5.0 EFFECTS OF LEVELS AND TYPES OF DIETARY LIPID ON PIGS GROWING AT HIGH AMBIENT TEMPERATURES

5.1 Introduction

Results from Laboratory Experiments 1 and 2 indicated that highly concentrated diets enhanced the growth performance of pigs living in high ambient temperature environments. It was also pointed out (see II-4.2) that some sources of dietary energy such as fat have a lower heat increment than traditional dietary energy sources such as carbohydrates. It follows that diets with lower heat increments may further enhance the growth performance of pigs at high ambient temperatures. Two experiments were therefore conducted in this part of the study; Laboratory Experiments 3 and 4. Tallow and rice pollard were used in Experiment 3 while mixed vegetable oil and rice pollard were used in Experiment 4 as the sources of additional lipid. In this latter experiment it was hoped to demonstrate a beneficial effect of combining animal fat provided in meat meal with vegetable oil *per se* and oil in rice pollard.

5.2 Materials and Methods

The same facilities and methods employed in the previous experiments (see III-4.2) were used, with a new batch of pigs being acquired for each experiment.

5.3 Treatments

5.3.1 Treatments of Laboratory Experiment 3

The treatments were as follows:-

Treatment 1:	Diet A	Hotroom
Treatment 2:	Diet B	
Treatment 3:	Diet C	
Treatment 4:	Diet D	
Treatment 5:	Diet B	Control-room
Treatment 6:	Diet D	

Details of the diets used in Laboratory Experiment 3 are given in Table 25.

5.3.2 Treatments of Laboratory Experiment 4

The treatments were as follows:-

Treatment 1:	Diet A	Hotroom
Treatment 2:	Diet B	
Treatment 3:	Diet C	
Treatment 4:	Diet D	
Treatment 5:	Diet A	Control-room
Treatment 6:	Diet D	

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).

Table 25. Diet composition (g/kg) in Laboratory Experiment 3 (air dry basis).

Ingredients	Diet A	Diet B	Diet C	Diet D
Wheat	180.0	242.1	191.4	210.3
Sorghum	260.6	200.0	208.1	200.0
Oats	300.0	179.7	208.6	266.8
Triticale	12.0	53.1	38.0	38.0
Soyabean Meal (M)	50.0	69.0	45.0	50.0
Fish M	60.0	55.0	43.8	45.0
Cotton seed M	67.0	66.3	50.0	60.0
Tallow	50.0	0.0	0.0	20.0
Starch	0.0	70.5	0.0	0.0
Dextrose	0.0	44.5	0.0	0.0
Rice pollard	0.0	0.0	210.6	105.3
Rice hull	16.0	15.0	0.0	0.0
Lysine-HCl	0.4	0.3	0.5	0.6
Vitamin and minerals	1.0	1.0	1.0	1.0
Lime	3.0	3.0	3.0	3.0
Calculated:				
DE MJ/kg (DM)	14.05	13.60	13.66	13.85
DCP (DM) %	16.37	16.59	16.49	16.32
Total Lysine (DM) %	0.80	0.80	0.80	0.80
CF (DM) %	6.63	5.42	6.45	6.38
Energy:Protein (MJ/kg):(%)	1:1.16	1:1.22	1:1.21	1:1.18

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 20 g; Iodine 400 mg; Zinc 75g; and Ethoxyquin 250 mg per kg.

Table 26. Diet composition (g/kg) in Laboratory Experiment 4 (air dry basis).

Ingredients	Diet A	Diet B	Diet C	Diet D
Sorghum	743.0	681.4	713.8	757.8
Cotton Seed M	44.5	0.0	17.3	0.0
Meat M	0.0	97.6	0.0	97.8
Blood M	39.5	32.3	45.3	0.0
Starch	0.0	160.6	0.0	0.0
Rice pollard	138.6	0.0	204.2	138.7
Rice hulls	0.0	20.8	0.0	0.0
Vegetable oil	13.7	0.0	0.0	0.0
Lysine-HCl	0.92	0.46	0.46	1.85
Vitamin and minerals	1.91	1.90	1.91	1.91
Salt	1.86	1.86	1.88	1.89
Lime	8.49	0.0	8.53	0.0
Bone M	7.56	0.0	6.63	0.0
Calculated:				
DE MJ/kg (DM)	15.44	14.30	15.46	15.56
DCP (DM) %	15.30	15.40	15.30	15.30
CF (DM) %	3.20	2.00	3.60	2.70
Total Lysine (DM) %	0.75	0.75	0.75	0.76
Energy:Protein (MJ/kg):(%)	1:0.99	1:1.08	1:0.99	1:0.98

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 20 g; Iodine 400 mg; Zinc 75g; and Ethoxyquin 250 mg per kg.

Control-room: 21±2° C continuously 24 hours per day, relative humidity was not controlled but was found to range from 60 to 90%.

5.3.3 Analysis of Data

Analyses of variance were performed on the biological performance data and Duncan's Multiple Range Test was applied whenever appropriate.

5.4 Results

5.4.1 Results of Laboratory Experiment 3

Results from analyses of variance including six treatments (Table 27) revealed that there were significant differences in DMI ($P<0.01$), EI ($P<0.001$), and DRG ($P<0.001$; Figure 23) but not in FCR, ECR and dressing percentage. Table 27-1 shows that pigs on diet B (no fat) in the control-room consumed more ($P<0.05$) feed and energy per day (2190 g/d and 31.0 MJ/d respectively) than all groups in the hotroom. There were no significant differences between diets B and D in the control-room. The pigs on diet D in the hotroom consumed less energy ($P<0.05$; 21.1 MJ/d) than pigs on diet C (26.1 MJ/d) also living in the hotroom. These differences in DMI and EI were reflected in the DRG values such that pigs on diet B in the control-room grew faster (804 g/d; $P<0.05$) than all other groups except those on diet D in the control-room (707 g/d). The results further revealed that there were no significant differences in growth rate between pigs on diets A (5% Tallow, 492 g/d) and C (10% rice pollard, 669 g/d) in the hotroom. The DRG of pigs on diet B in the hotroom (551 g/d) was

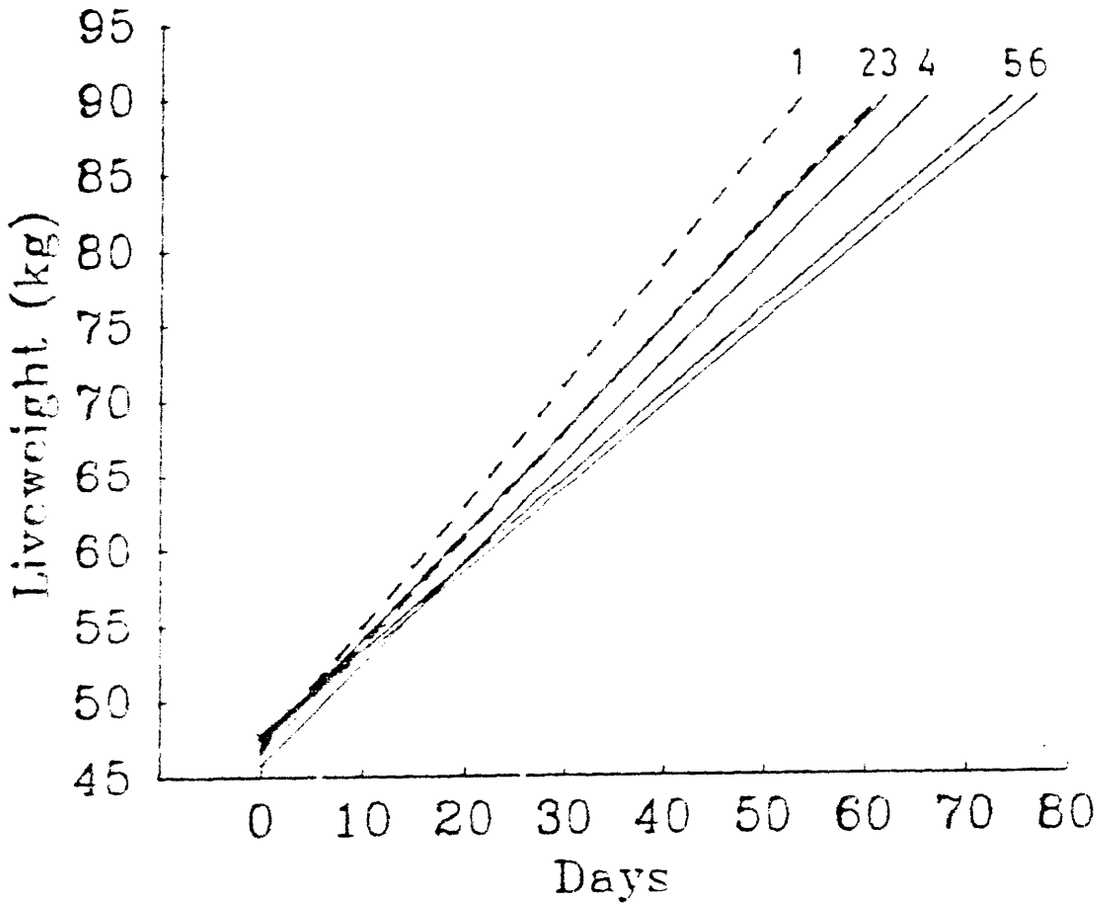

Figure 23. Plots of linear regressions of liveweight of pigs which received different dietary and ambient temperature treatments over days of experiment in Laboratory Experiment 3

