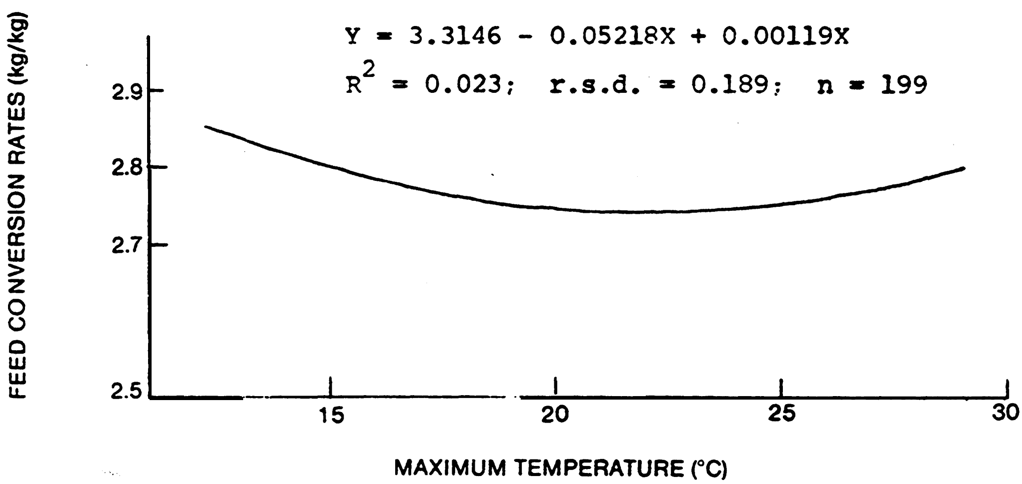

Figure 5 FCR of pigs (zones 1 + 2) as related to mean monthly maximum temperature.

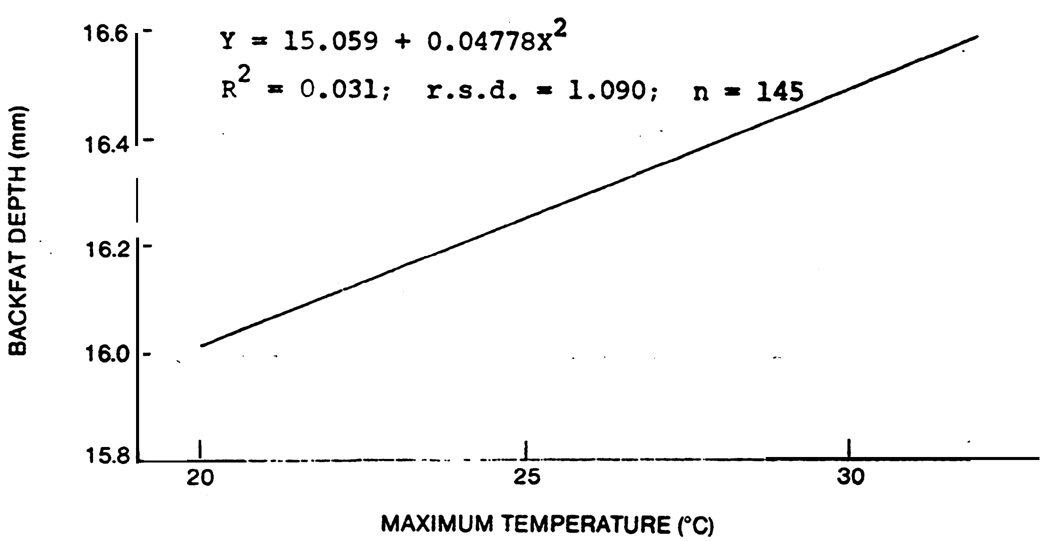

Figure 6 Backfat thickness of pigs at Gatton, Queensland, as related to mean monthly maximum temperature.

