Feed intake, live mass-gain, body composition and protein deposition in pigs fed three protein levels

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A group of 82 genetically lean and 90 obese Landrace pigs was allotted to three dietary treatments with lysine concentrations of 1,22 (T1), 1,02 (T2) and 0,83% (T3), corresponding concentrations of crude protein (CP) of 19,7, 16,8 and 13,7% and digestible energy (DE) concentrations of 14,4; 14,2 and 14,0 MJ/kg diet. Diets were fed *ad libitum* from 8 weeks of age up to slaughter for whole body chemical analyses, at ± 20, ± 30 or 90 kg live mass. Appropriate regression relationships were used to measure the effect of dietary protein level on the patterns of DE intake, daily gain and the deposition rates of protein (PDR) and fat (FDR) over the growth period 30—90 kg live mass. Dietary CP content had no significant effect on mean voluntary DE intakes and daily gains. DE intakes (MJ/d) for pigs from T1, T2, and T3 were 32,1; 32,2 and 32,8 respectively. Daily gains (g/d) were 737, 728 and 738 and DE: gain ratios were 43,8; 44,6 and 45,0 for the three treatments respectively. Obese pigs consumed highly significantly more DE than lean pigs (33,4 vs. 31,1 MJ/d), and also needed highly significantly more DE/kg gain (46,0 vs. 42,7 MJ), but they had similar daily gains (733 and 736 g/d). DE intake, daily gain, PDR and FDR followed curvilinear patterns. PDR curves peaked at ± 56 kg live mass (51 kg for obese gilts and 64 kg for lean boars). Deposition rates increased from a mean of 106 g/d (93 g for obese gilts and 118 g for lean boars) to 124 g (103 g for obese gilts and 143 g for lean boars) at peak deposition, only to decline thereafter to 105 g/d (85 g for obese gilts and 132 g for lean boars) at 90 kg live mass. A reduction of 15% in dietary protein content (T2) had no apparent effect on protein deposition. Pigs from T3, fed 30% less protein than pigs from T1, deposited only 2 g (1,9%) less protein/d at 32 kg live mass, 2 g (1,6%) less at maximum deposition and 2 g (1,9%) less at 90 kg live mass.

Drie dieetbehandelings met lisienkonsentrasies van 1,22 (T1), 1,02 (T2) en 0,83% (T3), ooreenstemmende ruproteïen-(RP)-konsentrasies van 19,7, 16,8 en 13,7% en verteerbare energie(VE)-konsentrasies van 14,4, 14,2 en 14,0 MJ/kg voer, is aan 'n groep van 82 geneties-maer en 90 vet Landrasvarke toegeken. Diëte is *ad libitum* vanaf 8-weke-ouderdom gevoer totdat die diere vir heel-liggaam chemiese samestelling, op ± 20, ± 30 of ± 90 kg lewende massa geslag is. Paslike regressieverwantskappe is gebruik om die effek van dieetproteïenpeil op die patrone van VE-inname, daaglikse toename en die neerleggingstempo's van proteïen (PDT) en vet (VDT) te meet oor die groeiperiode 30—90 kg lewende massa. Dieet RP-inhoud het geen betekenisvolle effek op gemiddelde vrywillige VE-innames en daaglikse toenames uitgeoefen nie. VE-innames (MJ/d) vir T1-, T2-, en T3-varke was 32,1; 32,2 en 32,8 onderskeidelik. Daaglikse toenames (g/d) was 737, 728 en 738 en VE: massatoename-verhoudings was 43,8, 44,6 en 45,0 vir die drie groepe onderskeidelik. Vet varke het hoogsbetekenisvol meer VE as maer varke ingeneem (33,4 teenoor 31,1 MJ/d), en het ook hoogsbetekenisvol meer VE/kg-toename (46,0 teenoor 42,7 MJ) benodig, maar het nie van maer varke verskil in massatoename nie (733 teenoor 736 g/d). VE-inname, daaglikse toename, PDT en VDT het kurwilineêr verloop. PDT-kurwes het 'n piek op ± 56 kg lewende massa (51 kg vir vet soggies en 64 kg vir maer soggies) bereik. Neerleggingstempo's het toegeneem vanaf 'n gemiddelde 106 g/d (93 g vir vet soggies en 118 g vir maer bere) tot 124 g (103 g vir vet soggies en 143 g vir maer bere) met piek-neerlegging, net om daarna tot 105 g/d (85 g vir vet soggies en 132 g vir maer bere) op 90 kg lewende massa af te neem. 'n Verlaging van 15% in dieetproteïen-inhoud (T2) het geen beduidende effek op proteïenneerlegging gehad nie. Groep T3-varke, wat 30% minder proteïen as T1-varke gevoer is, het slegs 2 g (1,9%) minder proteïen/d op 32 kg lewende massa neergelê, 2 g (1,6%) minder met maksimum deponering en 2 g (1,9%) minder op 90 kg lewende massa.

Keywords: Feed intake, growth rate, body composition, protein deposition, pigs.

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Introduction

The accurate prediction of growth response to energy and protein (amino acid) intake, or conversely of the probable energy and protein requirements to attain a desired level of performance, is of fundamental importance for efficient production (Stranks *et al.*, 1988).

Siebrits *et al.* (1986) characterized and quantified protein deposition of growing pigs and found substantial type and sex differences in the amount and pattern of protein deposition within the same breed. Boar pigs from a gentically lean line had a peak protein deposition rate of 156 g/d at a live mass of 60 kg and obese line gilts only 101 g/d at a live mass of only 40 kg. Kemm *et al.* (1988) studied patterns of feed intake and growth of pigs highly divergent in growth rate. Although the two pig groups in their study consumed the same mean daily amount of feed to grow from 35 to 85 kg in live mass, distinct intake and growth patterns were found between slow (ADG = 850 g/d) and fast (ADG = 1102 g/d) growing pigs. The fast-growing pigs were able to grow and consume feed at an increasing rate throughout the period of study. The rate of intake of the slow-growing pigs, however, tended to increase at a declining rate as they approached 85 kg in live mass. Consequently, the slow-growing pigs not only consumed less feed (263 g/d at 85 kg live mass) towards the end of the growth period, but also grew at a slower rate after 70 kg live mass.

From the work reported above it is obvious that the rate, composition and pattern of growth is influenced by the type (lean or obese), sex and live mass of the pig. Hence, the absolute amount and pattern of feed intake is primarily dictated by the animal's inherent rate, pattern and composition (protein : fat ratio) of growth.

Differences in nutrient requirements are implied. If pigs are to be fed to their maximum ability for protein deposition, it is essential that the effects of dietary protein content on *ad libitum* feed intake be known. In a review paper, Henry (1985) concluded that feed intake and, consequently, growth performance is depressed by a severe deficiency in the dietary limiting amino acid and by excessive supply of total protein and some essential amino acids. McCracken & Stockdale (1989) observed a drop of approximately 9% in mean daily feed intake, but found protein intake to remain similar when the protein content of the diet fed to Testing Station pigs of high genetic potential was increased from 21 to 24% and the lysine content from 1,0 to 1,2%.

