Protein deposition in pigs as influenced by sex, type and livemass. 1. The pattern and composition of protein deposition

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One hundred pigs were slaughtered sequentially to characterize and quantify protein deposition in two types (lean and obese) and sexes (boars and gilts) of Landrace pigs. The pigs were fed *ad lib* on a diet containing 18% protein, 1% lysine and 13,46 MJ DE/kg feed on an 'as is' basis from 6 weeks of age to a maximum livemass of 110 kg. Growth rate, feed intake, and rate of protein deposition followed a curvilinear pattern. Lean pigs had a higher rate of protein deposition than obese pigs, and boars a higher rate than gilts. Sex, type and livemass had no effect on the amino acid composition of porcine protein within the mass interval (30 – 110 kg livemass) in the present study.
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Om proteïenneerlegging in twee tipes (maer en vet) en geslagte (bere en soggies) Landrasvarke te bepaal, is 100 varke opeenvolgend geslag. Die varke is *ad lib* op 'n dieet met 18% proteïen, 1% lisien en 13,46 MJ VE/kg lugdroë voer vanaf 6-weke-ouderdom tot op 110 kg lewende massa gevoer. Groei-, voerinname- en proteïenneerleggingstempo het 'n kromlynige patroon gevolg waar 'n maksimum tempo bereik is gevolg deur 'n afname. Maer varke het 'n hoër proteïenneerleggingstempo as vet varke en bere 'n hoër tempo as soggies gehad. Die aminosuursamestelling van varkliggaamsproteïen is nie deur geslag, tipe of lewende massa (30 – 110 kg lewende massa) beïnvloed in hierdie studie nie.
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Introduction

The rates of protein and fat deposition are major factors involved in the economic production of lean meat. Consequently many studies have been conducted in an attempt to quantify these parameters. The consumer demands lean meat with minimal fat. In order to meet these demands, breeding programmes have been directed towards the selection of lean pigs. Animals with larger mature size, fatten at relatively higher bodymasses (Wood, MacFie, Pomeroy & Twin, 1980). Selection was therefore probably biased towards large mature sizes so that advantage could be taken of the relatively longer lean growth phase maintained by animals with larger mature sizes.

It is generally accepted in pigs that females are fatter than males and that castrates are fatter than females (Blair & English, 1965; Fuller & Livingstone, 1978; Fuller, Gordon & Aitken, 1980). This implies that the male body contains more protein and/or water than that of the female and that hormones influence body composition. These differences can be affected by differences in food intake and/or differences in metabolic efficiency, i.e. heat production. Maximum rates of protein accretion suggested for boars, gilts and castrates are 130 – 160 g/day, 110 – 115 g/day and 97 – 103 g/day respectively (Kielanowski, 1969; Rérat, 1972).

There are breed differences regarding body composition and protein deposition. Fielder & Curran (1970) found that the Pietrain breed had a higher nitrogen retention rate on average (6 g N/day) than the Large White and a greater efficiency of N retention than Landrace pigs. Davies (1974a & b) found a higher proportion of lean in the Pietrain compared to the Large White, illustrating the effect of genotype on body composition. Kielanowski (1969) suggested a genetic base to the potential daily rate of protein growth which can be achieved, proposing values of 30 g/day for unimproved pigs, 110 g/day for 'meat type' pigs, and 130 g/day for exceptionally fast growers. Within breeds there is also variation in the leaneness of pigs — certain lines of pigs tend to be more obese than the lean lines. Obesity, however, does not necessarily imply a lower rate of lean tissue growth rate.

In view of the current and predicted protein shortage (Cloete, 1981), ways should be found to utilize this important resource optimally. By describing protein deposition, feeding strategies can be devised to maximize protein utilization. Henry, Duee & Sevé (1979) stated that the most precise parameter for estimating amino acid requirements is to determine lean tissue gain. The present study was consequently performed to characterize and quantify protein deposition at various livemasses in pigs different in type (lean and obese) and sex (boars and gilts).

Materials and Methods

Figures released by the National Pig Recording Scheme were used to identify two pig herds with diverse types within the same breed (Landrace). Six gilts and a boar were bought from a herd with exceptionally lean pigs and six gilts and a boar from a herd with comparatively obese pigs in order to breed animals for this experiment. The gilts were bred with a boar of their respective lines and the offspring weaned at 5 weeks of age.

