3.0 FIELD EXPERIMENTS - THE PERFORMANCE OF COMMERCIAL PIGS AS AFFECTED BY AMBIENT TEMPERATURE AND SEASON OF YEAR

3.1 Introduction

The opportunity was taken to supplement the field data collected from the commercial piggeries with a small series of more closely controlled experiments in which more complete temperature and biological performance data were collected. The first of these (III-3.1; Field Experiment 1) was designed by the author and conducted in collaboration with Mr. R. M. Kelly, the producer who made facilities available. The remaining two (Field Experiments 2 and 3), where the prime aims were to investigate the effects of feeding regimes and lysine levels on the growth performance of pigs, were designed and supervised by Mr. E. B. Greer of the N.S.W. Department of Agriculture, who kindly made the relevant biological and climatic data available to the author for analysis.

3.2 Field Experiment 1

This experiment was carried out at "Braemar Park" piggery, Parkes, N.S.W. It consisted of 3 field trials, each conducted over a period of approximately three months at intervals between June 1980 and August 1981:

Trial 1: Winter: 19/6/80 to 4/9/80

Trial 2: Summer: 30/9/80 to 30/12/80

Trial 3: Winter: 27/4/81 to 13/8/81

3.2.1 Materials and Methods

In all trials the same pens within the shed (Figure 16) were used. Thermohygrographs were placed approximately two metres above the passageway separating each pair of pens to record shed temperatures and humidities. These instruments were calibrated to record temperature and humidity at pig level (30 cm above the floor). The shed in which the experiments were conducted measured 40.5 m X 9.5 m and was of galvanised iron construction

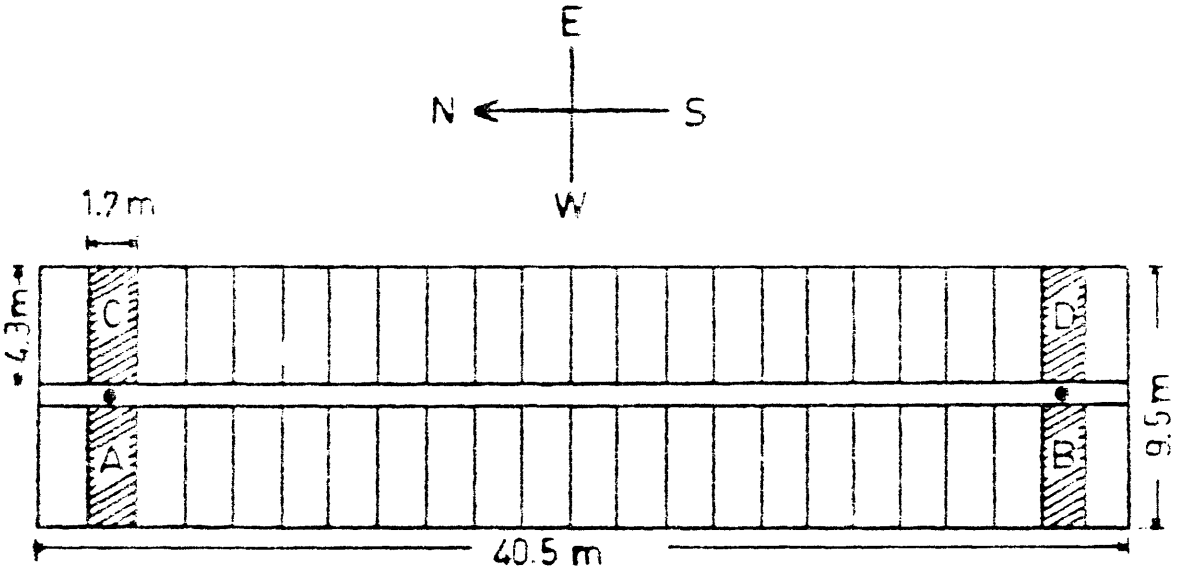

Figure 16. Location within the shed of the pens in Field Experiment 1 (●-position of the thermohygrographs).

with large ventilation flaps along both sides. Foam spray insulation was added to the ceiling at the beginning of Trial 3. Individual pens measured

4.3 m X 1.7 m with a slatted dunging passage at the rear. With an average of 10 pigs per pen each pig thus had a floor area allowance of 0.73 m^2. The partitions between the pens were of 10 cm thick concrete to a height of 40 cm and angle iron bars thereafter to a total height of 90 cm, while the front wall was of sheet iron. Each pen was fitted with an automatic feeder and one drinking nipple.

3.2.2 Animals and Husbandry

For each trial, 40 entire Large White X Landrace male pigs were used. The mean starting weight was approximately 40 kg in each case and animals were allocated to pens in groups of ten by stratified random sampling according to initial liveweight. The pigs were kept until slaughter at 90 kg liveweight, at which time carcase and backfat depth (P2) data were collected. All pigs were fed a pelleted ration *ad libitum* on the concrete floor by an automatic feeder. The amount of feed consumed was recorded and the pigs were weighed weekly and also immediately before leaving for the abattoir by multi-decked road transport, a distance of 380 km.

3.2.3 Treatment of Data

Where appropriate the data obtained were treated both on an overall experiment and/or a weekly basis as follows:

a) Daily rate of gain of overall experimental period (DRG_E): The weekly liveweights of individual pigs were regressed over time for the interval 40-90 kg liveweight and the slope of

the resultant line provided an estimate of the average DRG_E (g/d).

b) Daily rate of gain - for each week (DRG_W): Values were obtained by determining the differences in liveweights between any two consecutive weekly weighings and dividing by the number of days between them.

c) Feed conversion ratio of overall experimental period (FCR_E): Determined for each group of pigs:

$$FCR_E = \frac{\text{Total feed consumed}}{\text{Total weight gained}}$$

d) Feed conversion ratio - for each week (FCR_W): Determined for each group of pigs:

$$FCR_W = \frac{\text{Mean daily feed consumption for the week}}{\text{Mean daily rate of gain for the week}}$$

Because of the group feeding method used, it has been assumed for the purpose of these calculations that all pigs living in the same pen consumed the same amount of feed. The same assumption was used as a basis for correcting group values in these pens in which deaths occurred.

e) Dressing percentage (Dress%): Determined for individual pigs:

$$\text{Dress\%} = \frac{\text{Carcase Weight}}{\text{Final Liveweight}} \times 100\%$$

f) The maximum and minimum temperatures within the shed were also averaged weekly.

g) Backfat depth was recorded after slaughter using the "Introscope" (Wolfking, Denmark) at the standard P2 position (Kempster, Cuthbertson and Owen, 1979). Pigs in this experiment were, for commercial reasons, sent to slaughter at weights between 80 and 110 kg. To correct the backfat data to a standard 90 kg liveweight basis the 1 mm/4 kg liveweight correction factor used by the Queensland Department of Primary Industries (Fearon, pers.comm.) was thus applied.

3.2.4 Analysis of Data

The DRG_E, FCR_E and dressing percentage were analysed using analysis of variance (Steel and Torrie, 1980) and Duncan's Multiple Range Test (Duncan, 1955) was applied when significant ($P<0.05$ and better) differences were revealed. The DRG_W and FCR_W values were regressed against weekly maximum, minimum and mean temperatures, respectively, using polynomial regression techniques (Steel and Torrie, 1980).

Canonical analyses were conducted to determine the associative relationships between maximum and minimum temperatures and, separately, DRG_W and FCR_W.