It was therefore considered necessary to measure the effect of dietary protein level on the rate and pattern of feed intake of *ad libitum* fed pigs known to be different in their ability to deposit protein and in their pattern of protein deposition. Consequently, lean and obese pigs from the breeding stock described by Siebrits *et al.* (1986) were used in this experiment to investigate the effects of three dietary protein levels, fed at a constant dietary DE content, on the feed intake and growth performance of pigs fed *ad libitum* from eight weeks of age up to 90 kg live mass. The responses examined included means for DE intake, DE conversion, mass gain, body protein and body fat and also the patterns of DE intake and the deposition of protein and fat over the growth interval 30—90 kg live mass.

Experimental procedure

Experimental animals and treatments

Eighty-two lean type and 90 obese type Landrace piglets from the breeding stock described by Siebrits *et al.* (1986) were used as experimental animals. The pigs were weaned at five weeks of age and fed *ad libitum* on a standard growth diet (with 17,4 MJ DE/kg, 18,3% protein and 1,2% lysine) in flat-deck cages up to eight weeks of age when they were randomly allotted (within sex and type) to three dietary treatments. The experimental diets were fed until the pigs were slaughtered. The treatment and the slaughter mass allotment of the pigs are outlined in Table 1.

Table 1 Treatment and slaughter mass allotment of pigs

	Approx. mass at slaughter			Total
	20 kg	30 kg	90 kg	slaughtered
Treatment 1				
Lean boars	2	4	8	14
Lean gilts	2	5	7	14
Obese boars	2	4	9	15
Obese gilts	2	4	9	15
Treatment 2				
Lean boars	2	4	7	13
Lean gilts	2	4	8	14
Obese boars	2	4	9	15
Obese gilts	2	4	9	15
Treatment 3				
Lean boars	2	4	8	14
Lean gilts	2	4	7	13
Obese boars	2	4	9	15
Obese gilts	2	4	9	15
Total	24	49	99	172

From the commencement of the trial period the pigs were individually housed in cages (1,6 m × 1 m), fitted with a selffeeder and an automatic water nipple. Temperatures in the building were controlled to the extent that minimum temperatures were kept above 20 °C. Pigs were fed *ad libitum* at all stages. Feed intake and live mass for each pig were recorded every four days. Feed and water were not withdrawn before mass determinations had been done. Feed intakes (kg/d) for each pig, representing mean values of the amounts recorded every four days, are presented in Appendix Figures 1(a), (b) and (c). Each data point represents 0,25 of *ad libitum* intake measured at four-day intervals.

Dietary treatments

In order to ensure maximum tissue growth with no nutritional limitation imposed on protein deposition, a diet formulated to contain protein, amino acids and digestible energy (DE) in excess of the recommended allowances (ARC, 1981) was fed to pigs from Treatment 1 (high protein diet) (Table 2). The diets fed to pigs from

Table 2 Composition (g/kg) and analyses means ± *SD* of experimental diets

	Diets		
	1 High protein	2 Medium protein	3 Low protein
Maize meal	658	696	747
Fishmeal	174	111	54
Skim milk powder	–	15	19
Wheaten bran	154	156	150
Monocalcium phosphate	–	–	2
Limestone powder	–	7	13
Salt	10	10	10
Synthetic lysine	2,4	3	3,6
Minerals & vitamins	2	2	2
DM* (%)	91,0 ± 0,93	90,8 ± 0,98	90,1 ± 1,18
Digestible energy, MJ/kg (calculated)	14,4	14,2	14,0
Crude protein* (%)	19,70 ± 0,60	16,80 ± 0,59	13,70 ± 0,51
Lysine** (%)	1,22 ± 0,08	1,02 ± 0,09	0,83 ± 0,09
Methionine** (%)	0,48 ± 0,06	0,37 ± 0,03	0,30 ± 0,04
Cystine** (%)	0,41 ± 0,05	0,39 ± 0,03	0,36 ± 0,04
Threonine** (%)	0,69 ± 0,05	0,58 ± 0,07	0,48 ± 0,05
Leucine** (%)	1,59 ± 0,09	1,39 ± 0,15	1,22 ± 0,11
Isoleucine** (%)	0,68 ± 0,04	0,55 ± 0,08	0,43 ± 0,04
Valine** (%)	0,81 ± 0,08	0,69 ± 0,10	0,54 ± 0,08
Tryptophan (%) (calculated)	0,24	0,20	0,16

* Representing analyses of 10 mixtures for Diet 1 and 11 for Diets 2 and 3.

** Representing analyses of 8 mixtures for Diets 1 and 2 and 7 for Diet 3.

Treatments 2 (medium protein) and 3 (low protein) were formulated to respectively contain 15 and 30% less protein than Treatment 1. Dietary amino acids were balanced according to the ideal protein concept (Cole, 1979; Cole *et al.*, 1980). Lysine, as a percentage of protein, was kept constant in the mixed diets. The high protein diet (Treatment 1) contained 0,85 g lysine/MJ DE, with 15 and 30% less lysine/MJ DE in the other two diets.

Slaughter procedure

A slaughter mass was allocated to each pig when eight weeks of age as set out in Table 1. On reaching ± 1 kg of its slaughter mass, the pig's live mass was recorded, the pig was slaughtered and the whole body placed in a strong watertight plastic bag and stored at −20 °C, before mincing 48 h later. A 'Wolfking' carcass grinder was used to grind the frozen whole bodies (after they were sawn into smaller pieces with a band saw) five times in succession using two sieves, one with 12-mm die holes and the other with 5-mm holes. As bone and meat tended to accumulate between the sieves and knives after the first grinding, the machine was opened at this stage, and these pieces were taken out and added to the rest of the ground material. The material was then ground a further four times before sampling. One *ca.* 500 g sample was taken to be freeze-dried for chemical analyses, and a further three samples (600—800 g each) were taken for immediate oven DM determination.

Chemical analyses of samples

The 500 g sample was freeze-dried until it had approximately 6% moisture. The dried sample was then manually divided into little blocks (10—20 mm), and mixed with three to four times its volume of dry ice (solid CO_2). The mixture was then ground in a laboratory mill through a 2-mm sieve. The use of frozen samples and a precooled mill ensured that the fat in the samples did not accumulate on the inside walls of the mill.

The ground sample was then transferred into a plastic bag and left open until all the dry ice had sublimated. The sample was then stored at −15 °C until it was chemically analysed.

Frozen samples were thawed overnight at room temperature to allow for temperature and humidity equilibration and then analysed for DM, N and ether extract as described by Kemm & Ras (1976).