In order to ensure maximum growth and that no nutritional limitation was imposed on protein deposition, a diet formulated to contain 18% protein, 1% lysine and 13,46 MJ DE/kg (Table 1) which is more than the recommended allowances (ARC, 1981; NRC, 1973) was fed *ad lib* to the pigs.

Table 1 Experimental diet (on an 'as is' basis)

Component	%
Yellow maize meal	67,07
Wheaten bran	15,00
Fish meal	16,00
Salt	1,00
Limestone powder	0,70
Mineral and Vitamin premix	0,20
Synthetic L-lysine	0,03
Calculated composition:	
Digestible energy (MJ/kg)	13,46
Protein (%)	18,17
Lysine (%)	1,07
Methionine and cystine (%)	0,68
Threonine (%)	0,73
Tryptophane (%)	0,19
Leucine(%)	1,60
Isoleucine (%)	0,82
Histidine (%)	0,41
Tyrosine and phenylalanine (%)	1,18
Valine (%)	0,93
Calcium (%)	1,02
Phosphorus (%)	0,72

Fifty piglets of each type were divided into four experimental groups of 25 pigs each, namely lean boars (LB) lean gilts (LG), obese boars (OB), and obese gilts (OG). Four piglets from each group were slaughtered at 7 weeks of age. Livemass and cumulative feed intake measurements of the remaining 21 pigs per group were recorded every 3 days at 08h00. A slaughter mass was allocated randomly to each pig when 6 weeks old. Subsequently one pig from each group was slaughtered at 5 kg intervals between 20 and 105 kg livemass. The remaining three pigs per group were slaughtered at a livemass of 110 kg. When a pig reached ± 1 kg of its allocated slaughter mass it was stunned electrically, bled into a container of known mass and eviscerated. Warm carcass mass as well as mass of offal (blood and intestines minus gut contents) were measured. The offal was immediately frozen in a plastic bag whilst the carcass was hung at 4°C for 24 h after which it was halved medially, its mass determined, and the left side frozen in a sealed plastic bag.

The loss of mass during the 24-h chilling period was assumed to be a loss of moisture. A correction was made accordingly by adding moisture loss to the determined carcass moisture content. The frozen offal and left side (including half the head) of each carcass were ground seperately in a Wolfking carcass grinder with a 5 mm sieve. It was passed through the mincer five times to ensure proper mixing before a sample of *ca* 1,5 kg was taken for dry matter determination and chemical analyses (Hofmeyr, 1972).

Dry matter content was determined by drying *ca* 300 g samples in triplicate at 100°C for 48 h in a forced convection drying oven. A further 200 g sample was freeze-dried to a dry matter content of approximately 95% after which it was milled through a 2 mm sieve in a Christy & Norris laboratory mill together with three to four times its volume of dry ice (solid CO_2). The use of a pre-cooled mill and a super cooled sample ensured that the fat in the sample did not accumulate on the inside walls of the mill. The ground sample mixture was then left open in a plastic bag until all the dry ice had sublimated and was subsequently stored in a deep freeze. Protein content ($N \times 6{,}25$) was determined using an Auto Analyser.

Fat content was determined by extraction with petroleum ether (boiling point 40 – 60°C) for 16 h in a Soxhlet apparatus (AOAC, 1975). The two defatted portions of each duplicate sample were then pooled and milled through a 40 mesh sieve in a laboratory Wiley mill after which a sub-sample of *ca* 25 mg (in duplicate) was hydrolysed for subsequent amino acid analysis.

The allometric autoregression (AA) growth model as described by Roux (1976) and substantiated by Meissner (1977), Siebrits (1979), Roux (1981), Roux & Kemm (1981) and Roux, Meissner & Hofmeyr (1982) was employed to analyse and describe growth and body composition in the present study. Because the estimators (ρ, α, μ, a_1 & b_1) of the AA model contain sufficient information of growth and have normal distributions under the usual regularity assumptions (Roux, 1981), only these parameters were subjected to ordinary statistical analyses (two-way analysis of variance). A regression between ln(cumulative DE intake) and ln(body protein) was also calculated for each group of pigs (i.e. LB, LG, OB & OG). Growth rates and rates of protein deposition and feed intake were calculated by differentiation as described by Siebrits (1979).

Results and Discussion

The (mean) growth parameters of the various experimental groups are presented in Table 2.