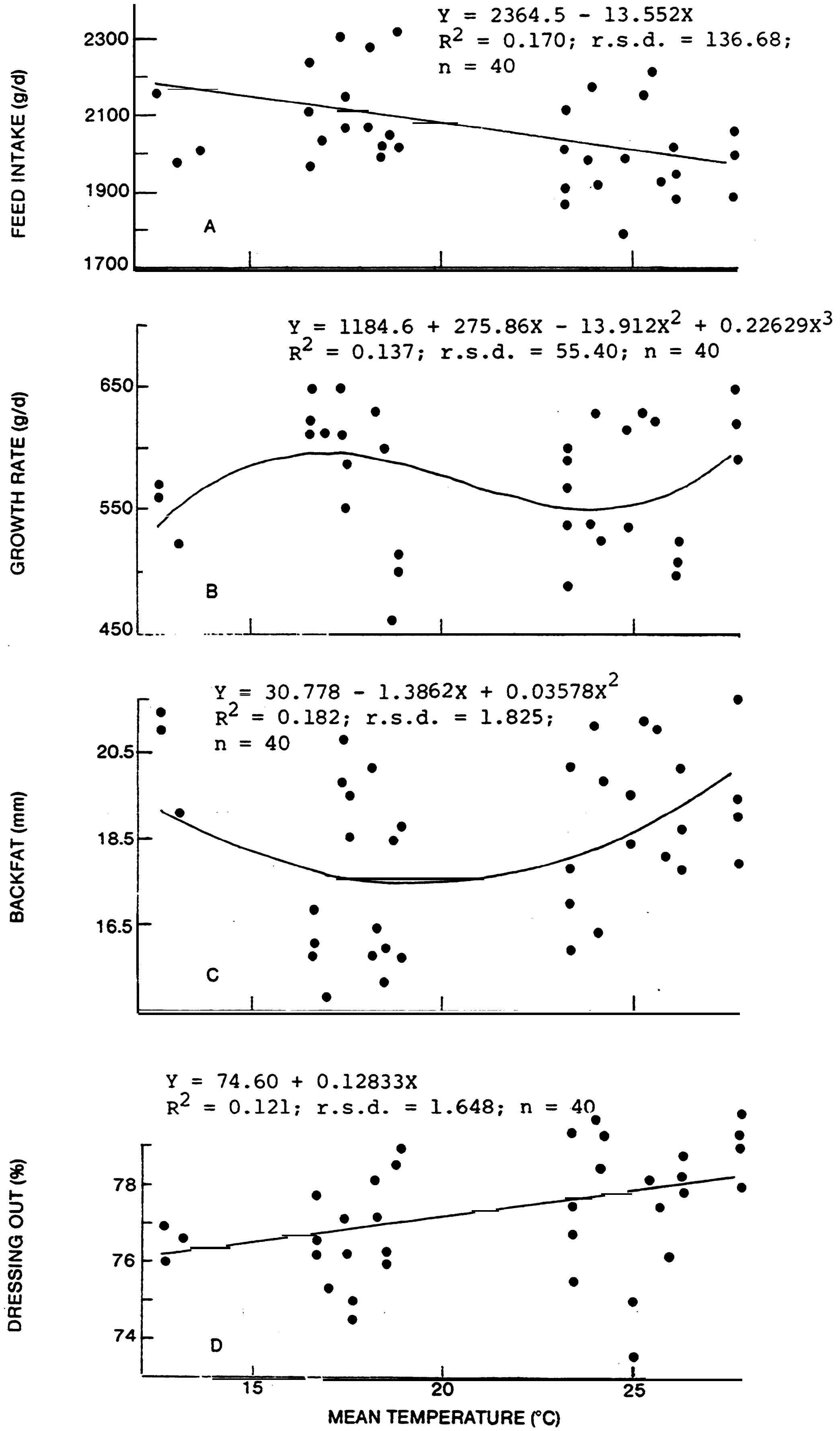

Figure 7 Relationships between daily (A) feed intake, (B) growth rate, (C) backfat thickness (P2) and (D) dressing out percentage and mean shed temperature of pigs in the field experiment.

the pigs converted feed most efficiently at a mean maximum temperature of 22°C and a mean temperature of 16°C.

Within zone 1, significant linear relationships were observed between FCR and maximum ($p < 0.01$), mean ($p < 0.01$) and minimum ($p < 0.01$) temperatures. The relationships were such that FCR increased at the rate of 0.011, 0.012 and 0.009 units/°C in mean maximum (12-35), mean average (12-20), and mean minimum (8-27) temperatures, respectively.

Backfat

Although backfat (P2) declined linearly when regressed against both mean maximum and mean temperature for data from all three zones, a cubic relationship was also significant. Between 20 and 25°C mean maximum and 14 and 20°C mean, backfat increased significantly; above these temperatures, fat thickness declined at an accelerating rate. When data for individual producers were examined only one showed a significant trend. There was an increase of 0.05 mm in backfat with each °C increase in mean maximum temperature (Figure 6).

Field experiment

Feed intake declined linearly ($p < 0.01$) when plotted against mean temperature (Figure 7A) by 12 g/°C. There was no significant effect of temperature on FCR. There was a significant ($p < 0.05$) relationship between growth rate and both mean maximum and mean temperatures (Figure 7B). Daily gain was at a maximum at a mean temperature of 17°C and a minimum of 24°C. Growth rate then started to increase.