3.2.5 Results

One pig from pen A in Trial 2 died in transit to the abattoir and one from pen B in Trial 3 died during the course of the experiment, while a

second pig from the same pen had both of its hams trimmed at the abattoir. All results from these three pigs were excluded from the analyses, which were subsequently conducted by estimating missing values (Steel and Torrie, 1980).

From Table 10 it can be seen that the daily rates of gain varied significantly between trials, with the mean value in the first winter (661 g/d) being higher ($P<0.05$) than that of pigs raised during summer in Trial 2 (599 g/d), which in turn was higher ($P<0.05$) than that during the second winter (490 g/d).

Although there were no significant differences in feed conversion ratios over the experimental period as a whole (FCR_E), there were significant differences ($P<0.01$) in dressing percentage. The results revealed that the dressing percentage of pigs in Trial 3 (the second winter; mean 73.9%) was higher ($P<0.05$) than the corresponding values in both the first winter (Trial 1; mean 71.8%) and the summer (Trial 2; 71.6%). There were no significant differences in dressing percentage between pigs in Trials 1 and 2.

Analysis of the uncorrected backfat depth data revealed that there were significant differences ($P<0.01$) between pigs raised in different seasons such that values in both Trials 1 and 2 were higher ($P<0.05$) than those in Trial 3. There were no significant differences in uncorrected backfat depths between Trials 1 and 2 but when these data were corrected to a standard 90 kg liveweight basis the level of significance of the seasonal differences increased to the 0.1 percent level and the values recorded in both winter trials were lower ($P<0.05$) than in the summer trial (Table 10).

With regard to possible effects due to pen position (see Figure 16), it was found that, irrespective of season, there were significant differences

Table 10. Mean values for overall Daily Rate of Gain (DRG_E), Feed Conversion Ratio over the experimental period (FCR_E), Dressing Percentage (Dress%) and Backfat Depth (P2) in four groups of pigs raised in each of the three seasons.

	Parameter				
	DRG_E (g/d)	FCR_E (kg/kg)	Dress% (%)	P2 (mm)	P2 corr. (mm)
Trial 1 (12 - 21° C)	661[a]	3.55	71.8[b]	17.5[a]	15.4[b]
Trial 2 (17 - 30° C)	599[b]	3.42	71.6[b]	18.2[a]	17.6[a]
Trial 3 (12 - 20° C)	490[c]	3.67	73.9[a]	15.3[b]	15.1[b]
LSD(5%)	44	0.32	1.1	1.1	1.0
Sig. Level	***	N.S.	***	***	***
Pen A	568[b]	3.80[a]	72.6	16.7	16.1
Pen B	580[a,b]	3.50[a,b]	72.2	17.0	15.9
Pen C	629[a]	3.25[b]	72.4	17.3	16.0
Pen D	556[b]	3.64[a]	72.6	16.9	16.1
LSD(5%)	51	0.37	1.3	1.3	1.2
Sig. Level	*	*	N.S.	N.S.	N.S.
Interaction: Trial (season) X Pen					
LSD(5%)	88	0.64	2.3	2.2	2.1
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.

Means with the same superscript within each column are not significantly different (5% level).

only in DRG_E ($P<0.05$) and FCR_E ($P<0.05$). The mean DRG_E for pigs in pen C (629 g/d) was higher ($P<0.05$) than that in both pens A (568 g/d) and D (556 g/d). There were no significant differences in DRG_E between pigs in pens A, B (580 g/d) and D, nor between pens B and C. The FCR_E values for pigs in pens A (3.80 kg/kg) and D (3.64 kg/kg) were higher ($P<0.05$) than those in pen C (3.25 kg/kg). There were no significant interactions between season and pen for the above biological parameters.

There were no significant relationships between either mean weekly weight gains or feed conversion ratios and maximum, minimum or mean weekly shed temperatures. Furthermore, canonical analysis failed to indicate any significant associative relationships between these biological and meteorological parameters.

3.2.6 Discussion

Field Experiment 1 (and numbers 2 and 3 in the following sections) was undertaken in order to improve upon the precision of the data collected in the Field Survey (III-2.0) by the adoption of more rigorous weighing regimes and the monitoring of actual shed temperatures. In general, the current results from Field Experiment 1 confirm the field survey finding that pigs in Australia perform better during the cooler months of the year.

Although DRG_E in pigs raised during the first winter (Trial 1) was higher than that in summer (Trial 2), the second winter trial in the following year failed to confirm this overall trend. In fact, DRG_E during Trial 3 in the second winter was actually lower than the summer value. This anomalous result cannot be fully explained. Health problems amongst the pigs in pen B during Trial 3 may have contributed to their poor growth,

but discussion with the producer failed to reveal any significant differences in genotype, management or feed type between the trials.

The results for dressing percentage and uncorrected backfat depth in Trial 3 failed to confirm the trends established in Trial 1. The inconsistency of dressing percentage results has previously been reported in the literature. For example, Hale and Johnson (1970) found no significant differences in dressing percentage due to season while Todd and Daniels (1968) reported that the dressing percentages of pigs raised in an environment of 11-43° C were (74.5%) significantly higher than those in 13-39° C environment (73.2%).

The significantly lower value for uncorrected backfat depth recorded in Trial 3 may have been due to differences in final liveweight, which tended to be lower in Trial 3. Thus when these data were corrected to a standard 90 kg liveweight, the results were similar in both the winter trials. This result further substantiates the trend established in the Field Survey (III-2.0) for backfat depth to be higher in summer than in winter.

No significant relationships between DRG and FCR and shed temperature parameters could be establised in the current experiment, possibly due to the fact that the pigs were subjected to varying temperatures as time of year progressed. At the same time the growth patterns of the pigs could be expected to have changed (McMeekan, 1940) as they aged. On the other hand, the potential effects of environmental temperature on pig performance may not have been fully realised due to physiological adaptation which has been found to take place over a period of 14 days or so (Ingram and Mount, 1965; Ingram and Slebodzinski, 1965). Weekly data, as employed in the current experiment, may thus not be sufficiently sensitive to establish the expected relationships.

The orientation of a shed with respect to the sun may also play an important part in affecting the performance of pigs within it. Thus it has been suggested in the past that the adverse effects of high temperatures on housed animals may be reduced by aligning the long axis of the shed in an east-west direction (Ansell, 1981; MacFarlane, 1981). This suggestion is supported by the results of the current experiment, in which pigs in pens A and B on the western side of the shed (most exposed to the effects of the afternoon sun) tended to have lower DRG_E (average for both groups 574 vs 592 g/d) and higher FCR_E values (3.65 vs 3.45 kg/kg) than those on the cooler eastern side.

3.3 Field Experiment 2

This experiment was conducted on six properties during the winter and spring of 1979 and was repeated during the summer and autumn of 1979/1980. The work was supervised by Mr. E. B. Greer of the N.S.W. Department of Agriculture, who made the data available to the author for analysis.

3.3.1 Materials and Methods

Data supplied by the Department of Agriculture, N.S.W. were for liveweight, daily feed intake (DFI), daily rate of gain (DRG), feed conversion ratio (FCR), dressing percentage, backfat depth (P2), and average daily shed maximum and minimum temperatures over each trial period. Pigs were put on trial in groups of 13 to 16 at a mean liveweight of 20 kg and were fed according to the following treatments to a slaughter weight of 95 kg.