1 - diet B; control-room
2 - diet D; control-room
3 - diet C; hotroom
4 - diet A; hotroom
5 - diet D; hotroom
6 - diet B; hotroom

Table 27. Mean values of Daily Rate of Gain (DRG), Dressing Percentage (Dress%), Daily Dry Matter Intake (DMI), Feed Conversion Ratio (FCR) Daily Energy Intake (EI) and Energy Conversion Ratio (ECR) of pigs on different dietary and environmental temperature treatments in Laboratory Experiment 3.

Treatment	Parameter					
(g/d)	DRG (%)	Dress% (g/d)	DMI (kg/kg)	FCR (MJ/d)	EI (MJ/kg)	ECR
(i) Analysed as 6 Treatments						
Diet A (hotroom)	692^{b}	76.9	1756$^{b c}$	2.54	25.2$^{a c c}$	36.4
Diet B (hotroom)	553^{e}	75.5	1540^{e}	2.85	21.2$^{e e}$	38.9
Diet C (hotroom)	669$^{b c}$	76.1	1816$^{b c}$	2.74	26.1$^{b c}$	39.4
Diet D (hotroom)	568$^{d e}$	74.7	1566^{c}	2.74	21.1^{d}	37.1
Diet B (control-room)	804^{a}	77.7	2190^{a}	2.73	31.0^{a}	38.7
Diet D (control-room)	707$^{a b}$	76.3	2014$^{a b}$	2.85	27.3$^{a b}$	28.7
LSD(5%)	112	2.9	308	0.41	4.3	5.5
Sig Level	***	N.S.	**	N.S.	***	N.S.
(ii) Analysed as 2 Diets X 2 Environmental Temperatures						
Diet B	637	76.6	1865	2.79	26.1	28.8
Diet D	679	75.5	1790	2.80	24.2	37.9
LSD(5%)	180	1.9	220	0.27	3.0	3.4
Sig Level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Hotroom	561^{b}	75.1	1553^{b}	2.80	21.2^{b}	38.0
Control-room	756^{a}	77.0	2102^{a}	2.79	29.1^{a}	38.7
LSD(5%)	94	1.9	220	0.27	3.0	3.4
Sig Level	**	-	***	N.S.	***	N.S.
Interaction: Diet X Environment						
LSD(5%)	133	2.7	310	0.38	4.2	4.8
Sig Level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

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

less ($P<0.05$) than that of all other groups except those on diet D (568 g/d) in the hotroom. All other between-group differences in growth rate were non-significant.

Furthermore, when analysed as 2 diets (Diets B and D) X 2 environmental temperatures (Hotroom and Control-room), the results (Table 27-ii) revealed that there were no significant differences in DMI, EI, DRG, FCR, ECR or dressing percentage between groups of pigs on diets B and D, irrespective of the environmental temperature they were exposed to. However, the results (Table 27-ii) also indicated that pigs in the control-room consumed more ($P<0.001$) dry-matter (2102 g/d) and energy (29.1 MJ/d) and consequently grew faster (755 g/d; $P<0.01$) than their counterparts fed the same diet in the hotroom (DMI 1553 g/d; EI 21.2 MJ/d; DRG 560 g/d respectively). There were no significant differences in either FCR, ECR or dressing percentage between pigs grown in the hotroom and control-room. Although pigs in the control-room dressed out (77.0%) appreciably better than their counterparts in the control-room (75.1%) the difference only approached significance ($0.05<P<0.10$). There were no significant interactions between diet and environment with respect to DMI, EI, DRG, FCR, ECR and dressing percentage.

When analysed including six treatments, Table 28-i shows that there were significant differences in the apparent digestibilities of dry matter (ADM; $P<0.01$), energy (ADE; $P<0.001$) and protein (ADP; $P<0.05$). It also shows significant differences in digestible energy (DE; $P<0.05$) and crude protein (DCP; $P<0.05$) between the four diets studied. The differences were such that the ADM of diet C (80.2%) was higher ($P<0.05$) than that of both diets B (77.1%) and D (hotroom: 74.9%; control-room: 75.6%).

The ADE of diet D in both the hotroom (71.8%) and the control-room (72.0%) was lower ($P<0.05$) than that of all other diets. The ADP of diet D

Table 28. Means of Apparent Digestibilities of Dry Matter (ADM), Protein (ADP) and Energy (ADE) and Digestible Energy (DE) and Crude Protein (DCP) contents of diets given to pigs living in either hot or cold environments in Laboratory Experiment 3.

Treatment	Apparent Digestiblity			Diet	
	ADM (%)	ADP (%)	ADE (%)	DE (MJ/kg)	DCP (%)
(i) Analysed as 6 Treatments					
Diet A (hotroom)	$77.6^{a\,b\,c}$	$81.3^{a\,b}$	78.5^{a}	14.3^{a}	14.1^{b}
Diet B (hotroom)	$77.1^{b\,c}$	$80.8^{a\,b}$	77.0^{a}	$13.7^{a\,b}$	13.9^{b}
Diet C (hotroom)	80.2^{a}	83.5^{a}	78.0^{a}	14.4^{a}	14.7^{a}
Diet D (hotroom)	74.9^{c}	$80.0^{a\,b}$	71.8^{b}	13.5^{b}	13.9^{b}
Diet B (control-room)	$79.2^{a\,b}$	82.2^{a}	79.5^{a}	$14.1^{a\,b}$	14.1^{b}
Diet D (control-room)	75.6^{c}	77.6^{b}	72.0^{b}	13.6^{b}	13.5^{b}
LSD(5%)	2.7	3.4	3.7	0.7	0.6
Sig. Level	**	*	***	*	*
(ii) Analysed as 2 Diets X 2 Environmental Temperatures					
Diet B	78.1^{a}	81.5	78.3^{a}	13.9	14.0
Diet D	75.2^{b}	78.8	71.9^{b}	13.5	13.7
LSD(5%)	2.0	2.8	2.6	0.5	0.5
Sig. Level	**	-	***	N.S.	N.S.
Hotroom	76.0	80.4	74.4	13.6	13.9
Control-room	77.4	79.9	75.8	13.9	13.8
LSD(5%)	2.0	2.8	2.6	0.5	0.5
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction: Diet X Environment					
LSD(5%)	2.9	3.9	3.7	0.7	0.7
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.

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

in the control-room (77.6%) was lower (P<0.05) than that of both diet B in the control-room (82.2%) and diet C (83.5%) in the hotroom.

The DE of diet C (14.4 MJ/kg) was higher (P<0.05) than that of diet D in both the hotroom (13.5 MJ/kg) and the control-room (13.6 MJ/kg) while DCP of diet C (14.7%) was higher (P<0.05) than that of all other diets.

When analysed on a 2 diets X 2 environments basis, the results (Table 28-ii) revealed that diet B had higher mean values for both ADM (78.1%) and ADE (78.3%; P<0.01 and P<0.001 respectively) than diet D (75.2% and 71.9% respectively). The ADP of diet B (81.5%) was also higher than that of diet D (78.8%), however, the difference in this case only approached significance (0.05<P<0.10).

From Table 29-(i) it can be seen that when analysed on a 6-treatment basis, backfat depth (both ultrasonic and optical estimates), carcase length and chest depth did not differ between-groups. The only significant differences observed between-groups were with respect to girth (P<0.01); the value in the control-room for pigs on diet B (102 cm) being larger (P<0.05) than those on diets A (99 cm), B (99 cm), C (100 cm) and D (99 cm) in the hotroom.