Table 3 Growth parameters for the allometric autoregressive growth model

	Growth parameters*				
	ρ	α	a	b	μ
Treatment 1					
Lean boars	0,9435	8,7734	−1,3326	0,7275	6,6201
Lean gilts	0,9451	8,7843	−1,2333	0,7015	6,5442
Obese boars	0,9468	8,9572	−1,1637	0,7005	6,6285
Obese gilts	0,9432	8,9169	−1,1324	0,6882	6,7477
Treatment 2					
Lean boars	0,9453	8,8011	−1,5738	0,7596	6,4718
Lean gilts	0,9419	8,8896	−1,2988	0,7100	6,5254
Obese boars	0,9388	8,7340	−1,3118	0,7169	6,5999
Obese gilts	0,9474	8,9392	−1,2012	0,6947	6,6388
Treatment 3					
Lean boars	0,9440	8,8641	−1,8648	0,7851	6,5451
Lean gilts	0,9463	8,8268	−1,6949	0,7584	6,5487
Obese boars	0,9412	8,7708	−1,7347	0,7661	6,5982
Obese gilts	0,9411	8,8507	−1,4032	0,7182	6,6308
Standard error					
Treatments	0,002	0,036	0,044	0,006	0,029
Boars	0,002	0,030	0,035	0,005	0,024
Gilts	0,001	0,030	0,036	0,005	0,024
Lean pigs	0,001	0,031	0,037	0,005	0,025
Obese pigs	0,001	0,029	0,034	0,005	0,023
Statistical significance					
Treatments	NS**	NS	<0,001	<0,001	NS
Sex	NS	NS	<0,001	<0,001	NS
Type	NS	NS	<0,001	<0,001	<0,007

* ρ = Slope of the autoregression; α = asymptote of cumulative DE intake; a = mean intercept of ln (live mass) as y and ln (cumulative DE) as regressions; b = mean slope of ln (live mass) as y and ln (cumulative DE) as regressions; μ = mean initial ln (cumulative DE intake) value.

** Not significant.

Table 4 Means for DE intakes, DE conversions and growth rates, calculated from the parameters of individual pigs for the growth interval 30—90 kg live mass

	Number of pigs	Mass gain (g/d)	DE intake (MJ/d)	DE conversion (MJ/kg gain)
Treatments				
1 (High protein)	33	737	32,1	43,8
2 (Medium protein)	33	728	32,2	44,6
3 (Low protein)	33	738	32,8	45,0
Sex means				
Boars	50	763	31,7	41,9
Gilts	49	705	33,1	47,1
Type means				
Lean	45	736	31,1	42,7
Obese	54	733	33,4	46,0
Standard error				
Treatment 1	33	15,3	0,64	0,84
Treatment 2	33	15,6	0,53	0,87
Treatment 3	33	19,3	0,58	0,80
Boars	50	14,0	0,46	0,63
Gilts	49	12,0	0,47	0,50
Lean pigs	45	14,3	0,41	0,67
Obese pigs	54	13,2	0,46	0,62
Statistical significance				
Treatments		0,916	0,567	0,485
Sex		0,002	0,025	0,000
Type		0,931	0,000	0,000

Statistical analyses of data

The allometric autoregressive growth model as described by Roux (1976), and substantiated in pig studies by Roux & Kemm (1981) and Siebrits (1984), was used to describe growth rate, feed intake and feed conversion.

The procedures followed in the application of the model to the data were exactly as described by Siebrits (1986). Autoregressions of ln(cumulative DE intake) were calculated for each individual pig by regressing the ln of cumulative DE intake at time (t − 1) as X with ln(cumulative DE intake) at time t as Y. The relationship between ln(cumulative DE intake) as X and ln(mass) as Y was then used to calculate feed and DE conversion for each pig for the live-mass interval 30—90 kg and the calculated data subjected to analyses of variance (Harvey, 1987). The linearized form $\ln Y = \ln a + b \ln X$ of the allometric relationship $Y = aX^b$ was used to describe the growth of whole body chemical components in relation to live mass at slaughter. The regression equations were calculated, per group, using all pigs slaughtered in each of the 12 pig groups, as set out in Table 1.

Because of the break point in growth identified at an age of approximately 81 days (see Siebrits, 1986), data points were plotted and the equations were calculated with the data points following the break, hence the choice of a 30—90 kg live-mass interval for data presentation. The mean statistical parameters, as tabulated in Table 3, were used to calculate the data presented in Tables 4 and 5.

Table 5 Calculated intakes per pig of feed (g/d), and lysine (g/d)

	Feed intakes				Protein intakes				Lysine intakes			
	1	2	3	Means	1	2	3	Means	1	2	3	Means
Intakes at 30 kg live mass												
Lean boars	1532	1556	1819	1636	301	262	250	271	18,7	15,9	15,1	16,6
Obese boars	1566	1718	1827	1704	308	289	251	283	19,1	17,5	15,2	17,3
Lean gilts	1573	1796	1726	1698	311	301	236	283	19,2	18,3	14,3	17,3
Obese gilts	1712	1662	1891	1755	338	279	259	292	20,9	16,9	15,7	17,8
Means	1596	1683	1816	1699	315	283	249	282	19,5	17,2	15,1	17,3
Intakes at 90 kg live mass												
Lean boars	2308	2366	2593	2422	455	398	355	403	25,8	24,1	21,5	23,8
Obese boars	2682	2310	2350	2447	528	389	322	413	32,7	23,6	19,5	25,3
Lean gilts	2121	2683	2299	2368	418	451	314	394	25,9	27,4	19,1	24,1
Obese gilts	2661	2556	2550	2589	524	249	349	434	32,5	26,1	21,1	26,6
Means	2443	2479	2448	2457	481	417	335	411	29,2	25,3	20,3	24,9
Peak intakes												
Lean boars	2398	2423	2686	2502	472	407	368	416	29,2	24,7	22,3	25,4
Obese boars	2703	2542	2572	2606	532	427	352	437	33,0	25,9	21,4	26,8
Lean gilts	2349	2810	2479	2546	463	473	339	425	28,7	28,7	20,6	26,0
Obese gilts	2779	2669	2794	2747	548	448	382	459	33,9	27,2	23,2	28,1
Means	2557	2611	2633	2600	504	439	360	434	31,2	26,6	21,9	26,6
Live mass (kg) at peak intakes												
Lean boars	75	78	74	76	75	78	74	76	75	78	74	76
Obese boars	82	69	68	73	82	69	68	73	82	69	68	73
Lean gilts	69	74	69	71	69	74	69	71	69	74	69	71
Obese gilts	75	75	70	73	75	75	70	73	75	75	70	73
Means	75	74	70	73	75	74	70	73	75	74	70	73

Results

The mean values of the statistical parameters calculated (Table 3) show no significant ($P > 0,1$) differences between all ρ and α values. Highly significant ($P < 0,001$) differences were, however, found between a (intercept) and b (slope) values of the cumulative DE intake (X) and live mass (Y) relationships. Therefore, significantly different DE intake and conversion patterns are implied between treatments, sexes and the two pig types. Hence, the individual growth parameters of each pig were used to calculate the mean DE intake, DE conversion and growth rate data for the growth interval 30—90 kg live mass presented in Table 4.