Four nutritional treatments were applied as follows:-

Treatment 1: Severely restricted feeding - the initial feeding rate of 1 kg/pig/d and was increased by 120 g/pig/d each week until a maximum rate of 2.03 kg/pig/d was reached.

Treatment 2: Moderately restricted feeding - starting at 1.05 kg/d feed was increased each week according to liveweight up to 3.29 kg/d at slaughter.

Treatment 3: High-Low feeding - These pigs were fed *ad libitum* to 50 kg liveweight and then at a constant rate of 2.25 kg feed/pig/d till slaughter.

Treatment 4: *ad libitum* feeding from 20 kg to slaughter at 95 kg.

All pigs were given a standard diet as detailed in Table 11.

The pigs were kept in intensive sheds with partly slatted floors similar to those in Field Experiment 1. The pigs in Treatments 1 and 2 were group fed on the floor while in Treatment 3 they were group fed on the floor until 50 kg and from self-feeder troughs thereafter. Pigs in Treatment 4 were fed from self-feeder troughs throughout. Each treatment was replicated on each farm in each of the seasons studied.

Shed temperatures were recorded daily from a maximum-minimum thermometer hung approximately one metre above each pen and backfat depths were taken after slaughter at the abattoir using an Introscope.

Table 11. Composition of the standard feed used in Field Experiment 2 (air dry basis).

Ingredient	g/kg
Barley	800
Meat bone meal (M)	150
Soyabean M	50
+ Vitamins and minerals mix (0.2%)	
Calculated composition of the feed:	
DE (MJ/kg)	12.60
DCP (%)	14.70
Lysine (total) %	0.81

3.3.2 Analysis of Data

The data supplied were in the form of group means with the number of animals in each group varying from 13 to 16. Unweighted analysis of variance was performed on each parameter and Duncan's Multiple Range Test was applied whenever appropriate. Polynomial regression analyses were carried out to relate DRG, FCR and backfat depth to shed average maximum, minimum and mean temperatures over each of the trial periods.

3.3.3 Results

The analyses revealed that errors in each of the seasons were homogeneous (except in the case of DRG where the variance ratio reached the 5% significance level) and so the seasons were pooled and overall analyses were carried out in order to examine seasonal effects.

Although the results (Table 12) indicated that DFI and FCR of the pigs were greater (1992 g/d and 3.34 kg/kg respectively) during summer than winter (1977 g/d and 3.28 kg/kg) and that DRG was greater during winter (604 g/d) than summer (593 g/d), these trends proved to be non-significant. Both P2 backfat depth and dressing percentage were significantly higher ($P<0.05$) in summer (19.0 mm and 76.8% respectively) than in winter (18.4 mm and 76.2%).

As expected, pigs subjected to the severely restricted feeding regime (Treatment 1) consumed less ($P<0.05$) feed than those only moderately restricted (Treatment 2), which in turn consumed less than the high-low (Treatment 3) and (Treatment 4) groups. Furthermore, the DFI of pigs in Treatment 3 was significantly lower ($P<0.05$) than that of pigs in both Treatments 2 and 4. There was no significant difference in DFI between Treatments 2 and 4.

The DRG of pigs in Treatment 1 (594 g/d) was lower ($P<0.05$) than that in the other three treatments (607, 603 and 633 g/d in Treatments 2, 3 and 4 respectively). There was no significant difference in DRG between Treatments 2 and 3, values for both of which were, however, lower ($P<0.05$) than in Treatment 4 (Table 12).

There were no significant differences in FCR between Treatments 1, 3 and 4 (3.22, 3.25 and 3.33 kg/kg, respectively); nor between Treatments 2 and 4. However, the FCR of pigs in Treatment 2 (3.44 kg/kg) was higher ($P<0.05$) than that in both Treatments 1 and 3.

Backfat depth was higher ($P<0.05$) in the *ad libitum* fed group (19.5 mm) than in those that were either severely restricted (17.8 mm) or fed on the high-low regime (18.4 mm). There were no significant differences in P2

Table 12. Mean values of Daily Feed Intake (DFI), Daily Rate of Gain (DRG), Feed Conversion Ratio (FCR), Backfat Depth (P2) and Dressing Percentage (Dress%) for pigs in Field Experiment 2.

Treatment	Parameter				
	DFI (g/d)	DRG (g/d)	FCR (kg/kg)	P2 (mm)	Dress% (%)
Winter (7.4-25.0° C)	1977	604	3.28	18.4[b]	76.2[a]
Summer (16.7-35.4° C)	1992	593	3.34	19.0[a]	76.8[a]
LSD(5%)	64	17	0.08	0.3	0.6
Sig. Level	N.S.	N.S.	-	*	*
Treatment 1	1787[c]	554[c]	3.22[a]	17.8[c]	76.4
Treatment 2	2079[a]	607[b]	3.44[b]	19.1[a,b]	76.5
Treatment 3	1962[c]	609[b]	3.25[a]	18.4[b,c]	76.2
Treatment 4	2112[a]	633[a]	3.39[a,b]	19.5[a]	76.9
LSD(5%)	90	24	0.11	0.7	0.9
Sig. Level	***	***	**	***	N.S.
Interaction: Season X Treatment					
Win.-Treat.1	1787	547	3.27[a,c]	17.7	76.4
Win.-Treat.2	2014	620	3.25[b,c]	18.8	76.0
Win.-Treat.3	1968	614	3.20[c]	18.0	75.7
Win.-Treat.4	2141	635	3.38[b]	19.1	76.6
Sum.-Treat.1	1788	560	3.18[c]	17.9	76.5
Sum.-Treat.2	2143	594	3.62[a]	19.3	77.0
Sum.-Treat.3	1956	593	3.30[c]	18.9	76.7
Sum.-Treat.4	2082	632	3.28[c]	19.9	77.1
LSD(5%)	127	34	0.15	1.0	1.2
Sig. Level	N.S.	N.S.	***	N.S.	N.S.

Means with the same superscript within each column are not significantly different (5% level).

between pigs in groups 1 and 3, 2 and 3 or 2 and 4. There were also no significant differences amongst the treatments for dressing percentage.

The only significant interaction observed between season and treatment was with respect to FCR ($P<0.001$). The results (Table 12) indicated that pigs growing through summer had the highest ($P<0.05$) FCR (3.62 kg/kg). Treatment 4 pigs growing through winter had a higher ($P<0.05$) FCR (3.38 kg/kg) than those on Treatment 3 in winter (3.20 kg/kg) and Treatment 1 in summer (3.18 kg/kg). During the winter period there were no significant differences in FCR between Treatments 1, 2 and 4, between Treatments 1, 2 and 3, nor between Treatments 3 and 4. During summer, FCR did not vary significantly between Treatments 1, 3 and 4.

When polynomial regression techniques were used to examine relationships between, respectively, DFI, DRG, FCR, P2 and dressing percentage and maximum, minimum and mean temperatures, irrespective of treatment, quadratic relationships were observed between DFI and both maximum and minimum shed temperatures (Appendix V; $P<0.05$).

The same analyses indicated that there were no significant relationships between DRG and the temperature parameters, nor between FCR and maximum temperature. However, there were significant quadratic ($P<0.05$) relationships between FCR and minimum temperature. Furthermore, there was a significant quadratic relationship ($P<0.01$) between FCR and mean shed temperature, the form of which suggested that minimum FCR values occurred at approximately 23° C.