When the above anatomical measurements were analysed on a 2 diets X 2 environments basis, the results (Table 29-ii) indicated that there were no significant differences between pigs on diets B and D. Pigs in the hotroom also had smaller girths (99 cm; P<0.01) than their counterparts in the control-room. The chest depths of pigs in the hotroom (29.9 cm) were also smaller than in the control-room but the differences in this case only approached significance (0.05<P<0.10).

Analysis of variance of the physiological parameters showed that there were significant differences (P<0.001) between groups in RR, RT and ST

Table 29. Means of Carcase Backfat Depth (P2) measured by ultrasonic (Scanoprobe) and optical (Introscope) methods, Carcase Length (CL), Chest Depth (CD) and Girth of pigs which received different dietary and environmental temperature treatments in Laboratory Experiment 3.

Treatment	Parameter				
	P2(mm)		Car.Length	Chest Depth	Girth
	Scanoprobe	Introscope	(cm)	(cm)	(cm)
(i) Analysed as 6 Treatments					
Diet A (hotroom)	15.8	19.8	78.1	30.6	99[b]
Diet B (hotroom)	16.6	20.0	77.8	29.8	99[b]
Diet C (hotroom)	15.2	19.0	78.4	30.8	100[b]
Diet D (hotroom)	16.2	21.2	76.2	30.0	99[b]
Diet B (control-room)	15.4	20.4	78.6	31.4	102[a]
Diet D (control-room)	17.4	21.2	77.2	30.4	101[a,b]
LSD(5%)	3.6	4.1	2.6	1.6	2
Sig. Level	N.S.	N.S.	N.S.	N.S.	**
(ii) Analysed as 2 Diets X 2 Environmental Temperatures					
Diet B	16.0	20.2	78.2	30.6	101
Diet D	16.8	21.2	76.7	30.2	100
LSD(5%)	2.8	3.5	1.9	1.2	2
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
Hotroom	16.4	20.6	77.0	29.9	99[b]
Control-room	16.4	20.8	77.9	30.9	101[a]
LSD(5%)	2.8	3.5	1.9	1.2	2
Sig. Level	N.S.	N.S.	N.S.	-	**
Interaction: Diet X Environment					
LSD(5%)	3.9	4.9	2.7	1.7	2
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.

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

Table 30. Means of Respiration Rate (RR), Rectal (RT) and Skin (ST) Temperatures of pigs which received different dietary and environmental temperature treatments in Laboratory Experiment 3.

Treatment	Parameter		
	RR (b/min)	RT (°C)	ST (°C)
(i) Analysed as 6 Treatments			
Diet A (hotroom)	135[a]	39.3[a]	37.7[a]
Diet B (hotroom)	115[b]	39.2[b]	37.3[b]
Diet C (hotroom)	116[b]	39.2[b]	36.8[c]
Diet D (hotroom)	143[a]	39.2[b]	37.2[b]
Diet B (control-room)	32[c]	38.9[c]	33.6[d]
Diet D (control-room)	39[c]	38.9[c]	33.4[d]
LSD(5%)	13	0.1	0.3
Sig. Level	***	***	***
(ii) Analysed as 2 Diets X 2 Environmental Temperatures			
Diet B	73[b]	39.1	35.4
Diet D	91[a]	39.1	35.3
LSD(5%)	8	0.04	0.3
Sig. Level	***	N.S.	N.S.
Hotroom	129[a]	39.2[a]	37.2[a]
Control-room	35[b]	38.9[b]	33.5[b]
LSD(5%)	8	0.04	0.3
Sig. Level	***	***	***
Interaction: Diet X Environment			
LSD(5%)	12	0.06	0.4
Sig. Level	*	N.S.	N.S.

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

(Table 30-i). The differences were such that pigs on diets B and D in the control-room had lower values for all the above physiological parameters ($P<0.05$) than those in the hotroom. In the hotroom pigs on diets A and D had higher ($P<0.05$) RR values (135 and 143 b/min, respectively) than those on diets B and C (115 and 116 b/min, respectively). Furthermore, pigs on diet A in the hotroom had higher ($P<0.05$) RT (39.3° C) and ST (37.7° C), and pigs on diet C had lower ($P<0.05$) ST (36.8° C) values than all other groups in that environment. All other differences were non-significant.

When analysed on a 2 diets X 2 environments basis, the results (Table 30-ii) indicated that while overall values for RR, RT and ST were higher ($P<0.001$) in the hotroom, the only significant between-diet difference was that RR of pigs on diet B (73 b/min) was lower ($P<0.001$) than on diet D (91 b/min).

The only significant interaction detected between diet and environmental temperature was with respect to RR ($P<0.05$).

5.4.2 Results of Laboratory Experiment 4

From Table 31-i it can be seen that when analysed on a 6 treatments basis, there were no significant differences between-groups in DRG (Figure 24), Dress%, DMI, FCR, EI and ECR. However, when analysed on a 2 diets X 2 environmental temperatures basis, the results (Table 31-ii) indicated that pigs on diet D (13.9% rice pollard + 9.8% meat meal) converted feed (3.00 kg/kg) more efficiently ($P<0.05$) than those on diet A (1.37% blended vegetable oil; 3.35 kg/kg). Although the ECR of pigs on diet A (49.8 MJ/kg) was higher than on diet D (46.2 MJ/kg), in this case the differences only approached significance ($0.05<P<0.10$).

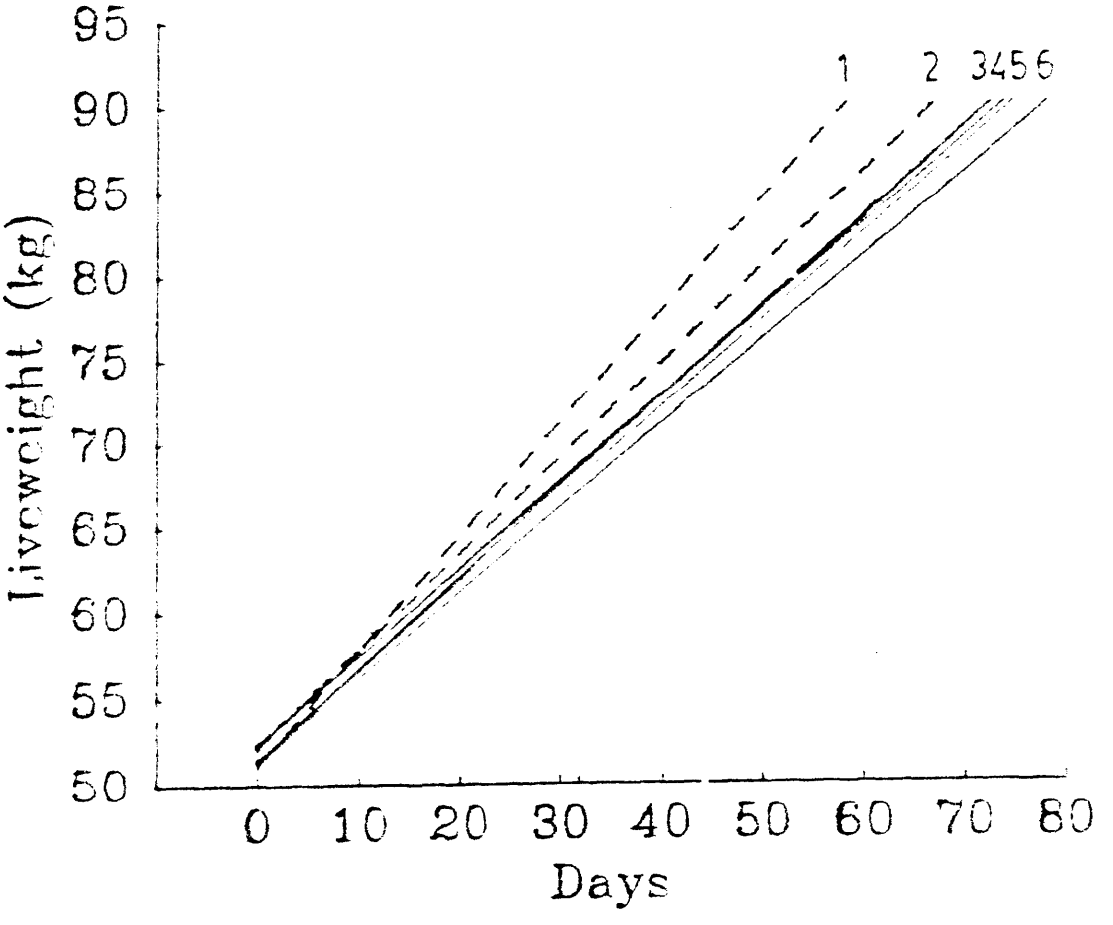

Figure 24. Plot of linear regressions of liveweights of pigs which received different dietary and and ambient temperature treatments over days of experiment in Laboratory Experiment 4.

