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INFLUENCE OF DIETARY ENERGY CONCENTRATION ON PROTEIN DEPOSITION OF AD LIB FED GROWING PIGS

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OPSOMMING: DIE INVLOED VAN DIEëTENERGIEKONSENTRASIE OP PROTEïENNEERLEGGING VAN AD LIB GEVOERDE GROEIENDE VARKE

Vyf diëte wat gelyke hoeveelhede (23%) ruproteïen en verskillende energiekonsentrasies bevat, strekkende van 11,5 tot 17 MJ ME/kg DM is *ad lib* aan 52 Landras X Grootwit kruisburge gevoer. Dieetenergiekonsentrasie is gemanipuleer deur mieliestysel met gelyke inkremente dennehoutsaagsels te vervang. Die varke in elke groep, is agtereenvolgens, met twee-week intervalle van 11 tot 31 weke ouderdom geslag, gemaal en vir liggaamsproteïeninhoud ontleed. Deur die Roux-model te gebruik is die daaglikse proteïenneerleggingstempo's van die varke in die 5 behandelings oor die groeiperiode (25 – 100 kg lewende massa) bereken. Die proteïenneerleggingstempo is deur dieetenergiekonsentrasie beïnvloed; varke wat die hoogste energie behandeling ontvang het, het die hoogste proteïenneerleggingstempo (94 g/dag) behaal. Daaglikse proteïenneerlegging het, in al die behandelings, 'n maksimum by 45 kg lewende massa bereik, waarna dit weer afgeneem het.

SUMMARY:

Five diets, containing equal amounts (23%) of crude protein, and different energy concentrations, ranging from 11,5 to 17,0 MJ ME/kg DM, were fed *ad lib* to 52 Landrace X Large White barrows. Dietary energy content was manipulated by replacing maize starch by equal increments of pine wood sawdust. Pigs were slaughtered sequentially at two-weekly intervals from an age of 11 weeks up to 31 weeks, ground and analysed for body protein. Using the Roux mathematical model, daily protein depositions of the pigs on the 5 treatments were calculated over the growth period (25 – 100 kg live mass). The rate of protein deposition was influenced by dietary energy concentration, the pigs on the highest energy treatment attaining the highest rate of protein deposition (94 g/day). Daily protein deposition for all the treatments, peaked at 45 kg live mass, and declined subsequently.

The amount of protein and fat deposited in the body of a growing pig is greatly influenced by energy intake (Lewis & Hardy, 1970; Cooke, Lodge & Lewis, 1972; Lodge, Cundy, Cooke & Lewis, 1972). It is, therefore, important to relate the growth patterns of protein and fat to the energy consumption of the animal. Thorbek (1977) found that a reduction of 15% in energy intake, from 1,25 MJ ME/kg^{0,75} to 1,07 MJ ME/kg^{0,75} at a constant protein intake of 228 g of digestible protein, reduced the efficiency of protein utilization from 53 to 40%. Henry, Duee & Seve (1978) cited Hencken & Freese (1960) who found that pigs attain a maximum protein retention at about 40 kg live mass whereafter it remains constant up to a live mass of about 100 kg. However, Doornenbal (1971, 1972) cited by Robinson (1976) in a review article found that protein deposition reaches a peak at a live mass of 65 – 75 kg and then declines. According to Thorbek (1975), Lund (1935) also described a curve for N-retention in Danish Landrace sows from 20 to 100 kg live mass. He found N-retention to be 14 g per day at 20 kg live mass, increasing to 23 g per day at 60 kg and thereafter declining to 19 g per day at 100 kg live mass.

The most accurate way to determine protein deposition is by using the comparative slaughter technique. By using nitrogen balance studies protein deposition can be overestimated by as much as 25% (Van Es, 1972; Wiesemüller, 1976, cited by Henry *et al.*, 1978).

This paper describes the rate and efficiency of protein deposition in pigs that were fed *ad lib* on diets with an adequate protein content, but with different energy concentrations, using the Roux mathematical model (Roux, 1976) to describe the data obtained from sequentially slaughtered pigs.

Materials and Methods

Fifty five Landrace X Large White barrows were divided into 5 groups and were fed the experimental diets *ad lib* from 8 weeks of age. The pigs were kept individually in flat deck-type cages 1,6 x 1 m in size, fitted with a self feeder and an automatic water nipple. Temperatures in the building were controlled to the extent that minimum temperatures never dropped below 20°C, while maximum temperatures seldom rose above 30°C. All pigs received the same creep feed (19,59% crude protein in the DM, and a metabolizable energy, ME, content of 15,28 MJ/kg DM) from a week prior to weaning to 7 weeks of age. Thereafter the experimental diets, mixed with the creep feed on a 50:50 basis, were fed until 8 weeks of age when the full experimental diets were introduced. Pigs were fed *ad libitum* at all stages. Feed intake and live mass were recorded on the same day at weekly intervals. Feed and water were not withdrawn before mass determinations.