Although there were no significant relationships between P2 and either maximum or minimum temperatures, there was a cubic relationship ($P<0.05$) between P2 and mean shed temperature.

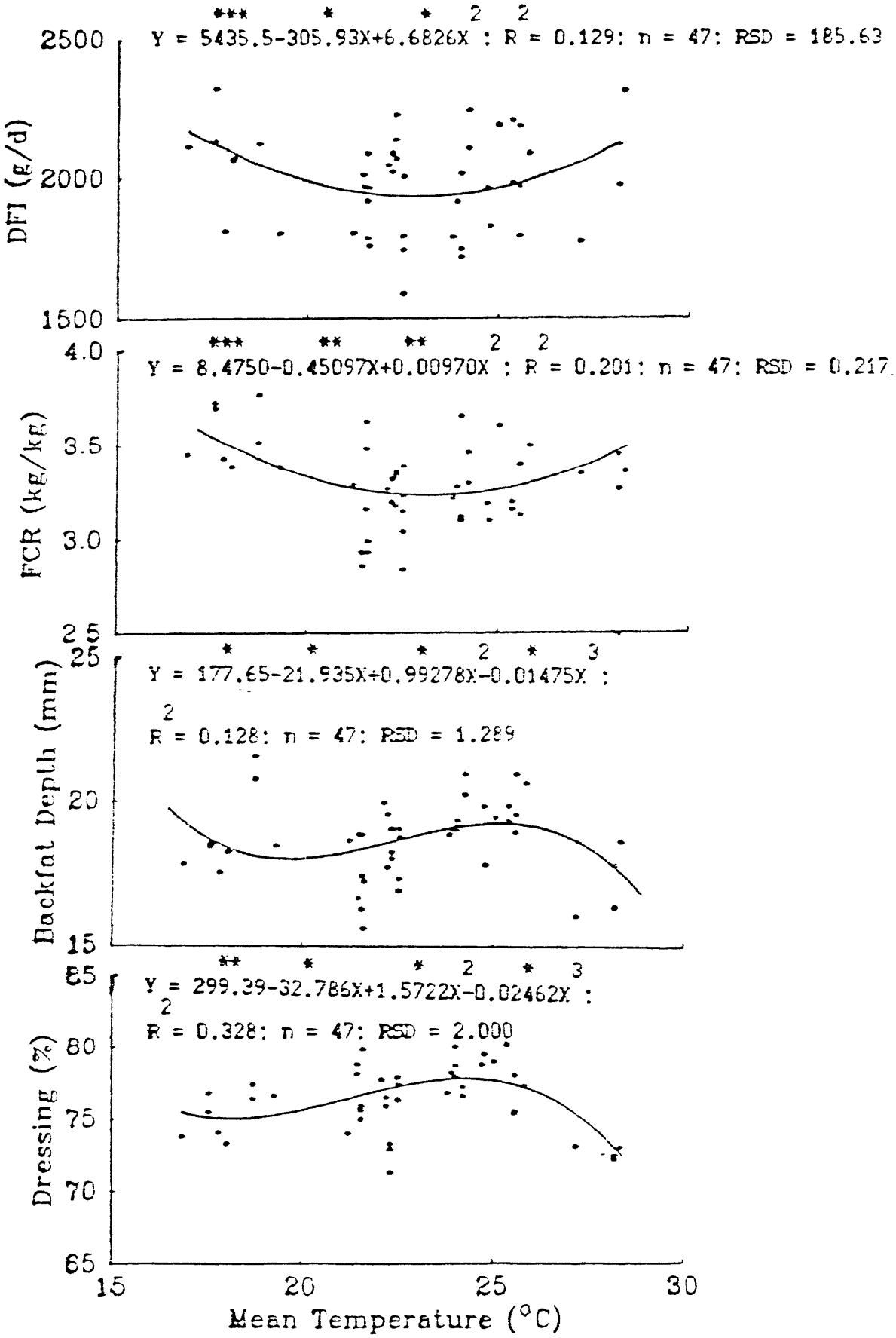

Figure 17. Relationships between Daily Feed Intake (DFI), Feed Conversion Ratio (FCR), Backfat Depth (FC) and Dressing Percentage (Dress%) and mean shed temperature in Field Experiment 2 (, represents 1 farm pooled across dietary treatments).

There were significant relationships between dressing percentage and maximum ($P<0.01$), minimum ($P<0.01$) and mean ($P<0.05$) shed temperatures. The curvilinear relationships of the biological parameters, except that of DRG, with mean shed temperature are illustrated graphically in Figure 17.

From Figure 17 it can be seen that the DFI of the pigs in the present study was lowest when mean shed temperature was 23° C, a temperature at which the lowest FCR values were also observed. On the other hand, backfat depth exhibited a cubic relationship with mean shed temperature, declining as temperature increased from 17 to 20° C, increasing between 20 and 25° C and then declining again between 25 and 28° C. A similar result was obtained with respect to dressing percentage. Figure 17 indicates that the dressing percentage of these pigs increased when the mean temperature increased from 18 to 24° C; below or above these temperatures the dressing percentage decreased with increasing mean temperature.

Results from the canonical analyses (Appendix VI) which were used to determine the relative importance of season, treatment, maximum and minimum temperature on the biological performance of the pigs studied, revealed that treatment was relatively most important for DFI, DRG and P2. Minimum temperature was relatively most important for FCR. There were no significant associative relationships among the independent variables for dressing percentage.

3.3.4 Discussion

The current results indicate that while both DFI and DRG were slightly (but non-significantly) higher in summer than in winter, FCR values were in fact significantly higher during the winter period ($0.05<P<0.10$). It is

acknowledged that the current data, being from commercial piggeries and related to different pigs in different seasons, may thus be subject to errors of unknown magnitude due to variation in, for example, management. However, one well-established relationship which could explain the conflicting trends noted above, is for the maintenance energy requirement of pigs to increase with increasing environmental temperature (Close, Mount and Brown, 1978).

The greater backfat depths found in pigs growing through summer than in those growing through winter supports the earlier findings of the Field Survey (see III-2.0). Backfat depth showed an increase of about two millimetres as the mean shed temperature increased from 20 to 25° C (Figure 17). The work of Stahly and Cromwell (1979) indicated similar trends; in their case the backfat depth of pigs maintained at 22° C was higher than that of those maintained at either 10 or 35° C. Stahly and Cromwell (1979) also observed that carcase fat content increased linearly as environmental temperature increased from 10 to 35° C. In the present study data on carcase fat percentage was not available but the higher dressing percentage detected in pigs grown through summer than through winter may reflect a higher carcase fat content in summer. Dressing percentage and carcase fat content are known to be positively related (Hiner, 1971; Robison, 1976). Such a possibility would be in agreement with the results of Stahly and Cromwell (1979).

The results of the canonical analysis indicate that the severity of the effects of high temperatures on the growth performance of pigs may be lessened, and economic gains thus improved, by using different feeding strategies during summer and winter. Thus the significant interaction between season and treatment with respect to FCR suggests that feed

restriction from 50 kg liveweight to slaughter after earlier *ad libitum* feeding (Treatment 3) might offer some advantages compared with a moderate feed restriction throughout growth (Treatment 2). Both these treatments yielded similar overall growth rates but animals on the high-low regime consumed less feed. Simple calculations based on the mean performance levels recorded and current (1984) feed prices of about $180/tonne, indicate that the high-low (Treatment 3) feeding regime would have returned the farmer $4.45/pig more than the moderately restricted regime (Treatment 2) during the summer period.