1 - diet I; control-room
2 - diet A; control-room
3 - diet D; hotroom
4 - diet B; hotroom
5 - diet A; hotroom
6 - diet C; hotroom

Table 31. Mean values of Daily Rate of Gain (DRG), Dressing Percentage (Dress%), Daily Dry Matter Intake (DMI), Feed Conversion Ratio (FCR) Daily Energy Intake (EI) and Energy Conversion Ratio (ECR) of pigs on different dietary and environmental temperature treatments in Laboratory Experiment 4.

Treatment	Parameter					
	DRG (g/d)	Dress% (%)	DMI (g/d)	FCR (kg/kg)	EI (MJ/d)	ECR (MJ/kg)
(i) Analysed as 6 Treatments						
Diet A (hotroom)	517	77.6	1694	3.29	25.3	49.1
Diet B (hotroom)	514	75.8	1632	3.22	25.4	50.0
Diet C (hotroom)	497	75.0	1552	3.13	24.0	48.4
Diet D (hotroom)	534	77.1	1664	3.14	25.6	48.2
Diet A (control-room)	567	76.9	1919	3.41	28.5	50.6
Diet D (control-room)	671	78.1	1916	2.87	29.6	44.2
LSD(5%)	131	3.2	363	0.38	5.5	5.2
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
(ii) Analysed as 2 Diets X 2 Environmental Temperatures						
Diet A	542	77.2	1806	3.35[a]	26.9	49.8
Diet D	602	77.6	1790	3.00[b]	27.6	46.2
LSD(5%)	91	1.7	261	0.31	4.0	4.3
Sig. Level	N.S.	N.S.	N.S.	*	N.S.	-
Hotroom	526[b]	77.3	1679	3.21	25.4	48.6
Control-room	619[a]	77.5	1917	3.14	29.0	47.4
LSD(5%)	91	1.7	261	0.31	4.0	4.3
Sig. Level	*	N.S.	-	N.S.	-	N.S.
Interaction: Diet X Environment						
LSD(5%)	129	2.4	369	0.44	5.6	6.1
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

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

Furthermore, although pigs in the control-room consumed more dry matter (1917 g/d) and energy (29.0 MJ/d) than their counterparts in the hotroom (1679 g/d and 25.4 MJ/d) the differences only approached significance ($0.05<P<0.10$). Nevertheless, the DRG of pigs in the control-room (619 g/d) was higher ($P<0.05$) than that of their counterparts in the hotroom (526 g/d). All other differences were non-significant and there were no significant interactions between diets and environmental temperatures in any of the above parameters.

Table 32-i shows that when analysed on a six treatments basis, there were no significant differences between groups in the apparent digestibilities (ADM, ADP and ADE) of the four diets studied. However, there were significant differences between groups in both DE and DCP. The differences were such that the DE values of diet A in both the hotroom (14.9 MJ/kg) and control-room (14.8 MJ/kg) were lower ($P<0.05$) than for all other diets, and the DCP of diet B (12.7%) was higher ($P<0.05$) than that of diets C (11.9%) and D in both the hotroom (11.7%) and control-room (11.7%). The DCP of diet A in the hotroom (12.4%) was higher ($P<0.05$) than that of diet D in both environments.

When analysed on a 2 diets X 2 environmental temperatures basis, the results (Table 32-ii) show that diet A had higher ADP (74.8%; $P<0.05$) and DCP (12.6%; $P<0.01$) values but lower ones for DE (14.9 MJ/kg; $P<0.01$) than diet D (71.9%, 11.7% and 15.4 MJ/kg respectively). There were no significant differences in ADM and ADE between diets A and D. Furthermore, there were no significant differences between the hotroom and control-room nor any significant interactions between diet and environment for any of the above parameters.

Table 32. Means of Apparent Digestibilities of Dry Matter (ADM), Protein (ADP) and Energy (ADE) and Digestible Energy (DE) and Crude Protein (DCP) contents of diets given to pigs living in either hot or cold environments in Laboratory Experiment 4.

Treatment	Apparent Digestiblity			Diet	
	ADM (%)	ADP (%)	ADE (%)	DE (MJ/kg)	DCP (%)
(i) Analysed as 6 Treatments					
Diet A (hotroom)	82.9	75.5	82.3	14.9[a]	12.4[a b]
Diet B (hotroom)	83.8	76.4	83.3	15.6[a]	12.7[a]
Diet C (hotroom)	81.6	73.9	81.1	15.5[a]	11.9[b c]
Diet D (hotroom)	81.7	72.0	80.9	15.4[a]	11.7[c]
Diet A (control-room)	82.4	74.0	82.0	14.8[b]	12.1[a b c]
Diet D (control-room)	81.8	71.8	81.2	15.4[a]	11.7[c]
LSD(5%)	2.2	3.7	2.3	0.4	0.6
Sig. Level	N.S.	N.S.	N.S.	**	**
(ii) Analysed as 2 Diets X 2 Environmental Temperatures					
Diet A	82.6	74.8[a]	82.1	14.9[b]	12.6[a]
Diet D	81.8	71.9[b]	81.1	15.4[a]	11.7[b]
LSD(5%)	1.5	2.5	1.6	0.3	0.4
Sig. Level	N.S.	*	N.S.	**	**
Hotroom	82.3	73.8	81.6	15.1	12.0
Control-room	82.1	72.9	81.6	15.1	11.9
LSD(5%)	1.5	2.5	1.6	0.3	0.4
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction: Diet X Environment					
LSD(5%)	2.1	3.5	2.3	0.4	0.6
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.

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

From Table 33-i it can be seen that there were no significant differences between groups when analysed on a six treatments basis nor on a 2 diets X 2 environmental temperatures basis in backfat depth (both ultrasonic and optical estimates), carcase length, chest depth and girth. While pigs in the control-room had higher backfat depths when measured ultrasonically (24.7 mm) than their counterparts in the hotroom (21.6 mm), the difference only approached significance ($0.05<P<0.10$). There was no significant interaction between diet and environmental temperature in any of these carcase parameters.

The analysis of variance of the physiological parameters (Table 34-i) based on six treatments indicated that there were significant differences ($P<0.001$) between groups in RR, RT and ST. The differences were such that pigs in the control-room on both diets A and D had lower ($P<0.05$) RR, RT and ST values than those on each of the four diets studied in the hotroom. Furthermore, in the hotroom, pigs on diet C had a lower ($P<0.05$) RR (117 b/min) than those on diets A, B and D (130, 125 and 125 b/min). In the same environment pigs on diet C also had a lower ($P<0.05$) ST (37.1° C) than those on diets A and D (37.3 and 37.3° C), but not those on diet B (37.2° C).

When analysed on a 2 diets X 2 environmental temperatures basis, the results (Table 34-ii) revealed that the RR of pigs on diet A (82 b/min) was higher than that on diet D (77 b/min), however, this difference did not quite reach significance ($0.05<P<0.10$). In general, pigs in the hotroom had higher RR, RT and ST values (127 b/min, 39.5° C and 37.3° C) than their counterparts in the control-room (32 b/min, 39.0° C and 34.7° C, respectively; $P<0.001$). There was no significant interaction between diet and environmental temperature in any of the above physiological parameters.

Table 33. Means of Carcase Backfat Depth (P2) measured by ultrasonic (Scanoprobe) and optical (Introscope) methods, Carcase Length (CL), Chest Depth (CD) and Girth of pigs which received different dietary and environmental temperature treatments in Laboratory Experiment 4.