No significant differences ($P > 0{,}1$) were found between the ρ values of any of the groups. However, it was decided not to use a common value owing to the possibility of a type 2 error (erroneous pooling of data) (Rayner, 1967). Significant differences ($P \leq 0{,}05$) were found between the α values of the lean and obese pigs but with no differences between the sexes. The mean α values calculated for each sex were also kept separate for the reason already mentioned. As can be expected, no significant differences were found between the initial cumulative DE intakes (μ values) of the different groups. Significant ($P \leq 0{,}05$) sex differences were found in the slopes and intercepts of the cumulative DE intake-livemass relationships, but with no difference between the two pig types. Therefore, every group had an unique set of parameters which suggests significantly different growth patterns.

The regression equations describing the relationships between cumulative DE intake and body protein of the different experimental groups are presented in Table 3.

Table 2 Growth parameters of the allometric autoregression model*

Growth parameters	Lean boars (Mean ± SD)	Lean gilts (Mean ± SD)	Obese boars (Mean ± SD)	Obese gilts (Mean ± SD)
	Experimental group			
ρ^1	$0{,}95764^a \pm 0{,}008$	$0{,}96492^a \pm 0{,}006$	$0{,}96632^a \pm 0{,}004$	$0{,}96096^a \pm 0{,}006$
α^2	$8{,}80575^a \pm 0{,}199$	$8{,}87212^a \pm 0{,}134$	$9{,}15687^b \pm 0{,}209$	$8{,}93358^b \pm 0{,}233$
a^3	$-1{,}36245^a \pm 0{,}183$	$-1{,}19866^b \pm 0{,}215$	$-1{,}34613^a \pm 0{,}176$	$-1{,}19350^b \pm 0{,}099$
b^4	$0{,}73601^a \pm 0{,}024$	$0{,}71046^b \pm 0{,}032$	$0{,}72904^a \pm 0{,}023$	$0{,}69981^b \pm 0{,}014$
μ^5	$6{,}73878^a \pm 0{,}134$	$6{,}56136^a \pm 0{,}128$	$6{,}68542^a \pm 0{,}123$	$6{,}72383^a \pm 0{,}077$

*Values with different superscripts differ significantly ($P \leq 0{,}05$)
[1]ρ: slope of auto regression
[2]α: asymptote of cumulative DE intake
[3]*a*: mean intercept of ln(livemass) – ln(cumulative DE intake) regressions
[4]*b*: mean slope of ln(livemass) – ln(cumulative DE intake) regressions
[5]μ: mean initial ln(cumulative DE intake) value
The means of the coefficients of determination (r^2) of the autoregressions and the ln(cumulative DE intake) – ln(livemass) regressions were 0,9997 and 0,9979 respectively, indicating a very close fit.

Table 3 Regression equations describing the relationships between ln(cumulative DE intake) as independent variable and ln(body protein) as dependent variable

Group	*n*	Regression equation	r^2	Syx
Lean boars	18	$y = -3{,}53746 + 0{,}78591X$	0,9938	0,076
Lean gilts	17	$y = -3{,}45422 + 0{,}76384X$	0,9943	0,082
Obese boars	18	$y = -3{,}40882 + 0{,}75843X$	0,9311	0,100
Obese gilts	18	$y = -2{,}06689 + 0{,}57060X$	0,9703	0,0569

The results on growth rate and feed intake of the different experimental groups at various livemasses (Figures 1 & 2) indicate that both feed intake and growth rate increased to a maximum with a subsequent decline. The peak rate of feed intake was reached at a livemass about 20 kg higher than peak growth rate. The OB group reached both their growth and feed intake peaks at a higher livemass than the other groups. The protein deposition rates of the various groups are presented in Figure 3. From Figure 3 it is evident that the rate of protein deposition also followed a curvilinear pattern with a peak rate followed by a subsequent decline.

In the LB group a peak protein deposition rate was reached between 60 and 70 kg livemass (156 g/day), in the OB group at 80 kg (144 g/day), in the LG group between 60 and 70 kg (121 g/day), and in the OG group between 40 and 50 kg (101 g/day).

Several authors found that daily protein deposition or nitrogen retention increases to reach a maximum value whereafter it remains fairly constant (Hencken & Freese, 1960 cited by Henry, *et al.*, 1979; Oslage & Fliegel, 1965 cited by Cöp, 1974; Thorbek, 1969, 1975, 1977, 1980; Homb, 1972; Cöp, 1974; Wenk & Schürch, 1974; Whittemore & Elsley, 1976).