The high-low feeding regime also yielded superior economic results to the *ad libitum* one (Treatment 4), in which a higher DRG was achieved at the cost of a higher DFI, although in this case the actual monetary advantage to the farmer during the summer period would only have been about six cents/pig. This figure ignores the fact that the *ad libitum* carcases also had greater backfat depths. It is possible that this increase in fatness could lead to *ad libitum* carcases being down-graded at the abattoir with a consequent loss in terms of money, and consumer acceptability. Even if downgrading did not occur, leaner carcases are to be encouraged from the general point of view of consumer acceptance and industry development.

3.4 Field Experiment 3

The results of the preceding experiment showed quite clearly that a restricted feeding regime offered economic advantages in pigs grown to bacon weight. However, the question still remained as to whether the lysine requirements of the animals were affected by restricted feeding, or

by season of year. The study reported in this section was designed to investigate these questions and was conducted on five piggeries during the summer of 1980/81 and repeated during the winter of 1981 under the supervision of Mr. E. B. Greer of the N.S.W. Department of Agriculture, who made the data available to the present author for analyses.

3.4.1 **Materials and Methods**

Similar procedures were followed as in the preceding experiment (III-2.2.1) except that slaughter weight in this case was 100 kg and four different treatments were imposed:

Treatment 1: *ad libitum* feeding from 20 kg to 50 kg liveweight with a diet containing 0.81% total lysine and thereafter restricted feeding at 2250 g/pig/d of the same ration.

Treatment 2: *ad libitum* feeding from 20 kg to slaughter at 100 kg liveweight on a ration containing 0.81% total lysine.

Treatment 3: *ad libitum* feeding from 20 kg to 50 kg liveweight on a ration containing 1.02% total lysine followed by restricted feeding at 2200 g/pig/d of a ration containing 0.86% total lysine until slaughter.

Treatment 4: *ad libitum* feeding to 50 kg liveweight on a diet containing 1.02% total lysine and then *ad libitum* feeding until

slaughter on a ration containing 0.86% total lysine. The composition of the rations is given in Table 13.

Shed construction and temperature data recording were similar to those of Field Experiment 2. However, feeding methods employed for pigs in Treatments 1 and 3 and, Treatments 2 and 4 (*ad libitum*) were the same as those used for Treatment 3 and 4, respectively, in Field Experiment 2.

3.4.2 Analysis of Data

As a standard procedure the unweighted data were analysed by analysis of variance with respect to each parameter (DRG, DFI, FCR, P2 and dressing percentage) and Duncan's Multiple Range Test was applied when appropriate. Polynomial regression analyses were also performed on the parameters against maximum, minimum and mean shed temperatures. Canonical analyses

Table 13. Composition of the three rations containing different levels of total lysine in Field Experiment 3 (air dry basis).

Ingredient	Diet(g/kg)		
	0.81% Lysine	0.86% Lysine	1.02% Lysine
Barley	800	790	780
Meat bone meal (M)	150	70	70
Soyabean M	50	14	15
Lysine-HCl	0	0	1.8
Calculated:			
DE MJ/kg	12.60	12.91	12.93
DCP %	17.44	17.67	18.03

were performed to determine the nature of the associative relationships between the various biological parameters and season, treatment, maximum and minimum temperatures.

3.4.3 Results

The results revealed that the error mean squares in the two seasons were homogeneous (except in the case of DRG; $P<0.05$) and so the data from both seasons were pooled and overall analyses were carried out in order to examine seasonal effects.

Results from the analyses of variance (Table 14) revealed that the pigs consumed significantly more ($P<0.001$) feed during winter (2142 g/d) than during summer (1994 g/d). DRG was also higher in winter than in summer by approximately 14 g/d, but this difference only approached significance ($0.5<P<0.10$). Furthermore, during summer the pigs converted feed (3.54 kg/kg) more efficiently ($P<0.01$) than during winter (3.72 kg/kg). Backfat depth was found to be greater ($P<0.05$) in pigs grown through summer (18.8 mm) than in their winter counterparts (17.6 mm); dressing percentage was also higher ($P<0.05$) in pigs grown through summer (77.7%) than those grown through winter (76.9%).

Irrespective of season, pigs on *ad libitum* feeding consumed 184 g/d more and grew 52 g/d faster ($P<0.001$) than those on the high-low feeding regime. Pigs on the *ad libitum* feeding regime also had backfat depths 1.3 mm greater ($P<0.01$) than their high-low counterparts. Furthermore, although the difference in dressing percentage of pigs on the two different feeding regimes approached significance ($0.05<P<0.10$), there was no suggestion of any significant difference in FCR.

Table 14. Mean values of Daily Feed Intake (DFI), Daily Rate of Gain (DRG), Feed Conversion Ratio (FCR), Backfat Depth (P2) and Dressing Percentage (Dress%) of pigs in Field Experiment 3.

Treatment	Parameter				
	DFI (g/d)	DRG (g/d)	FCR (kg/kg)	P2 (mm)	Dress% (%)
Winter (7.4-25.0° C)	2142[a]	581	3.72[a]	17.6[b]	76.9
Summer (16.1-35.4° C)	1994[b]	567	3.54[b]	18.8[a]	77.7
LSD(5%)	41	16	0.13	0.9	0.9
Sig. Level	***	-	**	*	-
High-low	1976[b]	548[b]	3.64	17.6[b]	76.9
Ad libitum	2160[a]	600[a]	3.62	18.9[a]	77.7
LSD(5%)	41	16	0.13	0.9	0.9
Sig. Level	***	***	N.S.	**	-
Low lysine	2100[a]	561[b]	3.77[a]	18.2	77.1
High lysine	2035[b]	586[a]	3.49[b]	18.3	77.5
LSD(5%)	41	16	0.13	0.9	0.9
Sig. Level	**	**	***	N.S.	N.S.
Interaction					
Season X feeding regime Sig. Level	*	N.S.	N.S.	N.S.	N.S.
Season X lysine level Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
Feeding regime X lysine level Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
LSD(5%)	59	23	0.18	1.3	1.3

Means with the same superscript within each column are not significantly different (5% level).

When comparing the growth performance of pigs on high and low lysine diets, irrespective of season, it was revealed that (Table 14) those on the high lysine diet consumed 65 g/d less ($P<0.001$) feed than their low lysine counterparts. However, the former pigs grew 25 g/d faster ($P<0.01$) and converted (3.49 kg/kg) more efficiently than low lysine ones (3.77 kg/kg). There were no significant differences in either P2 or dressing percentage of pigs on the two different dietary lysine levels. The only significant interaction ($P<0.05$) found was between season and feeding regime for DFI.

Polynomial regression techniques were used to determine the relationships between the biological parameters and various aspects of shed temperature, irrespective of treatment and season. It was found (see Appendix V) that the DFI decreased linearly at rates of 12.0, 14.2 and 13.5 g/d/°C increment in maximum ($P<0.01$), minimum ($P<0.05$) and mean ($P<0.01$) shed temperature respectively.

Although there were no significant relationships between DRG and minimum shed temperature, there were cubic relationships between DRG and both maximum ($P<0.05$) and mean ($P<0.05$) temperatures. No significant relationships were observed between FCR and the temperature parameters, nor between P2 and maximum temperature. However, there were quadratic relationships between P2 and both minimum ($P<0.01$) and mean ($P<0.05$) shed temperatures.