From Table 4 it is evident that treatment (protein level) did not have any significant ($P > 0,48$) effect on mean DE intake, DE conversion and growth rate when measured between 30 and 90 kg live mass. Significant sex and type effects were, however, found. Male pigs consumed 4,4% less DE per day ($P < 0,025$), converted consumed DE 12,4% more efficiently ($P < 0,001$) and had 8,2% better mean daily gains ($P < 0,002$) than females. Lean pigs consumed 7,4% less DE per day ($P < 0,001$) but converted DE 7,2% more efficiently ($P < 0,001$) into live mass-gain than obese pigs. Mean growth rate, however, did not differ between the two pig types studied.

Feed nutrients were consumed in a curvilinear pattern as shown in Table 5 and in the DE intake curves in Figures 1(a) and (b).

Feed intakes increased for all treatments from a mean 1699 g/d (range 1532 to 1891) at 30 kg live mass to peak at 2600 g (2349 to 2779) at a mean live mass of 73 kg (68 to 82), only to decline subsequently to 2457 g/d (2121 to 2683) at 90 kg live mass.

Protein intakes increased from 282 g/d (250 to 338) at 30 kg to 434 g/d (339 to 548) at maximum intake, only to decline to 411 g/d (314 to 528) at 90 kg live mass. The corresponding intakes of lysine were 17,3 g/d (14,3 to 20,9) at 30 kg, 26,6 g/d (20,6 to 33,9) at maximum intake and 24,9 g/d (19,1 to 32,7) at 90 kg live mass. Maximum intakes were achieved at 75 (69 to 82), 74 (69 to 78) and 70 kg (68 to 74) live mass for Treatments 1, 2 and 3 respectively.

The means $\pm SD$ for live mass at slaughter and whole body protein and fat content are given in Table 6. Using these data regression equations (Appendix Table 1) between ln(live mass) as independent variable X and ln(body protein or fat) as dependent variable Y were calculated. Significant treatment, type and sex differences in both regression slopes and intercepts were found using the mixed model and maximum likelihood computer model of Harvey

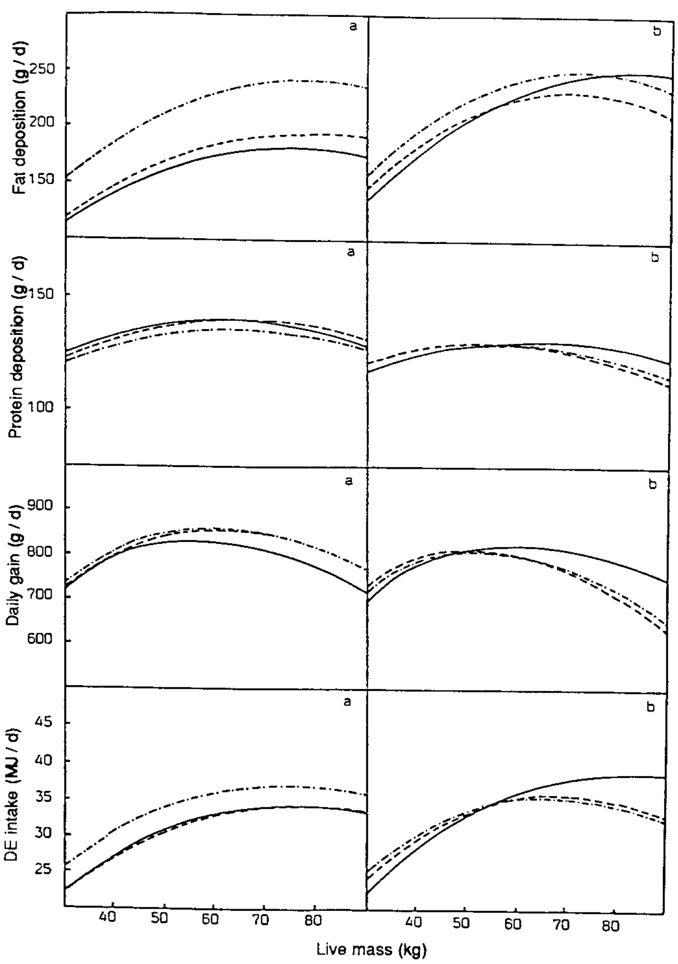

Figure 1a Daily intakes of DE, live mass-gains and deposition rates of protein and fat by (a) lean and (b) obese boars fed Treatments 1 (——), 2 (----) and 3 (-· -· -).

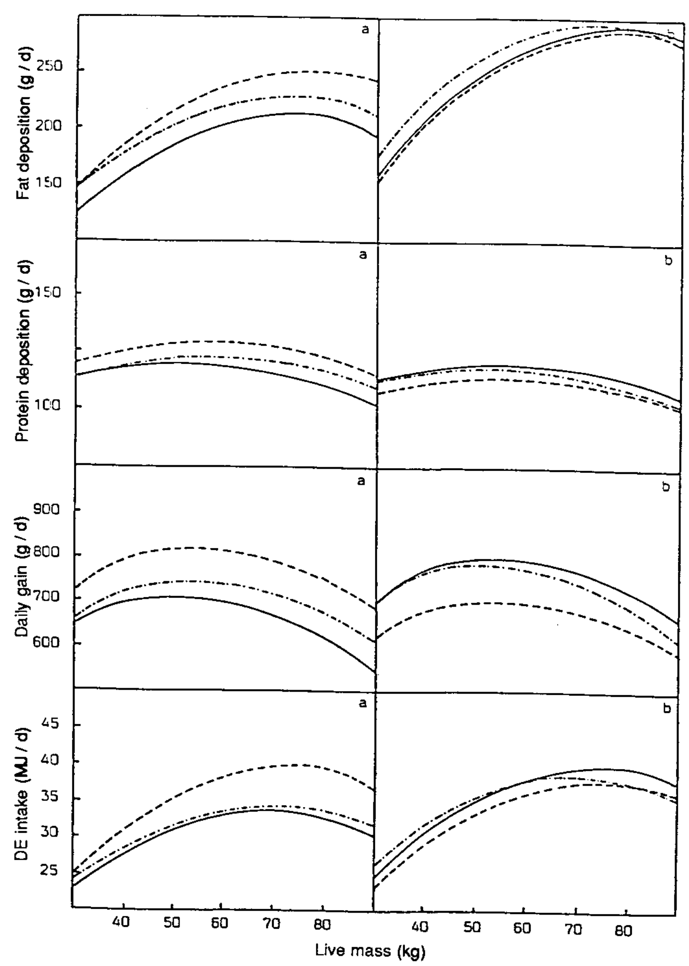

Figure 1b Daily intakes of DE, live mass-gains and deposition rates of protein and fat by (a) lean and (b) obese gilts fed Treatments 1 (——), 2 (----) and 3 (-· -· -).