Treatment	Parameter				
	P2(mm)		Car.Length	Chest Depth	Girth
	Scanoprobe	Introscope	(cm)	(cm)	(cm)
(i) Analysed as 6 Treatments					
Diet A (hotroom)	21.3	21.1	81.6	32.4	102
Diet B (hotroom)	23.5	20.5	82.4	31.2	103
Diet C (hotroom)	22.9	18.1	80.4	31.4	102
Diet D (hotroom)	21.9	24.7	82.8	30.8	102
Diet A (control-room)	23.5	26.9	80.7	30.2	101
Diet D (control-room)	25.9	25.7	79.8	31.0	104
LSD(5%)	4.1	7.3	3.9	2.5	6
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
(ii) Analysed as 2 Diets X 2 Environmental Temperatures					
Diet A	22.4	24.0	81.1	31.3	102
Diet D	23.9	25.2	81.3	30.9	103
LSD(5%)	3.5	5.8	2.9	2.0	4
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.
Hotroom	21.6	22.9	82.2	31.6	102
Control-room	24.7	26.2	80.2	30.6	103
LSD(5%)	3.5	5.8	2.9	2.0	4
Sig. Level	-	N.S.	N.S.	N.S.	N.S.
Interaction: Diet X Environment					
LSD(5%)	6.9	8.3	4.1	2.8	6
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.

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

Table 34. Means of Respiration Rate (RR), Rectal (RT) and Skin (ST) Temperatures of pigs which received different dietary and environmental temperature treatments in Laboratory Experiment 4.

Treatment	Parameter		
	RR (b/min)	RT (°C)	ST (°C)
(i) Analysed as 6 Treatments			
Diet A (hotroom)	130[a]	39.6[a]	37.3[c]
Diet B (hotroom)	125[a]	39.5[a]	37.2[c,b]
Diet C (hotroom)	117[b]	39.5[a]	37.1[c]
Diet D (hotroom)	125[a]	39.5[a]	37.3[c]
Diet A (control-room)	34[c]	39.0[c]	34.7[a]
Diet D (control-room)	30[c]	39.0[c]	34.6[a]
LSD(5%)	7	0.1	0.2
Sig. Level	***	***	***
(ii) Analysed as 2 Diets X 2 Environmental Temperatures			
Diet A	82	39.3	36.0
Diet D	77	39.3	36.0
LSD(5%)	5	0.1	0.2
Sig. Level	-	N.S.	N.S.
Hotroom	127[a]	39.5[a]	37.3[b]
Control-room	32[c]	39.0[b]	34.7[a]
LSD(5%)	5	0.1	0.2
Sig. Level	***	***	***
Interaction: Diet X Environment			
LSD(5%)	7	0.1	0.2
Sig. Level	N.S.	N.S.	N.S.

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

5.5 Discussion

The results of the current studies (Laboratory Experiments 3 and 4) confirmed those in the previous section (III-4.0) in that the growth performance of pigs living in a hot environment was lower than that of comparable animals living in a thermoneutral environment. While high ambient temperature caused a 27.1% reduction in growth rate in Laboratory Experiments 1 and 2, in the current experiments the reduction was of the order of 20.9%. Results from the Field Survey (III-2.0; Figure 3) indicated that the DRG of pigs was 6.1% lower in summer than in winter. The greater depression in DRG achieved in Laboratory Experiments 1-4 was probably due to the fact that the pigs were exposed to high temperature more consistently and over a longer period than is usual under commercial situations.

Although the apparent digestibility of dry matter of a diet may be lowered by as much as 3.2% when given to pigs at temperatures below thermoneutrality (Phillips, Young and McQuitty, 1982), it appeared that this was not the case for pigs exposed to a temperature above the thermoneutrality. The results from the current experiment (Tables 28-ii and 32-ii) indicate that the apparent digestibilities of dry matter, energy and protein were not affected by high ambient temperature. This result is in agreement with that of Holmes (1974) and is consistent with the demonstration by Jenkinson, Young and Ashton (1967) that the apparent digestibility of the diet in pigs is unaffected by level of intake. In the current experiments, of course, hotroom treatment significantly reduced feed intake.

While the results of the current study are in agreement with most published literature (Irving, 1956; Ingram, 1964a; Morrison, Heitman and Bond, 1969; Holmes, 1973, 1974) with respect to the effect of high ambient temperature on such physiological activities as RT and RR, the magnitude of the observed increases of these activities was smaller than expected. This is probably due to the fact that pigs in the hotroom were subjected to an ambient temperature which fluctuated from 25° C at night to 35° C by day. The optimum temperature calculated by Morrison, Heitman and Bond (1969) for pigs at 68 kg liveweight was 22.2° C; a temperature similar to that used in the control-room in the present experiments (21° C). The mean value for the hotroom was 30° C, which is thus well above the optimum temperature for pigs with a mean weight of 67.8 kg (range 45 to 90 kg). The extent to which elevated respiration rates, rectal and skin temperatures may in themselves depress economically important parameters such as DRG and FCR is unknown. It is possible, for example, that chronically elevated respiratory rate could interfere with normal ingestive behavior and thus depress DMI, EI and consequently DRG. On the other hand, changes in these physiological parameters may simply be another manifestation of the heat stress being experienced by the pigs and unrelated, in any causal way, with ingestive behavior.

In present day situations there are number of by-products from both the meat and oilseed industries which contain significant amounts of lipid that may be utilized as constituents of pig feed. In the current experiments it appeared that diets containing lipid derived from an animal source (e.g. tallow or meat meal) offered no advantage over that derived from plants (e.g. vegetable oil and rice pollard) in terms of apparent digestibility. It is thus not unexpected that the mixing of lipids from animal and plant

sources did not affect the apparent digestibility of the diet when compared to those which contained lipid from either animal or plant sources only.

It is well known that under thermoneutral conditions pigs eat to satisfy their energy requirement (Stahly, 1982). Heat dissipation becomes increasingly difficult as temperature rises (Mount, 1964) and a common thermoregulatory response is to decrease feed intake (Straub *et al.*, 1976). Two energetic aspects arise: the inseparable heat production associated with an animal's metabolic heat production at any time, and the heat increment of the feed. It has been shown that the heat increment of dietary lipid is lower than that of the carbohydrate (Forbes and Swift, 1944; Forbes *et al.*, 1946; Swift and Black, 1949). Hence diets containing fat have lower heat increments than iso-energetic ones without lipid supplements (Hillman and Annison, 1979; Ewan, 1979; Just, 1980) and from this it follows that when feeding pigs in hot climates a diet containing added lipid might lower the animal's metabolic heat load, allow an increase in energy intake and thus subsequently improve their rate of growth. The results from the present study confirm that pigs fed a diet containing five per cent tallow did in fact have the highest growth rate in the hotroom while those on the "low lipid" diet (Diet B) had the lowest growth rate (Laboratory Experiment 3).

Despite a presumably lower heat increment due to the inclusion of five per cent tallow, pigs on diet A had significantly higher physiological (RR, RT and ST) activities in the hotroom than those on diets with no added fat. The higher physiological activities on the tallow diet could on the one have stemmed from the higher growth rate associated with this diet. Thus the dry matter and energy intakes of pigs on the five per cent tallow diet were higher than those of animals on diets with no added fat (B, Table 17),

Stahly and Cromwell (1979) reported an increase of 10.4% in DMI and 17.6% in DRG and a decrease in FCR of 12.4% when tallow was added to a diet given to finishing pigs living at 35° C. The results of Stahly and Cromwell (1979) are consistent with those of the current study, where increases of 12.3% in DMI, 20.6% in DRG and a decrease of 10.9% in FCR were observed when comparing two diets of similar digestible energies but in one in which part of the energy supplied was replaced by tallow (diets B vs A; Table 25).

In order to achieve an overall level of four per cent dietary lipid, a diet containing 21% rice pollard was used in the hotroom in Laboratory Experiment 3 (Table 25). Compared to diet B with no added lipid, pigs fed on the 21% rice pollard diet ingested more dry matter (15.2%) and energy (18.8%). Nevertheless, pigs on diet D, which was formulated with tallow (2%) and rice pollard (19%) to yield a total of about four per cent lipid (the same as that of diet C containing 21% rice pollard) had similar EI and DRG values to pigs that received no added dietary lipid (diet B).

In the subsequent experiment (Laboratory Experiment 4) the results (Table 31-i) indicate that there were no significant differences in DRG of pigs on the different dietary treatments. This may be due to the fact that all of the diets used contained either animal or plant lipid, or both. Thus, it might be expected that the heat load resulting from feed consumed would have been similar on all diets, and consequently the stress due to additional metabolic heat in animals on the different diets in each environment would also have been similar.