The linear relationships observed between dressing percentage and the temperature parameters indicated that this parameter increased by 0.10, 0.16 and 0.13% per 1°C increment in maximum ($P<0.05$), minimum ($P<0.05$) and mean ($P<0.05$) shed temperature respectively.

The relationships between DFI, DRG, P2 and dressing percentage and mean shed temperaure are illustrated in Figure 18. From these graphs it can be

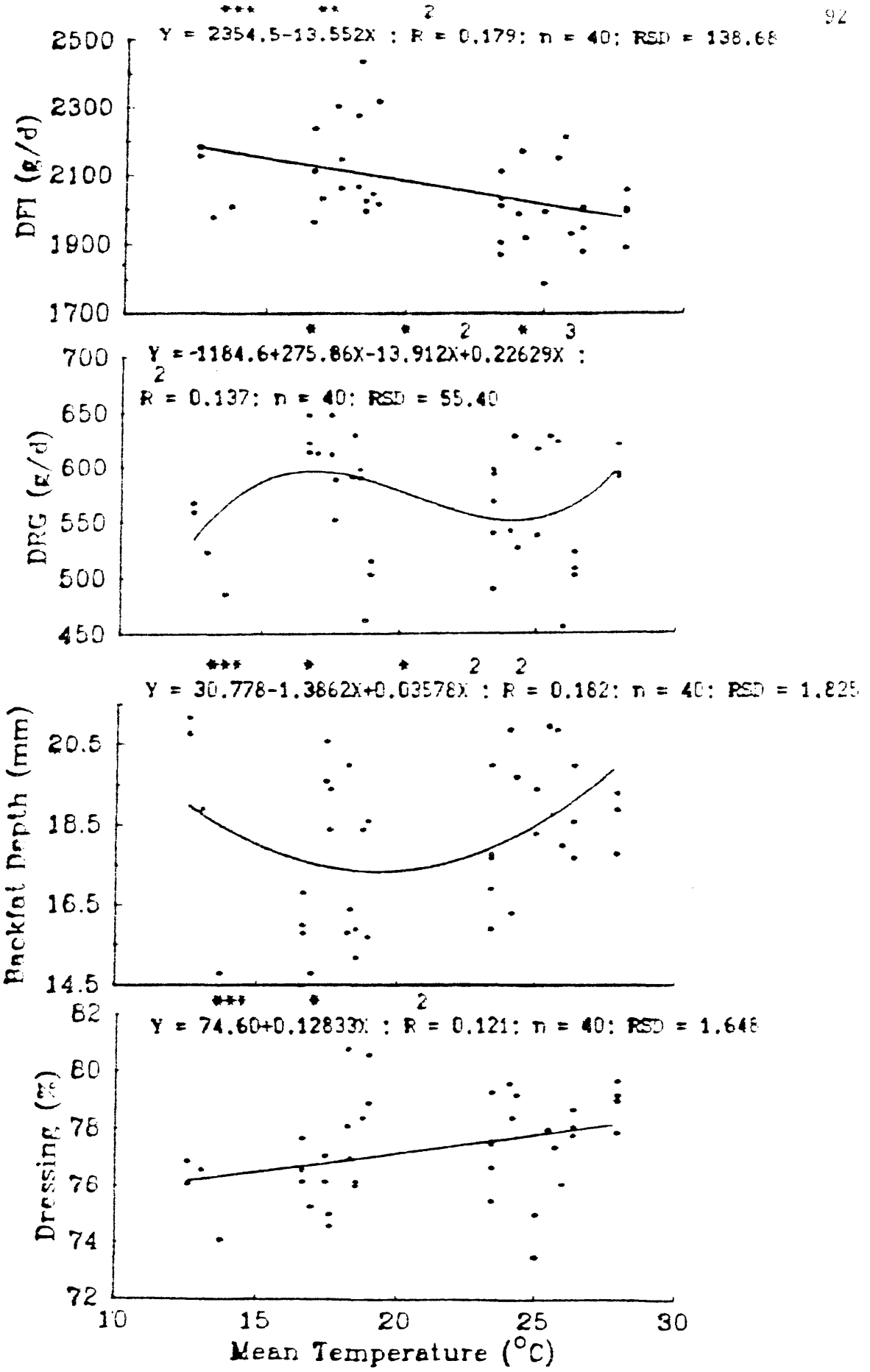

Figure 18. Relationships between Daily Feed Intake (DFI), Daily Rate of Gain (DRG), Backfat Depth (P2) and Dressing Percentage (Dress%) and mean shed temperature in Field Experiment 3 (represents 1 farm).

seen that the DRG decreased as mean shed temperature increased from 16.8 to 24.2°C. Above or below this temperature range the DRG was positively related to mean shed temperature. The curvilinear relationship between backfat depth and mean shed temperature (Figure 18) indicates that minimum P2 values were recorded when the mean shed temperature was about 19°C. At higher and lower mean shed temperatures the P2 increased.

The only significant ($P<0.05$) associative relationships detected by canonical analysis of the relative importance of season, treatment, maximum and minimum temperatures on biological parameters were with respect to DFI. The results (Appendix VI) reveal that season exerted more influence on DFI than either treatment, maximum or minimum temperature.

3.4.4 Discussion

The results of the current experiment confirmed the previous finding (III-2.0) that the DRG of pigs under Australian commercial conditions was lower during summer than in winter. A number of subsidiary factors could contribute to this seasonal effect. As well as temperature changes, which are the prime concern of this thesis and for which data are available, variations in humidity, air movement, daylength and management could possibly have been involved. The experimental design does not allow causative relationships between the biological parameters and variations in shed temperature to be established, but when the data were pooled DRG was found to be significantly related to mean temperature (Figure 18). The cubic form of this relationship is, however, somewhat anomalous in that it indicates that DRG was actually increasing at the upper end of the observed temperature range. There are two possible explanations. The first

concerns the available data (Figure 18) which are not uniformly distributed over the temperature range and in which one of the five farms consistently recorded high growth rates during summer. A second possible explanation is that the mean temperatures did not exceed 28° C. Such temperatures would not be expected to greatly depress growth rate. Heitman, Kelly and Bond (1958) indicated that in 45 kg pigs, the decreases in daily rate of gain were 1.5 and 30% at ambient temperatures of 28 and 32° C when compared to the daily rate of gain at 21° C. In the present study, the daily rate of gain in summer was 2.4% lower than in winter where mean temperatures during winter and summer were 16 and 26° C, respectively. The latter possibility is to some extent contra-indicated by the fact that DFI was lower in summer (1994 g/d) than in winter (2142 g/d) and by the negative relationships between DFI and mean shed temperature (Figure 18). Lower feed intakes would normally be associated with lower growth rates.

The FCR results in this experiment contradict those obtained in sections III-2.0 and III-3.2. Although non-significant relationships were found between FCR and the temperature parameters, the results do indicate that the pigs converted feed more efficiently in summer when the temperature was high than during winter. Food conversion efficiency generally peaks at 85-100% of full feed, with the actual peak depending on factors such as liveweight, ambient temperature and protein level. For example Giles, Murison and Wilson (1981) showed that pigs fed 12.5% less than that recommended by ARC (1967) on the one hand had a lower DRG than those fed *ad libitum* but on the other hand converted feed more efficiently.