Table 6 Mean ± *SD* for whole body protein and fat content at slaughter

	Treatment 1				Treatment 2				Treatment 3			
	n	Slaughter mass (kg)	Body protein (kg)	Body fat (kg)	n	Slaughter mass (kg)	Body protein (kg)	Body fat (kg)	n	Slaughter mass (kg)	Body protein (kg)	Body fat (kg)
Lean boars	2	21,1 ± 3,0	3,26 ± 0,43	2,08 ± 0,56	2	19,5 ± 0,7	2,84 ± 0,03	2,04 ± 0,23	2	20,4 ± 1,2	2,93 ± 0,05	2,41 ± 0,15
	4	31,4 ± 3,2	4,88 ± 0,64	3,67 ± 0,42	4	30,3 ± 1,6	4,65 ± 0,24	3,56 ± 0,55	4	30,6 ± 0,3	4,40 ± 0,18	4,99 ± 0,68
	8	90,8 ± 1,4	15,07 ± 1,46	15,92 ± 1,46	7	91,1 ± 1,7	14,80 ± 0,05	18,50 ± 1,19	8	90,8 ± 1,0	13,96 ± 0,38	20,19 ± 1,31
Obese boars	2	20,3 ± 1,8	2,93 ± 0,38	2,17 ± 0,20	2	19,1 ± 0,9	2,80 ± 0,25	2,24 ± 0,19	2	19,6 ± 0,5	2,75 ± 0,02	2,16 ± 0,06
	4	30,5 ± 1,3	4,64 ± 0,32	3,96 ± 0,48	4	30,1 ± 1,3	4,51 ± 0,20	3,83 ± 0,09	4	30,6 ± 1,5	4,28 ± 0,26	5,09 ± 0,25
	9	93,0 ± 1,5	12,76 ± 0,97	26,47 ± 3,98	9	91,2 ± 1,0	14,00 ± 1,16	21,32 ± 3,52	9	90,0 ± 2,9	13,63 ± 0,39	22,40 ± 2,55
Lean gilts	2	19,9 ± 0,2	3,03 ± 0,03	2,11 ± 0,21	2	20,8 ± 0,4	3,04 ± 0,01	2,49 ± 0,39	2	19,6 ± 0,5	2,85 ± 0,11	2,52 ± 0,36
	5	31,1 ± 0,84	5,04 ± 0,25	3,35 ± 0,41	4	30,4 ± 0,8	4,75 ± 0,16	3,96 ± 0,40	4	30,6 ± 0,7	4,44 ± 0,11	5,00 ± 0,54
	7	90,7 ± 2,6	13,87 ± 0,12	23,87 ± 0,87	8	93,2 ± 3,1	14,25 ± 0,86	22,58 ± 3,22	8	89,3 ± 5,1	13,62 ± 1,00	21,92 ± 2,11
Obese gilts	2	21,1 ± 1,9	3,18 ± 0,25	2,46 ± 0,22	2	19,9 ± 1,9	2,80 ± 0,33	2,61 ± 0,33	2	19,5 ± 0,0	2,77 ± 0,06	2,49 ± 0,15
	4	34,1 ± 6,3	5,02 ± 0,80	5,56 ± 1,97	4	33,1 ± 4,6	5,07 ± 0,56	4,88 ± 0,90	4	33,3 ± 5,2	4,62 ± 0,67	5,99 ± 1,94
	9	91,5 ± 1,7	13,01 ± 0,56	25,01 ± 2,66	9	91,2 ± 0,9	12,87 ± 0,43	26,77 ± 2,09	9	92,0 ± 1,7	12,92 ± 0,83	27,17 ± 2,83

(1987). Hence, the regression equations calculated had to be kept separate for each group.

Whole body protein (WBP) and fat (WBF) contents calculated from the regression equations are graphically presented in Figures 2(a) and (b) for boar and gilt pigs respectively.

Figure 2(a) shows WBP to increase with both dietary protein content and live mass in the lean boar. WBP increased from 15,6% at 30 kg live mass to 16,6% at 90 kg for pigs from Treatment 1, from 15,2% to 16,1% for pigs from Treatment 2 and from 14,5% to 15,3% for pigs from Treatment 3. Obese boars not only had less WBP than lean boars, but pigs from Treatments 1 and 2 had a similar percentage of WBP with very little increase from 30 to 90 kg live mass (14,9% at 30 kg and 15,2% at 90 kg). Pigs from Treatment 3, however, had only 14,1% WBP at 30 kg live mass but WBP increased to 15% at 90 kg.

As expected, WBF content increased with live mass in both lean and obese boars [Figure 2(a)], while obese boars had more fat than lean boars. In both types, pigs fed Treatment 2 had only slightly more WBF than pigs from Treatment 1. WBF was, however, appreciably higher, particularly in the lean boar, when the diet with the lowest protein content (Treatment 3) was fed. Lean boars contained 11,4%, 11,9% and 15% WBF at 30 kg live mass and 17,4%, 17,9% and 22,3% at 90 kg when fed Treat-

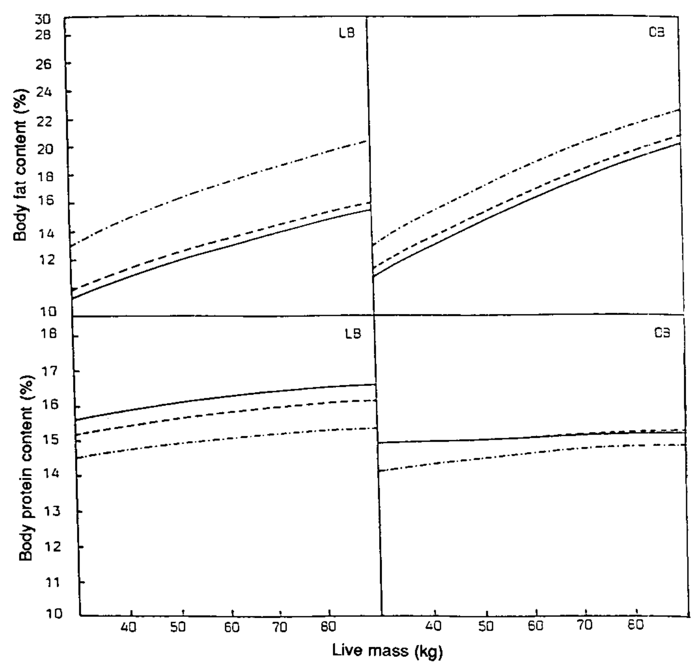

Figure 2a Body protein and fat content for lean (LB) and obese (OB) boars fed Treatments 1 (———), 2 (----) and 3 (-· -· -).