Furthermore, when a comparison was made between the responses of pigs fed diets containing 20% rice pollard in Laboratory Experiments 3 and 4 it was found that DMI, EI and DRG were lower in Experiment 4 than in

Experiment 3 (e.g. DRG was 26% lower). However, previous workers have suggested that the optimum level of inclusion of rice pollard in pig diets is about 20% (Warren, Gerdes and Farrell, 1981) at thermoneutrality. The markedly different results between the two current experiments could be explained by differences in the rice pollards used; Farrell and Warren (1982) for example have demonstrated that pollard from rice harvested in different years gave significantly different growth responses in chickens.

Although the inclusion of lipids in diets has been shown to improve the growth performance of heat stressed pigs the question of whether some sources of lipid are more suitable than others clearly requires further detailed study. As discussed in the earlier review (page 21), almost all studies which have dealt with the addition of lipids to an otherwise standard diet have used only a single lipid source. The only exception to this, prior to the current work, were the experiments of Hillcoat and Annison (1974) which strongly suggested that tallow-supplemented diets would be superior to maize oil-supplemented ones in a hot environment.

Hillcoat and Annison (1974) studied the metabolic consequences of adding lipid to diets and found that the rate of heat production of pigs fed either 2.5 or 5% tallow or maize oil were similar (means of 12.70 and 13.01 MJ/d). At an inclusion level of 7.5%, however, the heat production of animals on the tallow diet (12.15 MJ/d) was very much lower than that of pigs on the maize oil diet (12.88 MJ/d). On his basis it would be expected that pigs fed a tallow-supplemented diet, with a lower metabolic heat production, would be more productive in a hot environment than comparable animals supplemented with maize oil. As discussed above, tallow also proved superior to rice pollard in the current work. It is obvious, however, that further work is required to examine exhaustively all the

various possible lipid sources. Such work is time consumming and will require considerable resources in terms of both pigs and suitable stressful hot environments. It would seem that the assessment of metabolic heat production on small numbers of animals would be a useful indicator of the potential benefits of the various lipid additives which could precede large-scale field trials.

6.0 NITROGEN RETENTION EXPERIMENT

6.1 Introduction

Results from Laboratory Experiments 1 and 2 indicated that a diet with high concentrations of both energy and protein increased growth performance in pigs under high environmental temperature conditions. In order to understand the mechanism(s) of such an increase in growth performance, this present experiment (Laboratory Experiment 5) was designed to investigate the efficiency of nitrogen retention by pigs exposed to high environmental temperature.

6.2 Materials and Methods

6.2.1 The Climate Laboratory

Four Shirfield metabolic crates (Frape, Wolf, Wilkinson and Chubb, 1968) were located in both the hotroom and control-room, which were maintained at 35±1°C, 50% R.H. and 21±2°C, 50-70% R.H. respectively. Both rooms had 12 hours day light, the lights were automatically switched on at 06.00 and off at 18.00 h.

6.2.2 Animals and Husbandry

Eight Large White X Landrace entire male pigs of approximately 32 kg liveweight were obtained from Fielders Gillespie Ltd., Australia and were allocated to the crates and rooms by randomized stratification. Hence there were four pigs in the hotroom and each of these had a counterpart in

the control-room.

An acclimatization period of ten days was allowed while the temperature of the climate chamber was brought gradually up to the predetermined levels (over a period of 6 days) and a dummy run on the feeding and sample collection procedures to be used was conducted (days 7-10). The pigs were treated with "Worm Guard" at weaning to remove any endoparasites and were sprayed with acaricide "Nuvidol" once every three weeks during the course of experiment to remove any ectoparasites.

6.2.3 Treatments

There were two temperature (see III-6.1.1) and four dietary treatments:

a) HH: High Energy - High Protein

b) HL: High Energy - Low Protein

c) LH: Low Energy - High Protein

d) LL: Low Energy - Low Protein

Details of diet composition are given in Table 35.

6.2.4 Feeding

The animals were fed and watered twice daily at 0900 h and 1600 h. The amount of feed (g) offered daily was determined using the equation $Y = 120W^{0.75}$; W = liveweight in kg. Each pig in the control-room was pair-fed to a counterpart in the hotroom. Feed refusals and spillages were collected and dried in a force-draft oven for 24 h. Hence the exact dry matter intake of each pig in the hotroom could be calculated, and this exact amount was then offered to its counterpart in the control-room one day later. Care was taken to ensure that pigs in the control-room consumed

Table 35. Composition (g/kg) of the diets used in Laboratory Experiment 5 (air dry basis).

Ingredient	Diet			
	HH	HL	LH	LL
Wheat	250.0	169.0	0.0	0.0
Sorghum	300.0	422.5	0.0	0.0
Barley	120.0	155.0	360.0	531.0
Oats	0.0	0.0	220.0	120.0
Cotton seed Meal (M)	77.0	38.0	25.0	25.0
Soyabean M	60.0	15.0	53.0	0.0
Meat M	50.0	40.0	45.0	25.0
Wheaten Bran	130.7	149.0	280.5	275.5
Lysine-HCl	1.25	1.5	1.5	1.25
Salt	2.0	2.0	2.0	2.0
Vitamin/minerals	2.0	2.0	2.0	2.0
Bone M	1.0	3.0	0.0	0.0
Lime	6.0	8.0	11.0	18.25
Calculated:				
DE MJ/kg (DM)	14.61	14.59	12.53	12.54
DCP (DM) %	16.99	15.51	16.36	13.25
CF (DM) %	4.79	4.34	9.21	8.60
Lysine (DM) %	0.92	0.79	0.94	0.73
Energy:Protein (MJ/kg):(%)	1:0.77	1:0.94	1:0.77	1:0.95

Vitamin 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 20 g; Iodine 400 mg; Zinc 75 g; and Ethoxyquin 250 mg per kg.

all the feed offered to them in each feeding session.

Since this experiment was designed as a 2 X 2 replicated Latin Square there were several changes of diet for each pig. At each such change each pig in the hotroom was assigned to a diet at random and pigs in the control-room subsequently received the same diet as that assigned to their counterparts in the hotroom.

During each feeding cycle, the pigs were introduced to their new diets gradually over a period of four days, with day 5 being set as the first day of full feeding of the new diet. On the morning of day 6, only 100 g feed containing 10 g ferric oxide was given to each pig as a faecal marker for the beginning of the collection period. At the afternoon feeding session of day 6 the pigs were offered their daily allowance of $120W^{0.75}(-90)$ g of feed instead of half that amount to compensate for the small quantity fed in the morning of day 6. On the morning of day 11, the ferric oxide marker was fed again to mark the end of the collection period.

6.2.5 Collection and Treatment of Samples

A standard 5-day collection period was adopted. Urine strained through two millimetre wire mesh and then cotton wool was collected in a plastic bottle (see Plate 5) containing ten millilitres of 50% H_2SO_4. Collection was on a 24-hour basis over a period of five days (starting at 09.00 h on day 6 and ending at 09.00 h on day 11). Prior to the removal of urine each day, each pan was rinsed with 20 ml distilled water. Each day a ten per cent subsample of the urine from each pig was collected. These urine subsamples from each pig in each cycle were then bulked and stored at 0° C for later analysis.

Plate 5. An experimental pig in one of the "Shinfield" metabolic crates used in the determination of nitrogen retention. The feeder/water container is at the left, the urine collecting bottle underneath and the faeces collecting tray immediately behind the pig.

Faecal collection started when the ferric oxide marker first appeared in the faeces and ended when the marker re-appeared at the end of each dietary period. The faeces were removed from the collection trays (see Plate 5) twice daily to minimize the loss of nitrogen that might have occurred, particularly at high environmental temperatures. Faeces were stored in sealed plastic bags at -16° C.

At the end of each collection period all of the faeces from each pig was bulked and mixed in an industrial mixer with the addition of a known amount of distilled water. A subsample of approximately 500 g wet faeces was taken, refrozen and then freeze-dried prior to further analysis. Total faecal dry matter output was calculated from the total weight of wet bulked faeces and the dry matter of the subsample. Faecal nitrogen and energy contents were determined by standard Kjeldahl and bomb calorimetry procedures.

Two subsamples of the diets used were taken during each collection period. One was dried in a forced-draft oven at 90° C for 24 h for the calculation of dry matter percentage while the other was stored at 0° C and then bulked at the end of the experiment for further chemical analysis.