Oslage, Fliegel, Farries & Richter (1966) found N retention to peak at 20 – 40 g livemass after which it remained constant to about 130 kg and subsequently declined. Fuller & Boyne (1971) also found protein deposition to peak with a subsequent decrease. Siebrits, Kemm & Ras (1981) fed barrows restrictively and found that daily protein deposition reached a maximum at a livemass of about 75 kg whereas *at lib*-fed barrows reached a peak deposition rate at 45 kg livemass (Siebrits, Kemm, Roux & Ras, 1982). Cöp (1974) also found a difference between restrictively fed and *ad lib*-fed pigs: The restricted group had a steady increase in protein deposition to about 90 kg livemass where a plateau was reached, whereas

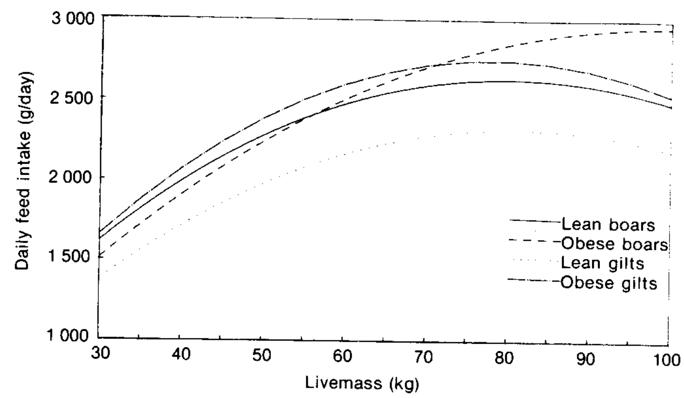

Figure 1 Daily feed intake at various livemasses

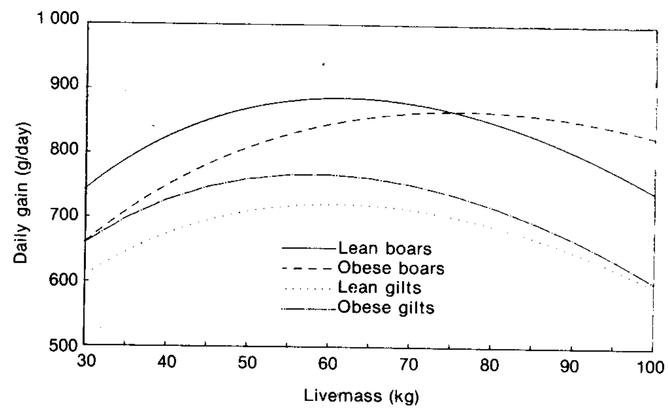

Figure 2 Growth rates at various livemasses

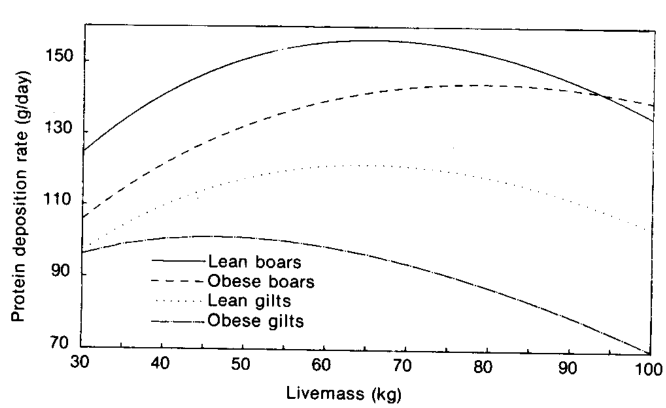

Figure 3 Daily protein deposition at various livemasses

the *ad lib*-group reached a maximum at about 50 kg livemass with a constant rate to about 120 kg whereafter it declined rapidly. It seems that most of the discrepancies in the literature regarding the pattern of daily protein deposition can be ascribed to differences in feeding regimes and the genetic make-up of the animals.

Pigs fed *ad lib* reached a maximum growth rate with a subsequent decrease in growth (Hansson, 1974; Neely, Johnson, Walters & Venel, 1977; Wenk, Pfirter & Bickel, 1980; Henderson, Ellis, Smith, Laird & Whittemore, 1981; Siebrits, *et al.*, 1981, 1982).