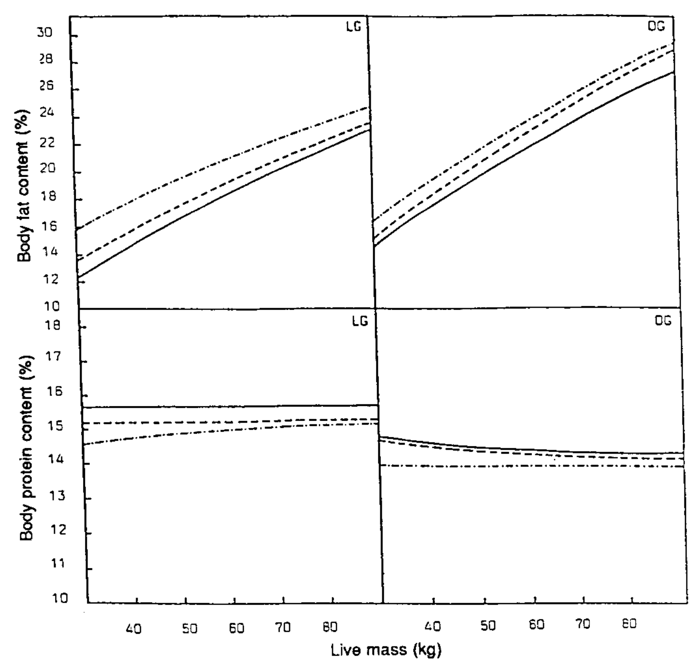

Figure 2b Body protein and fat content for lean (LG) and obese (OG) gilts fed Treatments 1 (———), 2 (----) and 3 (-· -· -).

ments 1, 2 and 3 respectively. Correspondingly, obese boars had 12,9%, 13,5% and 15% WBF at 30 kg live mass and 22,2%, 22,8% and 24,7% at 90 kg when fed Treatments 1, 2 or 3.

Figure 2(b) shows gilts to have a lower WBP content than boars. Also contrary to what was obseved in the boar, a tendancy was shown for WBP content to either stay constant between the live-mass interval studied or to decline as live mass increased. WBP content was reduced by feeding a diet with less protein, while lean and obese gilts reacted differently to the treatments imposed. Lean gilts contained 15,7%, 15,2% and 14,6% WBP at 30 kg and 15,7%, 15,3% and 15,2% WBP at 90 kg live mass when fed Treatments 1, 2 and 3 respectively. Obese gilts, on the other hand, had 14,9%, 14,8% and 14,1% WBP at 30 kg and 14,3%, 14,2% and 14,0% WBP at 90 kg live mass when fed Treatments 1, 2 and 3 respectively.

The content of WBF in the gilt was also dependent on the treatment imposed, the type of pig used and also live mass [Figure 2(b)]. Lean type gilts had 12,3%, 13,5% and 15,7% WBF at 30 kg and 23,0%, 23,4% and 24,6% WBF at 90 kg live mass when fed Treatments 1, 2 and 3 respectively. Obese gilts had more WBF at 30 kg live mass (14,5%, 15,1% and 16,4%) and appreciably more WBF at 90 kg live mass (27,0%, 28,6% and 29,2%).

The regressions were also used to construct equations for the calculation of protein deposition rate (PDR) at any given live mass:

The equation $\ln Y = a + b \ln X$ was transformed to its allometric form $Y = aX^b$, and then differentiated to

$$\frac{dy}{dx} = b.aX^{b-1}$$

It then followed that $dy = b.aX^{b-1}.dX$

therefore, $PDR = b.aM^e.dM$

where b = slope of the ln(live mass)X – ln(body protein)Y regression,
a = the antilog of the intercept,
$e = b - 1$,
dM = live mass-gain in g/d,
M = live mass of the animal in kg.

Likewise, the fat deposition rate (FDR) equations were constructed from the ln(live mass)X – ln(body fat)Y regressions. The respective equations with standard errors for the calculation of PDR and FDR are given in Appendix Table 2.

Deposition rates of protein (PDR) and fat (FDR), graphically presented in Figures 1(a) and (b), also follow curvilinear patterns. The data presented show that, at any given point of the growth curve, the amount of DE consumed can be considered to be the major determining factor for fat gain and to a lesser extent for protein and live mass-gain.

Daily live mass-gains increased from 702 g (647 to 733) at 30 kg live mass to reach a maximum at 805 g (718 to 858) at 56 kg (51 to 61) live mass, followed by a steady decline to 673 g (545 to 774) at 90 kg live mass.

The PDR curves also peaked at about 56 kg (51 to 64) live mass. Deposition rates increased from a mean of 106 g/d (93 to 118) at 30 kg live mass to 124 g (103 to 143) at peak deposition only to decline thereafter to 105 g/d (85 to 132) at 90 kg live mass.

Fat deposition, 145 g/d (114 to 177) at 30 kg live mass, increased to a maximum 242 g/d (181 to 293) at 77 kg (72 to 85) live mass, and then at a slightly declining rate to 233 g/d (175 to 281) at 90 kg live mass.

The data in Figures 1(a) and (b) furthermore show that a reduction of 15% in dietary protein content (Treatment 2) had no apparent effect on protein deposition. Pigs from Treatment 3, although they were fed a diet with 30% less protein than pigs from Treatment 1, deposited only 2 g (1,9%) less protein per day at 30 kg live mass, 2 g (1,6%) less at maximum deposition and 2 g (1,9%) less at 90 kg live mass.

Boars deposited between 10,5 g (at 30 kg live mass) and 20 g (at maximum gain) more protein per day in their bodies than gilts, and lean pigs between 6,5 and 14,5 g more than obese pigs. It is also important to emphasize the big differences of up to 47 g/d (55%) in protein deposition found between group means (lean boars vs. obese gilts fed Treatment 2 at 90 kg live mass) when compared at a specific live mass.

Initially the rate of fat deposition (mean per treatment) increased as dietary protein decreased, from 134 g/d (Treatment 1) to 158 g/d (Treatment 3) at 30 kg live mass. Subsequently, pigs fed the diets with the higher protein contents (Treatments 1 and 2) tended to deposit fat at slightly faster rates so that, at the point of maximum growth, the rates of fat deposition were 233 g, 241 g and 252 g for Treatments 1, 2 and 3 respectively. Live mass at maximum fat deposition was 78 kg (73 to 85) for pigs from Treatment 1, 77 (72 to 80) and 75 (73 to 78) for pigs from Treatments 2 and 3.

Boars deposited between 19,5 (at 30 kg) and 56,5 g/d (at maximum) less fat than gilts and obese pigs between 18,5 and 79,5 g/d more fat than lean pigs. The biggest difference in group means, 106 g/d (59%), occurred between the lean boar and obese gilt groups at 90 kg live mass in Treatment 1.

Discussion

A severe deficiency in the dietary limiting amino acid and an excessive supply of total protein or some essential amino acids depress feed intake and growth performance (Henry, 1985). It was also found that an increase in dietary protein content from 21 to 24%, when fed to high genetic potential boars, caused a drop of approximately 9% in mean daily feed intake (McCracken & Stockdale, 1989). In this study it was, however, not possible to alter the mean daily intake of DE and live mass-gain, although dietary protein content was decreased from 19,7 to 13,7%. Only at the beginning of the experimental period did pigs, fed the low protein diets, consume 10,4% more DE, most probably in an attempt to compensate for a lower intake of protein or a particular amino acid. The pigs were, however, unable to sustain the higher intake as the trial period progressed. It was, however, not possible to ascertain to what extent the lack of response to an increase in dietary protein content can be ascribed to the amino acid profile of the diets fed. From Table 2 it can be calculated that the diets fed contained 6,2 g lysine/100 g crude protein. Literature values range between 7,0 (ARC, 1980) and 5,5 (INRA, 1984) with a recent estimate of 6,5 (Wang & Fuller, 1990). Furthermore, relative to lysine the ratios of threonine (0,57), isoleucine (0,35) and particularly valine (0,66) were slightly lower than those suggested by the ARC (1981), INRA (1984) and Wang & Fuller (1990).