Backfat thickness was least at a mean temperature of 19°C but increased on either side of this temperature (Figure 7C). Dressing out percentage also increased with increasing mean temperature (Figure 7D).

Summary of all data

Data collected from all sources and combined are given in Table 3.

TABLE 3 Mean (±SE) growth rate, feed conversion ratio (FCR) and backfat (P2) of pigs using combined data from all sources

	n	Mean	Range
Growth rate (g/d)	783	580 ± 6.0	280 - 980
FCR (kg/kg)	310	3.03 ± 0.02	2.31 - 4.50
Backfat (mm)	496	17.3 ± 2.1	11.0 - 25.4

DISCUSSION

In order to obtain the necessary information on any alteration in production trends as a consequence of temperature it is necessary to obtain a very large body of data. It is clear that in some areas insufficient data were obtained because of incomplete or inadequate records, Furthermore each individual pig production unit has a unique environment and although it was often statistically acceptable to combine data from various units or within zones this may make biological interpretation of the results difficult. Furthermore the seasonal changes in temperature may alter the ability of livestock to grow at their genetic potential when at high temperatures. Thus in regions in Queensland and in Victoria, pigs may perform quite differently even when under similar indoor environments. Moreover the use of meteorological data from stations located in the general area of a pig unit, as used here, may not represent the climate experienced by pigs in that unit.

It is comforting to note that the trends observed in the field survey were generally supported by the experimental data of Greer (1983b) and shown in Figure 7. Small differences would be expected because of the feeding systems used and the location of the production units.

Although it is well known that high ambient temperature generally depresses growth rate, the survey data indicated the extent of that depression. A decline of 10 g per 1°C increase in mean ambient temperature between 12 and 27°C agrees well with a mean value of 11 g between 15 and 30°C reported by Close et al. (1978). However there was a much more rapid decline when the mean temperature exceeded 20°C, and the mean maximum temperature exceeded 27°C. Although these limited data should be treated with some caution, it appears that the rate of decline in growth may be three to four times that at temperatures above 20 and 27°C respectively. Clearly the rate of decline is not constant but will accelerate as the temperature increases. It was possible to calculate only an average value here. Other factors that determine the growth rate at high temperature include the level of feeding (Tonks et al. 1972). Seymour et al. (1964) showed that there was an effect of protein level on heat tolerance. Pigs on diets with a high protein content grew more rapidly than those on a low protein diet at both 15° and 32°C. Vajrabukka et al. (1981) also showed that pigs in a climate room at 35°C for 12 h (day) and 25°C for 12 h (night) grew significantly faster on a high energy and high protein diet than on other combinations of dietary protein and energy.

The increase in feed conversion ratio (FCR) on either side of a mean maximum temperature of 22°C, or a mean temperature of 16°C, is not really unexpected. Verstegen et al. (1978) showed that at temperatures below 15°C FCR increases and above this mean temperature it improves marginally. Holme and Coey (1967) and Fuller (1965) also showed an improvement in FCR with increasing temperature. On the other hand Straub et al. (1976) did not show any consistent trend in FCR when boars were kept at 15 or 35°C. If anything boars had a slightly improved FCR in the cold than in the warmth. Stahly and Cromwell (1979) reported that when pigs were grown from 24 to 60 kg on two diets with or without added fat at three different temperatures (10, 22.5 and 35°C) there was a minimum FCR at 22.5°C on both diets. The findings here that FCR has a minimum value at a given temperature and increases slightly outside this temperature is not inconsistent with much of the data in the literature although these do not normally span the range of temperatures that were examined here.

Backfat thickness and temperature relationships are not so easily identified. It would seem that there may be factors other than temperature that influence this parameter. For example at high temperatures backfat tends to decline but this may be related to reduced feed intake and therefore to a decreased amount of energy available for tissue synthesis (Stahly et al. 1979). At mean ambient temperatures between 14 and 20°C backfat thickness increased significantly in the present study. Stahly and Cromwell (1979) showed similar trends in backfat to those observed here. At 10°C and at 35°C backfat thickness was less than that at 22.5°C when pigs were fed diets without or with 5% added fat. Straub et al. (1976) observed that backfat thickness in boars housed at 35°C was significantly less than in boars at 15°C.

In summary, the adverse effects of high temperature on the growing pig under field conditions are to depress food intake and growth rate. Both of these decline at an accelerated rate when mean maximumtemperature is above 27°C. FCR reaches a minimum value and then increases slightly above a mean maximum temperature of about 220C. Backfat thickness increases in the warmth but then starts to decline at high ambient temperatures.

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