The higher backfat depth observed in pigs slaughtered during summer supports the earlier findings from both Field Surveys (see III-2.0) and the

preceding field experiments (see III-3.1 and III-3.2). Furthermore, the higher dressing percentage detected in pigs slaughtered during summer is consistent with the preceding experiment (III-3.2).

Except for the fact that Treatments 3 and 4 in the present experiment contained higher lysine levels, the treatment effects, regardless of seasonal influences, can be considered such that Treatments 1 and 3 were similar to the high-low treatment in the preceding experiment (III-3.2). Similarly, Treatments 2 and 4 in the current experiment correspond with the *ad libitum* treatment (No.4) in the preceding experiment (III-3.2). As was expected the results indicate that restricted feeding led to a reduction in DRG. A higher level of total dietary lysine offered an advantage in terms of DRG only when the pigs were fed *ad libitum*. Batterham (1974) showed that pigs fed on four grams added L-lysine/kg diet had better DRG than those which were fed two grams added L-lysine and control diets.

Although in the current study, feeding high lysine diets did not offer advantages in terms of backfat depth or dressing percentage, the results did indicate that pigs on high lysine diets tended to convert feed better than those on low lysine diets. If economy of feeding is to be considered in relation to growth performance, it can be seen that restricted feeding to bacon weight with high levels of dietary lysine would offer advantage over the other three treatments. This advantage possibly occurred during the summer months when there was lower feed consumption.

4.0 EFFECTS OF DIETARY ENERGY AND PROTEIN LEVELS ON GROWING PIGS AT HIGH AMBIENT TEMPERATURE

4.1 Introduction

There were two experiments in this part of the study. Since the climate laboratory was modified for this and subsequent experiments, Experiment 1 was designed to test the newly acquired equipment and to act as a preliminary study. Experiment 2 was a repeat of Experiment 1, the only slight difference being in the protein levels in the diets. These were slightly (0.7-1.7%) higher in Experiment 2 as a result of limitation in the availability of constituents (see Tables 15 and 16).

4.2 Materials and Methods

4.2.1 The Climate Laboratory

The experiments were carried out in the John Hammond Climate Laboratory, Department of Animal Science, University of New England, N.S.W. The hotroom used could accommodate comfortably 20 pigs grown to 95 kg and had a force-draught electric heater bank which allowed air temperature to be thermostatically controlled to within $\pm 1^{\circ}$C. Ambient humidity could be concurrently controlled to within $\pm 2\%$ R.H. The system allowed control of the rate of air circulation and of the intake of fresh air from the outside environment.

The control-room used was adjacent to the hotroom and could accommodate 10 baconers comfortably. It was fitted with two air conditioning units which allowed ambient temperature to be controlled to within $\pm 2^{\circ}$C.

4.2.2 Modification of the Climate Laboratory

Both the hotroom and the control-room were modified to accommodate pigs on suitable woven wire mesh flooring raised 50 cm above the existing cement floor.

Six pens of identical dimensions were constructed, four in the hotroom and two in the control-room. Each pen was designed to accommodate five pigs living communually with tilting feeding stalls which allowed all pigs to be fed individually (Plate 4). Each pen had a space allowance of 0.7 m^2 /pig.

Within each room there was a thermostatically controlled header tank from which water at room temperature was fed to a nipple-drinker in each pen. Air movement in both rooms was measured at 15 cm above the wire floor and adjusted to about 0.2 m/sec (Figure 19).

4.2.3 Animals and Husbandry

a) Animals:

Thirty entire male weaner pigs (Large White X Landrace) were purchased from a commercial piggery (Fielders Ltd., Australia) at 20 kg liveweight. All pigs used in this and subsequent laboratory experiments were drenched with "Worm Guard" at weaning to control endoparasites. The pigs were reared to approximately 40 - 45 kg liveweight in individual pens and were then transferred to the climate laboratory where they were allocated to pens and treatments by stratified randomization on the basis of liveweight. The experiment terminated when group mean liveweights reached 90 kg (range 82-100kg); groups being individually transported to the abattoir when this target weight was reached.

Plate 4. Feeding stalls being tilted into the vertical (non-feeding) position to maximize space allowence after feeding.

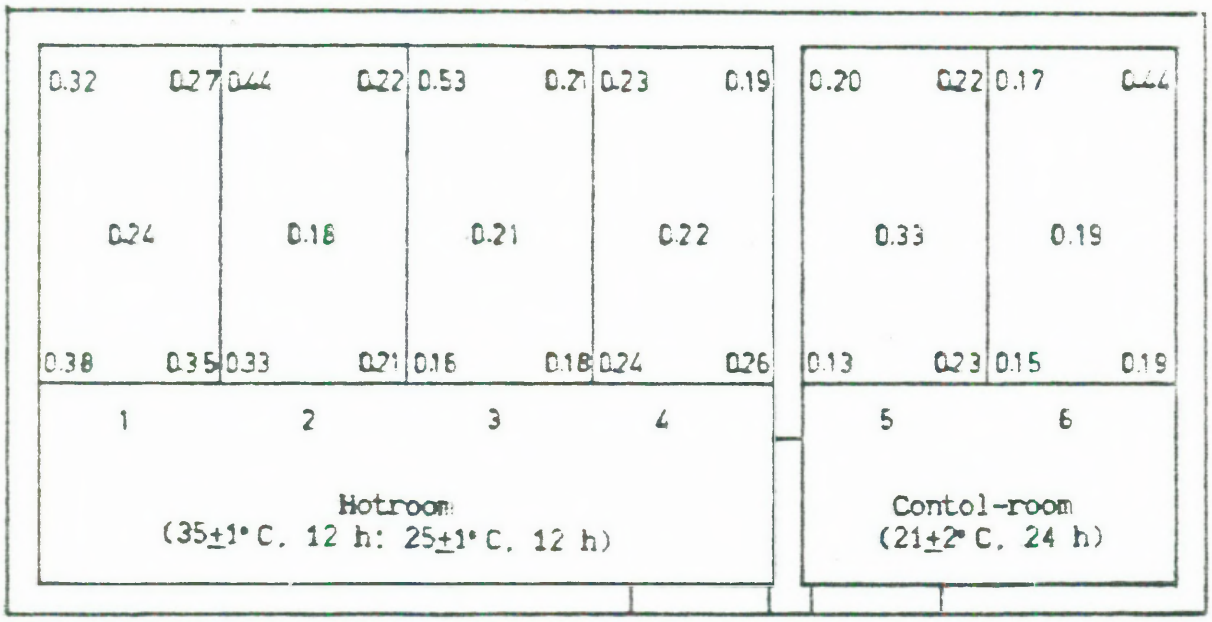

Figure 19. Air movement (m/s) measured at 15 cm above the wire mesh floor and 30 cm in from the corners of each pen and in the middle of each of the six pens.

b) Pre-Experimental Conditions:

A pre-experimental period of four days was allowed to enable the pigs to adjust to their new diet and surroundings. During this period the hotroom temperature was gradually increased to the experimental level (see III-4.2.4).

c) Feeding:

The pigs were fed individually twice a day; at 09.00 and 16.00 hours. The dry feed offered at each feeding session was calculated from the formula $Y = 60W^{0.75}$ g; where W = liveweight (kg). After each session individual feed refusals and spillage were collected and weighed. Other than at feeding times free access to water was always available.