6.2.6 Analysis of Data

Analyses of the data from the Replicated Latin Square design were carried out using a modified version of the NEVA (Burr, 1976) program for analysis of variance on a mainframe computer (DEC 2060). Duncan's Multiple Range Test was applied when significant differences were detected.

6.3 Results

When the data were analysed there was a large deviation from the means

in two observations for total nitrogen retention. Residuals were then examined and the two observations (both more than two standard deviations from the means) were rejected and missing values were estimated using the NEVA program (Burr, 1976).

From Table 36 it can be seen that there were no significant differences in either total dry matter intake, ADE or ADN between pigs in the hotroom and control-room. However, ADM of the diets given to pigs in the hotroom (74.2%) was significantly higher ($P<0.05$) than that of the same diets given to pigs in the control-room (73.1%). Furthermore, total nitrogen retention (TNR) and nitrogen retained as a percentage of total nitrogen ingested (TNR%) by pigs in the hotroom (52.4 g; 42.8%) were higher ($P<0.05$; $P<0.05$) than by pigs in the control-room (48.0 g; 38.9%).

When differences between the parameters were analysed irrespective of environmental temperature, it was found that there were significant differences among the diets in TDMI ($P<0.001$), ADM ($P<0.001$), ADE ($P<0.001$), ADP ($P<0.001$), and TNR ($P<0.001$). The differences among the diets in TNR% only approached significance ($0.05<P<0.10$). These differences were such that TDMI of pigs on diets HH and LH (4599 and 4498 g) was higher ($P<0.05$) than on diet HL (4352 g) which in turn was higher ($P<0.05$) than on diet LL (4214 g). ADM of diets HH and HL (78.7 and 77.4%) were higher ($P<0.05$) than on diets LH and LL (69.0 and 69.6%). Similarly, the ADE of diets HH and HL (78.4 and 76.8%) were higher ($P<0.05$) than of diets LH and LL (69.5 and 69.8%). The ADP of diet HH (81.6%) was higher ($P<0.05$) than that of diets HL, LH and LL (78.6, 79.5 and 77.4% respectively). Furthermore, the TNR of pigs on diets HH and LH (58.3 and 54.5 g) was higher ($P<0.05$) than that on diets HL and LL (46.2 and 41.7 g).

Table 36. Mean values of Total Dry Matter Intake (TDMI), Apparent Digestibilities of Dry Matter (ADM), Energy (ADE), Nitrogen (ADN), Total Nitrogen Retained (TNR) and as a Percentage of Nitrogen Ingested (TNR%).

Treatment	Parameter					
	TDMI	Apparent Digestibility			Nitrogen Retained	
		ADM	ADE	ADN	TNR	TNR%
	(g)	(%)	(%)	(%)	(g)	(% ingested)
Hotroom	4417	74.2[a]	73.9	79.7	52.4[a]	42.8[a]
Control-room	4414	73.1[b]	73.3	78.9	48.0[b]	38.9[b]
LSD(5%)	93	1.0	1.1	1.3	3.4	2.2
Sig. Level	N.S.	*	N.S.	N.S.	*	*
HH	4599[a]	78.7[a]	78.4[a]	81.6[a]	58.3[a]	38.3
HL	4352[c]	77.4[a]	76.8[a]	78.6[b]	46.2[b]	39.7
LH	4498[a]	69.0[b]	69.5[b]	79.5[b]	54.5[a]	43.3
LL	4214[c]	69.6[b]	69.8[b]	77.4[b]	41.7[b]	42.2
LSD(5%)	131	1.4	1.6	1.9	4.8	3.1
Sig. Level	***	***	***	***	***	-
Cycle 1	4165[c]	72.2[c]	72.3[c]	77.4[b]	47.9	41.3
Cycle 2	4212[c]	73.4[b c]	73.4[a b]	79.2[a b]	48.6	41.5
Cycle 3	4460[a]	74.9[a]	74.9[a]	80.4[a]	51.1	41.4
Cycle 4	4425[a]	74.2[a b]	73.8[a b]	80.2[a]	53.1	39.3
LSD(5%)	131	1.4	1.6	1.9	4.8	3.1
Sig. Level	***	*	*	*	N.S.	N.S.
Interaction:-						
		Temperature X Diet				
LSD(5%)	186	2.0	2.3	2.7	6.8	4.4
Sig. Level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
		Temperature X Cycle				
LSD(5%)	186	2.0	2.3	2.7	6.8	4.4
Sig. Level	N.S.	-	N.S.	N.S.	N.S.	N.S.

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

All other differences between dietary treatments were non-significant.

Although there were no significant differences between feeding cycles in either the weight of total nitrogen retained or the percentage of total nitrogen ingested, there were significant differences between cycles in TDMI ($P<0.001$), ADM ($P<0.05$), ADE ($P<0.05$) and ADP ($P<0.05$). The differences were such that the TDMI values in Cycles 1 and 2 (4165 and 4213 g respectively) were lower ($P<0.05$) than in Cycle 3 (4460 g) which in turn was lower ($P<0.05$) than in Cycle 4 (4825 g). The ADM of the diets in Cycles 1 and 2 (72.2 and 73.4%) were lower ($P<0.05$) than in Cycle 3 (74.9%), and the ADE of the diets in Cycles 1, 2 and 4 (72.3, 73.4 and 73.8% respectively) were lower ($P<0.05$) than in Cycle 3 (74.9%). The ADP in Cycle 1 (77.4%) was lower ($P<0.05$) than in Cycles 3 and 4 (80.4 and 80.2%). All other differences between cycles were non-significant.

There were no significant interactions between temperature and diet nor between temperature and cycle for any of the above parameters. However, the interaction between temperature and cycle for ADM approached significance ($0.05<P<0.10$).

Furthermore, opportunity was available for measuring diurnal variations in both respiration rate and rectal temperature of the above pigs. The results of rectal temperature and respiration rate measured at hourly intervals over a four day period are presented in Figures 25 and 26 respectively. Each point on the graphs represents a mean of 16 measurements. The results of the diurnal variations in both respiration rate and rectal temperature will be dicussed in the general discussion (Section IV).

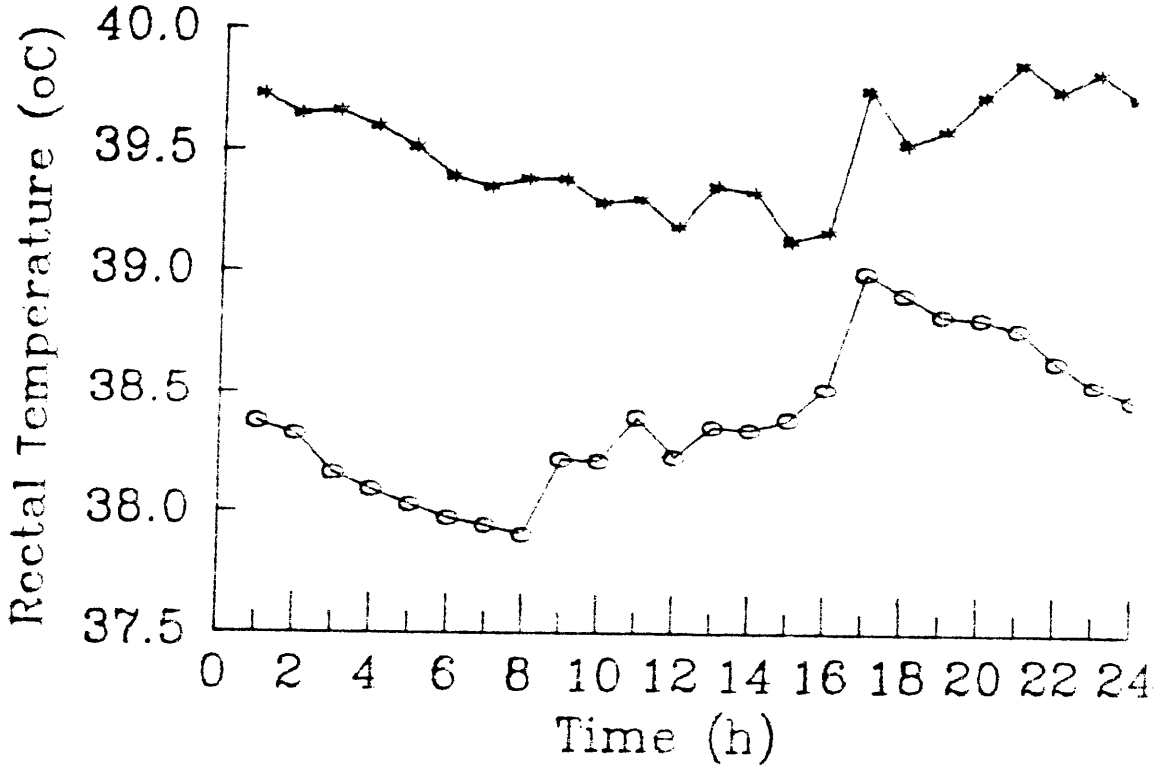

Figure 25 Rectal Temperature (RT) of pigs when exposed to constant environmental temperatures in the hotroom (—✱—) and the control-room (—○—) over a typical 24 hour period in Laboratory Experiment 5.