The daily intakes of lysine, protein and DE calculated for the pigs fed Treatments 1, 2 and 3, as shown in Table 5 and Figure 2, show that all protein intakes were in excess of the requirements suggested by Yen *et al.* (1986a; 1986b), Fuller *et al.* (1981), and the ARC (1981). Furthermore, lysine consumption was 7—30% in excess of requirements, but marginally less for pigs from Treatment 3 and just below the suggested requirement for a 30 kg pig fed Treatment 2.

Regressing daily feed intake on live mass, Whittemore *et al.* (1988) fitted a linear relationship between 5 and 85 kg for unimproved crossbred pigs. Subsequently to 85 kg they found daily food intake to oscillate widely about the mean, producing a broad plateau. Predicted values for daily protein retention increased rapidly from 20 kg to attain around 75 kg live weight, maxima of 130 g for entire males and 120 g for females. Between 45 and 110 kg live weight rates of protein retention were maintained within 10 g of the maximum rate.

Careful studies of plots of linearized raw data over a number of experiments as illustrated by Siebrits (1986) have, however, conclusively shown that feed intake and growth rate not only follow curvilinear patterns, influenced by factors such as sex and animal type, but also show distinct break points in the curves which must be taken into consideration. A separate set of growth parameters should therefore be calculated for each growth phase or alternately only the phase of interest should be studied, taking care not to extrapolate beyond the data set used. The allometric autoregressive growth description (Roux & Kemm, 1981; Siebrits, 1986) is a legitimate way of fitting the Gompertz curve. Hence it was considered an appropriate and accurate statistical procedure to use in presenting the data in this study.

The data on live mass-gains and protein deposition in Figure 2 confirm the findings of Siebrits *et al.* (1986) that DE (feed) intake in *ad libitum* fed pigs peaks at a live mass approximately 20 kg higher than live mass-gain and protein growth. Apart from type and sex effects, deposition rates not only tend to peak at a later stage in boars and lean type pigs (62 kg live mass for lean boars and 52 kg for obese gilts) but also decline at a slower rate thereafter. The rate of protein deposition is only slightly reduced by the level of dietary protein, but only at the lowest of the three levels fed (Treatment 3). No advantage could or should therefore be gained by feeding a protein level higher than the 16,8% (Treatment 2) to pigs equal in growth potential compared to those used in this study, providing the animals consume an adequate daily amount of DE.

Campbell & Taverner (1988) investigated the response of fast (strain A) and slow (strain B) growing boars and castrated male pigs of strain B to different intake levels between 45 and 90 kg live mass. On *ad libitum* feed intake the respective figures for mean daily DE intake, live mass-gain and protein gain were 40,8 MJ DE, 1202 g and 189 g for strain A boars, 41,5 MJ DE, 913 g and 125 g for strain B boars and 48,2 MJ DE, 898 g and 68 g for the castrates. For strain A boars the mean rate of protein deposition increased linearly from 92 to 188 g/d with increased energy intake from 22,2 MJ DE/d to *ad libitum*. For strain B boars and castrates the rate of protein deposition increased linearly with increased energy intake up to 33 MJ DE/d, but thereafter it remained constant at 128 and 85 g/d, respectively. For castrates, protein deposition was actually depressed ($P < 0{,}01$) when the diet was offered *ad libitum*.

In conclusion it is important to emphasize that after establishing distinct intake and growth patterns between pigs highly divergent in growth rate, Kemm *et al.* (1988) concluded that the absolute amount and pattern of feed intake is dictated by the animal's growth rate, its pattern of body protein and fat acretion and the amount of food used for maintenance. Hence, a follow-up trial will have to be conducted to measure the rate and pattern of protein deposition in the fast-growing pig of a high genetic potential before meaningful recommendations on nutrient requirements of *ad libitum* fed pigs of high genetic potential (growth rate in excess of 1000 g/d) can be made. This experiment has also shown that more data on the effects of dietary amino acid pattern on feed intake and growth performance would be useful.

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Appendix

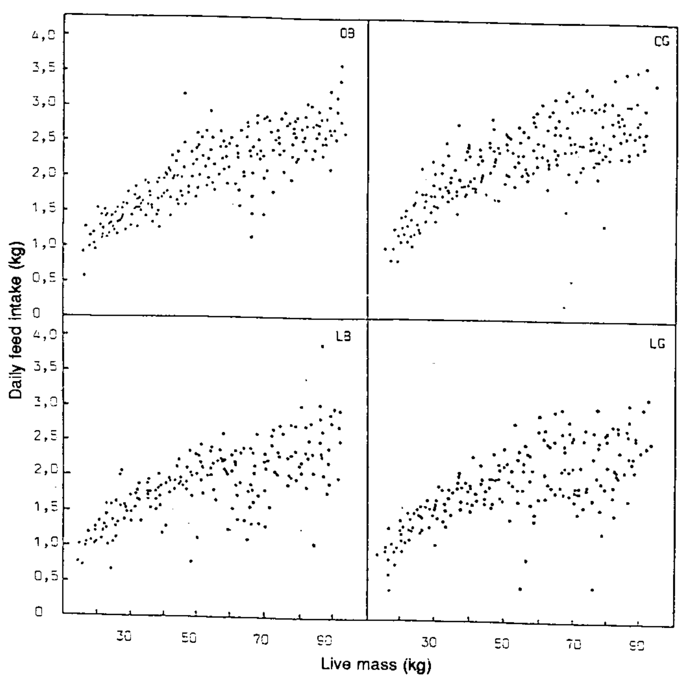

Figure 1a Daily feed intakes (kg, air-dry) by pigs from Treatment 1 given food to appetite. Each data point represents 0,25 of *ad libitum* feed intake, measured for each pig at 4-day intervals.