d) Weighing:

The pigs were weighed weekly before the morning feeding session.

e) Physiological Measurements:

At 14.00 hours each Wednesday during the experiment the respiration rate (RR), rectal (RT) and skin temperatures (ST) of each pig were recorded. The respiration rate was taken by counting flank movements over 15 seconds, the skin temperature was taken at the point of the wither and rectal temperature at a depth of 10 cm; both by thermister thermometer (Shibaura Denshi Seisakusho, Japan).

f) Anatomical Measurements:

At the end of the experiment height and girth were measured then the pigs were transported to Dorrigo Abattoir, N.S.W., where they were

slaughtered. Dressed weight, carcase length and backfat depth (Figure 20) were recorded on the warm carcases, the latter by the use of both the "Scanoprobe" (Ithaco Model 731A, N.Y., U.S.A) and the "Introscope" (S.F.K. Introscope, Wolfking, Denmark) respectively. Carcase length was measured between the anterior edge of the first rib and the rim of the pelvis.

g) Digestibility Measurements:

When the group average weight of the pigs reached 65 kg a digestibility trial was carried out using Cr_2O_3 as an indigestible marker. Samples were ashed and digested (Stevenson and DeLangen, 1960) and the chromium content determined by atomic absorption spectrophotometry (Perkin-Elmer, Model360, Norwalk, Connecticut, U.S.A) using a acetylene-nitrous oxide flame.

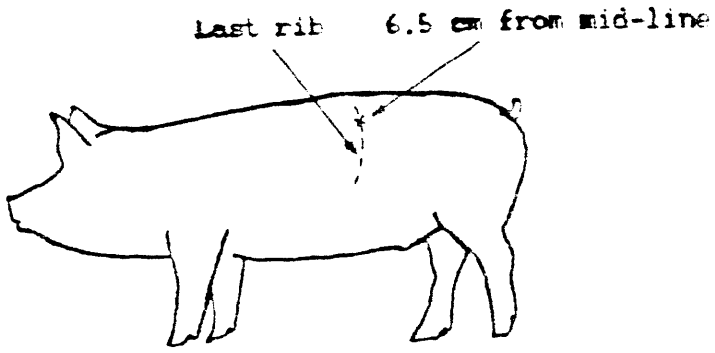

Figure 20. Positions at which Backfat Depth (P2) was measured.

In this and subsequent experiments, values for the apparent digestibilities of dry matter, nitrogen and energy were calculated from the results of the digestibility trials using the ratio method. Subsequently, values for DE and DCP were derived, using the digestibility trial data.

4.2.4 Treatments

Both Experiments 1 and 2 were continued until the group mean liveweight was 90 kg. The treatments were as follows:

Treatment 1:	High Energy - High Protein	Hotroom
Treatment 2:	High Energy - Low Protein	Hotroom
Treatment 3:	Low Energy - High Protein	Hotroom
Treatment 4:	Low Energy - Low Protein	Hotroom
Treatment 5:	High Energy - Low Protein	Control-room
Treatment 6:	Low Energy - Low Protein	Control-room

Hotroom: 35±1°C and 50-60% R.H. from 06.00 to 18.00 hours (day); 25±1°C and 60-70% R.H. from 18.00 to 06.00 hours (night).

Control-room: 21±2°C continuously 24 hours per day, relative humidity was not controlled but was found to range from 60 to 80%.

There were five pigs per treatment. Details of the diets used in Experiments 1 and 2 are given in Tables 15 and 16 respectively.

4.2.5 Analysis of Data

Analysis of variance (Steel and Torrie, 1980) was performed on the biological data and Duncan's Multiple Range Test (Duncan, 1955) was applied whenever appropriate.

Table 15. Diet composition (g/kg) in Laboratory Experiment 1 (air dry basis).

Ingredient	Diet			
	High Energy High Protein (HH)	High Energy Low Protein (HL)	Low Energy High Protein (LH)	Low Energy Low Protein (LL)
Sorghum	769.0	870.0	41.7	0.0
Barley	0.0	0.0	772.3	930.7
Wheaten Bran	0.0	0.0	0.0	20.0
Sunflower Meal (M)	0.0	0.0	137.2	0.0
Meat M	39.9	39.8	39.8	39.8
Soyabean M	184.7	83.0	0.0	0.0
Lysine-HCl	0.3	2.6	3.0	3.5
Vitamin and minerals	1.0	1.0	1.0	1.0
Salt	2.0	2.0	2.0	2.0
Lime	3.0	3.0	3.0	3.0
Calculated:				
DE MJ/kg (DM)	14.63	14.63	12.54	12.54
DCP (DM) %	17.50	13.50	15.50	11.50
CF (DM) %	2.56	2.04	6.88	6.60
Total Lysine (DM) %	0.76	0.78	0.92	0.88
Energy:Protein (MJ/kg):(%)	1:1.20	1:0.92	1:1.24	1:0.92

Vitamins A 5,000,000 iu; D3 500,000 iu; E 7,500 iu; K3 0.5 g; B2 1.5 g; B12 7.5 mg Nicotinic acid 7.5 g; Calc.-d-Pantothenate 5 g; Copper 1 g; Iron 40 g; Manganese 60 g; Iodine 400 mg; Zinc 75 g; and Ethoxyquin 150 mg per kg.

Table 16. Diet composition (g/kg) in Laboratory Experiment 2 (air dry basis).

Ingredient	Diet			
	High Energy High Protein (HH)	High Energy Low Protein (HL)	Low Energy High Protein (LH)	Low Energy Low Protein (LL)
Wheat	299.5	95.7	22.1	0.0
Sorghum	431.0	657.6	0.0	0.0
Barley	0.0	50.3	692.5	772.6
Cottonseed Meal (M)	37.3	0.0	76.0	0.0
Sunflower M	44.3	19.7	5.0	0.0
Soyabean M	38.8	42.8	10.0	0.0
Meat M	35.4	31.5	44.7	39.5
Blood M	29.5	0.0	0.0	0.0
Skim Milk Powder	0.0	45.7	0.0	0.0
Wheaten Bran	13.4	0.0	53.1	130.7
Rice Pollard	34.7	0.0	44.3	0.0
Rice Hulls	0.0	16.3	0.0	1.6
Corn Flour	36.6	23.9	43.7	48.3
Lysine-HCl	0.0	2.7	0.0	1.6
Vitamin and minerals	0.9	0.9	0.9	0.9
Salt	0.9	0.9	0.9	0.9
Lime	0.0	2.7	0.0	2.7
Bone M	7.7	2.8	6.8	2.8
Calculated:				
DE MJ/kg (DM)	15.75	15.70	13.90	13.75
DCP (DM) %	19.21	15.26	16.19	12.59
CF (DM) %	3.19	2.95	7.10	6.90
Total Lysine (DM) %	0.89	0.86	0.73	0.73
Energy:Protein (MJ/kg):(%)	1:1.22	1:0.97	1:1.16	1:0.92

Vitamins A 5,000,000 iu; D3 500,000 iu; E 7,500 iu; K3 0.5 g; B2 1.5 g; B12 7.5 mg Nicotinic acid 7.5 g; Calc.-d-Pantothenate 5 g; Copper 3 g; Iron 40 g; Manganese 30 g; Iodine 400 mg; Zinc 75 g; and Ethoxyquin 150 mg per kg.