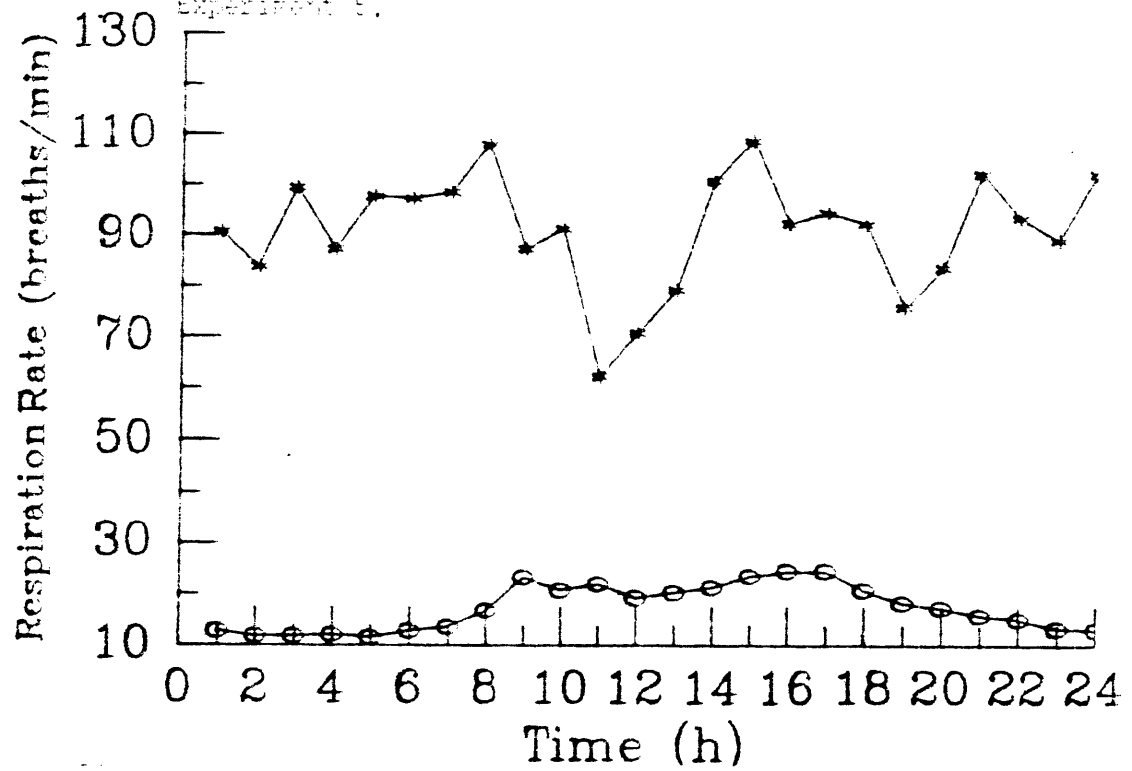

Figure 26 Respiration Rate (RR) of pigs when exposed to constant environmental temperatures in the hotroom (—✱—) and the control-room (—○—) over a typical 24 hour period in Laboratory Experiment 5.

6.4 Discussion

Since the pigs in the control-room were pair-fed to their counterparts in the hotroom, differences in dry matter intake between the two environmental temperatures were negligible. Therefore, any differences in results between the two environments that were observed were likely due to the influence of temperature and/or dietary treatments and not due to differences in level of nutrient intake.

In this present study, the results indicated that the apparent digestibility of dry matter of the diet given to pigs in the hotroom is higher ($P<0.05$) than in the control-room. This result contradicts that of Holmes (1973) who found that the apparent digestibility of dry matter at 34° C was lower than at 25° C. In contrast to the above results of this present study and that of Holmes (1973), Holmes (1974) found that there were no significant differences in the apparent digestibility of dry matter of diets between pigs held at 34° C and 25° C.

In the first report on this subject, Holmes (1973) also observed a significant decrease in the apparent digestibility of energy in pigs at 34° C, but not in the apparent digestibility of nitrogen, when compared with others at 25° C. However, he did not find any significant differences in the apparent digestibility of either energy or nitrogen at these two temperatures. The results from the current experiment are consistent with those of Holmes (1974) in that no significant differences in the apparent digestibilities of either energy or nitrogen due to environmental temperature treatment were observed. Compounding the results from previous (III-4.0 and III-5.0) and current experiments with those of Holmes

(1974), it is apparent that the digestibility of a diet is not influenced by high ambient temperature. Nevertheless, more work is needed to be carried out with larger numbers of animals and longer collection periods in order to confirm this conclusion.

Both total nitrogen retention and nitrogen retained as a percentage of nitrogen ingested (efficiency of nitrogen retention) observed in the current experiment were significantly higher in pigs in the hotroom (35°C) than in the control-room (21°C) by 8%. Close and Mount (1976b) established a relationship between protein intake and protein retention for pigs (20-50 kg) at various environmental temperatures such that at equal protein intake those at 20°C retained 12.3 and 7.6% less protein than comparable animals at 25 and 30°C respectively. Holmes (1970, 1974) found that pigs at 25°C retained 21% (average of the two experiments) more nitrogen than those at 34°C. From the results of the present study and those of Holmes (1970, 1974) and Close and Mount (1976b) it appears that maximal rates of nitrogen (or protein) retention occur in pigs living at temperatures near that optimal for growth. Close and Mount (1976c) reported, for example, that 25°C was the optimum temperature for growth in 25-50 kg pigs, that is, animals of the same weight as used in the current work. It would thus be expected that control animals at 21°C (i.e. below the optimum) and those at 35°C (clearly above the optimum) would both have recorded nitrogen retention rates (Table 36) below their maximum potential.

It has been suggested by both Babatunde, Olomu and Oyenuga (1970) and Fetuga, Babatunde and Oyenuga (1975) that pigs raised in hot climates might require higher than normal dietary protein concentrations because of their low voluntary feed intake. Although in the current experiment nitrogen retention as a percentage of total nitrogen ingested was only 4.6% higher

on the high protein than on the low protein diets, total nitrogen retention on the high protein diets was higher by 16.0% than on the low protein ones. This effect was presumably due largely to the fact that pigs on the high protein diets consumed more ($P<0.05$) feed than those on lower protein diets, since Fuller and Boyne (1971) have previously reported that at a weight of 55 kg, nitrogen retention in the pig increased with increasing daily feed intake. Holmes (1973, 1974) also found that nitrogen retention in pigs increased with increasing feed intake.

The higher apparent digestibility of "high energy" diets can be attributed largely to differences in fibre content, since low energy diets are usually associated with higher fibre contents and Bowland, Bickel, Pfirter, Wenk and Schurch (1970) found that apparent digestibility decreased with increasing dietary fibre levels. It can be seen (Table 35) that the low energy diets (LH and LL) in the current experiment contained twice as much fibre as the high energy ones (HH and HL).

The significant increase in feed intake which occurred as time progressed in the current experiment is most likely to be a function of increases in body weight and not a result of adaptation to high temperature since all pigs were acclimatized to the testing conditions over a period of 14 days. Although differences ($P<0.05$) in ADM, ADP and ADE between cycles (Table 36) were observed these were only of the order of 2% between the cycles. Although total nitrogen retention in the current experiment increased as feed intake increased, the differences were not statistically significant. Taken in conjunction with Thorbek's (1980) finding that protein retention (g/d) increased progressively as pigs grew heavier and consumed more energy, however, it would appear that the current trend was a real one. A longer experimental period would perhaps have allowed

difference due to time to have become significant.