Appendix *Continued*

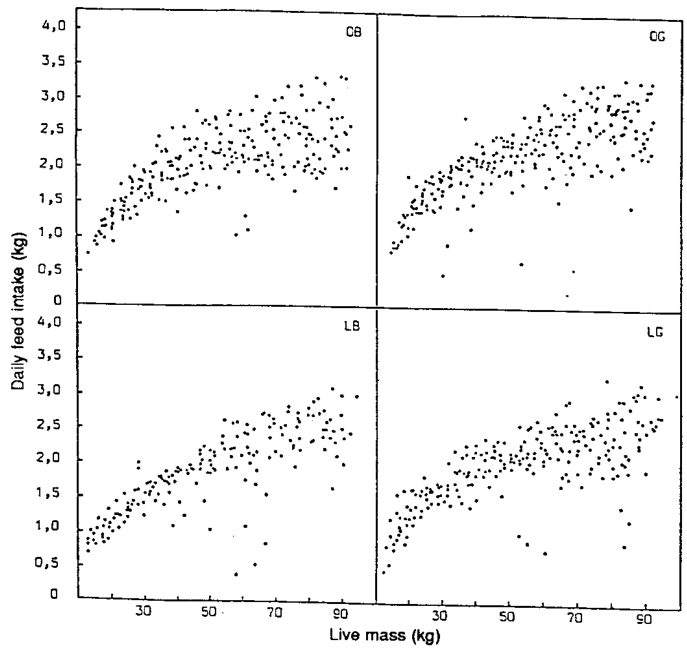

Figure 1b Daily feed intakes (kg, air-dry) by pigs from Treatment 2 given food to appetite. Each data point represents 0,25 of *ad libitum* feed intake, measured for each pig at 4-day intervals.

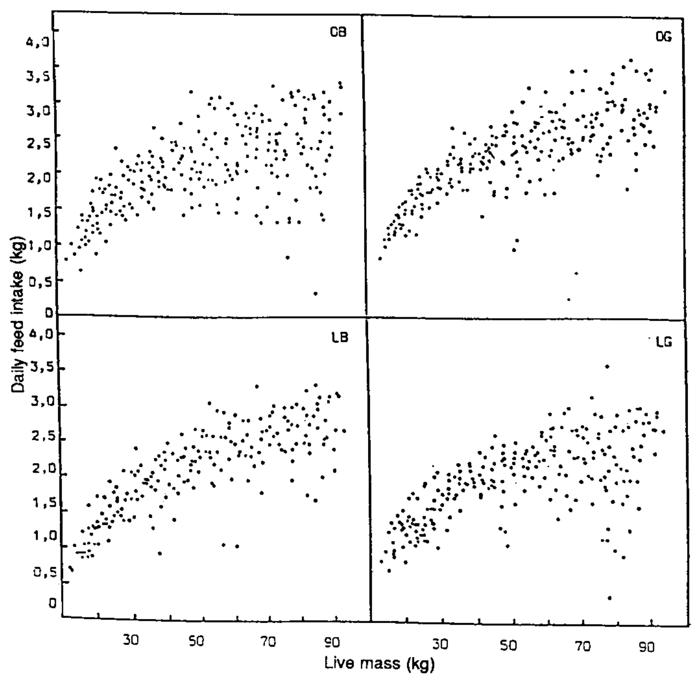

Figure 1c Daily feed intakes (kg, air-dry) by pigs from Treatment 3 given food to appetite. Each data point represents 0,25 of *ad libitum* intake, measured for each pig at 4-day intervals.

Appendix *Continued*

Table 1 Regression equations describing the relationships between ln(live mass) as independent variable (X) and ln(body protein or fat) as dependent variable (Y)

	Body protein					Body fat				
	a	b	*SE* (b)	S_{yx}	r^2	a	b	*SE* (b)	S_{yx}	r^2
Treatment 1										
Lean boars	−2,047	1,055	0,017	0,040	0,997	−3,507	1,391	0,033	0,076	0,993
Obese boars	−1,961	1,017	0,030	0,071	0,989	−3,736	1,496	0,061	0,146	0,993
Lean gilts	−1,856	1,001	0,018	0,041	0,996	−4,045	1,573	0,075	0,136	0,979
Obese gilts	−1,796	0,967	0,015	0,035	0,997	−3,854	1,566	0,039	0,089	0,973
Treatment 2										
Lean boars	−2,070	1,055	0,011	0,026	0,999	−3,407	1,375	0,048	0,110	0,987
Obese boars	−1,990	1,025	0,027	0,065	0,991	−3,638	1,480	0,056	0,138	0,981
Lean gilts	−1,908	1,007	0,015	0,034	0,998	−3,711	1,502	0,063	0,149	0,979
Obese gilts	−1,796	0,965	0,020	0,046	0,995	−3,869	1,582	0,043	0,099	0,991
Treatment 3										
Lean boars	−2,107	1,052	0,015	0,035	0,998	−3,125	1,361	0,045	0,104	0,987
Obese boars	−2,131	1,053	0,012	0,029	0,998	−3,407	1,446	0,045	0,107	0,988
Lean gilts	−2,053	1,038	0,016	0,037	0,997	−3,236	1,408	0,038	0,088	0,991
Obese gilts	−1,951	0,996	0,022	0,052	0,994	−3,603	1,527	0,040	0,096	0,991

Table 2 Equations derived to calculate protein deposition rate (PDR, g/d) and fat deposition rate (FDR, g/d) from live mass (M, kg) and daily gain (DG, g/d) with standard errors* in parentheses

	PDR	FDR
Treatment 1		
Lean boars	$0{,}136M^{0{,}055}$. DG (0,22 – 0,32)	$0{,}042M^{0{,}391}$. DG (0,23 – 0,59)
Obese boars	$0{,}143M^{0{,}017}$. DG (0,33 – 0,48)	$0{,}036M^{0{,}496}$. DG (0,55 – 1,90)
Lean gilts	$0{,}156M^{0{,}001}$. DG (0,13 – 0,23)	$0{,}028M^{0{,}573}$. DG (0,54 – 1,54)
Obese gilts	$0{,}161M^{-0{,}033}$. DG (0,14 – 0,12)	$0{,}033M^{0{,}566}$. DG (0,43 – 1,41)
Treatment 2		
Lean boars	$0{,}133M^{0{,}055}$. DG (0,14 – 0,21)	$0{,}046M^{0{,}375}$. DG (0,38 – 1,00)
Obese boars	$0{,}141M^{0{,}025}$. DG (0,26 – 0,42)	$0{,}039M^{0{,}480}$. DG (0,60 – 1,52)
Lean gilts	$0{,}149M^{0{,}007}$. DG (0,16 – 0,23)	$0{,}037M^{0{,}502}$. DG (0,67 – 1,95)
Obese gilts	$0{,}160M^{-0{,}035}$. DG (0,16 – 0,23)	$0{,}033M^{0{,}582}$. DG (0,45 – 1,51)
Treatment 3		
Lean boars	$0{,}128M^{0{,}052}$. DG (0,17 – 0,26)	$0{,}060M^{0{,}361}$. DG (0,58 – 1,48)
Obese boars	$0{,}125M^{0{,}051}$. DG (0,12 – 0,17)	$0{,}048M^{0{,}446}$. DG (0,56 – 1,42)
Lean gilts	$0{,}133M^{0{,}038}$. DG (0,14 – 0,20)	$0{,}055M^{0{,}408}$. DG (0,43 – 1,00)
Obese gilts	$0{,}142M^{-0{,}004}$. DG (0,17 – 0,27)	$0{,}042M^{0{,}527}$. DG (0,58 – 1,59)

* Figures represent extreme s.e. values when calculating PDR and FDR between 30 and 90 kg mass.