The protein accretion rate of empty bodymass gain, remained virtually constant, except in the OG group where it decreased from 16,3% at 30 kg livemass to 12% at 100 kg livemass. Percentage protein accretion in the LB group increased from 17,8% at 30 kg to 18,3% at 60 kg whereafter it remained constant. Empty bodymass gain in the OB group consisted of 17,5% protein at 30 kg and increased to 17,6% at 40 kg with a subsequent decline to 16,7% at 100 kg livemass. The LG group had 17,5% protein in their empty bodymass gain at 30 kg which subsequently declined to 16,5% at 100 kg. Schmidt, Veum, Clark & Krause (1973) expressed protein as a percentage of carcass mass and found a value of 17,97% at 26,8 kg decreasing to 14,88% at 81,8 kg livemass in barrows. Fortin (1982) analysed carcass sides of barrows and gilts and found protein content to decrease from 14,07% and 14,48% at 85 kg livemass to 13,11 and 13,18% at 103 kg livemass for barrows and gilts respectively.

Remarkable constancies were found when the derived amino acid content of any of the experimental groups at any livemass was expressed as a percentage of body protein content. Body protein amino acid composition was therefore calculated using least squares procedures (Snedecor & Cochran, 1973). The equations fitted are given in Table 4.

Table 4 Amino acid composition of body protein

Amino acid	Regression equation	Syx	% Amino acid[a]
Lysine	$Y^b = 0{,}0545X^c$	0,5321	5,45
Threonine	$Y = 0{,}0304X$	0,2964	3,04
Leucine	$Y = 0{,}0557X$	0,5436	5,57
Isoleucine	$Y = 0{,}0210X$	0,2065	2,10
Histidine	$Y = 0{,}0241X$	0,2337	2,41
Tyrosine	$Y = 0{,}0195X$	0,1902	1,95
Phenylalanine	$Y = 0{,}0293X$	0,2863	2,93
Valine	$Y = 0{,}0359X$	0,3522	3,59

[a]g amino acid/100 g body protein
[b]Y = kg amino acid in empty body
[c]X = kg empty body protein

The amino acid concentrations found in the present study are consistently lower than values given in the literature (Table 5). However, when expressed relative to lysine content they compare favourably.

The reason for the lower values could be due to differences in the definition of 'pig tissue'. The results of Wilson & Leibholz (1981) were obtained from 14 to 35-day old piglets on which whole body analyses were done. They found that the amino acid composition of the piglets did not vary with age or protein source fed (milk or soyabean protein). No exact definition of 'pig tissue' is given by the ARC (1981). Muscle protein contains more lysine than the whole body (8,75 g/100 g protein according to Madsen & Mortensen, 1979; 8,4 g/100 g according to Duee, Calmes & Desmoulin, 1980; 9,59 g/100 g according to Jelić, 1977). A value of 6,02 g/100 g body protein was obtained by Edmunds, Buttery & Fisher (1979).

Table 5 Amino acid composition of porcine protein (g/100 g protein)

	Analysis of			
Amino acid	Whole body[a]	Whole body[b]	Pig tissue[c]	Pig tissue[d]
Lysine	5,45	6,52	6,9	6,7
Threonine	3,04	3,79	3,5	3,5
Valine	3,63	5,56	4,9	4,7
Leucine	5,60	6,61	7,1	6,7
Tyrosine	1,95	3,23	5,6	6,3
Phenylalanine	2,93	4,16	5,6	6,3
Histidine	2,41	2,68	2,8	2,5
Isoleucine	2,10	3,65	3,9	3,6

[a]Present study
[b]Wilson & Leibholz (1981)
[c]Buraczewski (1972) cited by ARC (1981)
[d]Aumaitre & Duee (1974) cited by ARC (1981)

Conclusions

Protein accretion rate follows a curvilinear pattern where a peak is reached between 40 and 80 kg livemass under *ad lib* conditions depending on the animals' sex and type followed by a subsequent decline. The pattern of protein deposition is related to, but not dependent on, the pattern of feed intake because the peaks of these two processes do not coincide. Lean pigs had, as expected, a higher rate of protein deposition than obese pigs and boars a higher rate than gilts.

Sex, type and livemass has no effect on the amino acid composition of porcine body protein within the mass interval of the present study (30 – 110 kg livemass). Genotype and sex would therefore have no effect on the construction of the 'ideal protein' in terms of amino acid concentrations relative to lysine content (Yen, 1979). The results furthermore suggest that, if the efficiency of protein utilization remains constant, amino acid requirements for growth would increase curvilinearly in absolute terms to reach a maximum, along with protein deposition, with a subsequent decline.

The results of this study could therefore be used as a reference to conduct future studies on protein nutrition of *ad lib* fed pigs. An estimation of digestible ideal protein requirements is made in a subsequent paper.

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