Experimental treatments

The 5 diets fed from 8 weeks onwards (Table 1) were compounded to contain 20% crude protein, equal in protein quality and origin and known to be in excess of the requirements for optimum production.

A dilution of the dietary energy content of the diets was achieved by replacement of maize starch by equal increments of pine wood sawdust.

Pigs on any one treatment were slaughtered one at a time, at 2 week intervals from an age of 11 weeks up to 29 or 31 weeks when the last pig in a treatment was slaughtered. Two pigs from Treatment 2 and one from Treatment 4 were eliminated from the experiment due to poor feed intake and erratic growth. The pigs were slaughtered as described by Roux & Kemm (1981) and chemically analysed as detailed by Kemm & Ras (1976). Ages and live masses of the individual pigs at slaughter are presented by Roux & Kemm (1981).

Table 1

Experimental diets

Treatments	1	2	3	4	5
Maize meal, kg	34	34	34	34	34
Fish meal, kg	26	26	26	26	26
Maize Starch, kg	40	32	24	16	8
Sawdust, kg	–	8	16	24	32
Salt, kg	0,5	0,5	0,5	0,5	0,5
$Na2HPO_4$, kg	0,3	0,3	0,3	0,3	0,3
Vitamins*	+	+	+	+	+
Crude Protein, %**	23,8	23,6	23,2	23,4	23,2
Crude Fibre, %**	1,5	7,3	12,3	17,7	22,7
ME, MJ/kg***	16,97	15,57	13,97	12,87	11,49

* Commercial vitamin-mineral premix added according to manufacturers prescription.

** Determined on a DM basis according to AOAC procedures.

*** Determined in a metabolism trial with 6 pigs per diet.

Live mass, total body protein and total body fat are allometrically related to cumulative energy intake (Roux, 1974; Meissner, 1977; Siebrits, 1979) and can be described by linear functions in the logarithmic scale.

Cumulative energy intake in the time domain is described by equation 1 (Roux, 1976).

$$x_t = \alpha + \rho^t (\mu - \alpha) \quad \ldots\ldots\ldots\ldots (1)$$

where x_t = ln (cumulative energy intake) at time t

μ = ln (cumulative energy intake) at time t_o

ρ = slope of the autoregression of ln (cumulative energy intake)

α = (intercept of the autoregression of ln (cumulative energy intake))/$(1-\rho)$

= asimptotic limit of ln (cumulative energy intake)

Regressions were therefore calculated between ln (cumulative ME-intake) as the independant variable and ln (live mass), ln (total body protein) and ln (total body fat). Autoregressions of ln (cumulative ME-intake) were also calculated in order to use the Roux mathematical model to analyse the data (Roux & Kemm, 1981). Apparent ME-values, determined in a metabolism trail using 6 pigs per diet, were used for the calculation of cummulative ME-intakes (Kemm, 1978 unpublished data). The statistical parameters obtained are presented in Table 2. Meissner (1977) found that the parameters in Table 2 are sufficient to describe differences between treatments. Where no significant differences between treatments in these parameters were found, common values were used.

The parameters in Table 2 were used to calculate daily live mass gain, daily protein deposition and daily protein intake, firstly at different live masses and secondly at different ages.

Results and discussion

Results of the metabolism trial indicate that ME, expressed as a percentage of DE, decreased from 95,8 in Treatment 1 to 93,8 in Treatment 5. This was probably due to the fact that the crude fibre content in the diets increased from 1,5% in Treatment 1 to 22,7% in Treatment 5 (Table 1) and because protein: energy ratio increased from 14,03 g/MJ ME in Treatment 1 to 20,19 g/MJ ME in Treatment 5.

The daily protein depositions (y – axis) at different live masses (x – axis) for the 5 treatments are presented in Fig. 1.

Table 2

Statistical parameters

Treatment	1	2	3	4	5
ρ, ln per week	0,9105	0,9090	0,9183	0,9290	0,9292
α, ln (MJ)	8,8716	8,8716	8,8716	8,8716	8,8716
μ, ln (MJ)	6,4662	6,3302	6,2356	6,1253	5,9332
b (ME* x Mass**)	0,6787	0,6787	0,6787	0,6787	0,6787
a (ME x Mass)	−1,0583	−1,0445	−1,0512	−1,0883	−1,1347
b (ME x protein***)	0,5894	0,5894	0,5894	0,5894	0,5894
a (ME x protein)	−2,2984	2,2984	−2,2984	−2,2984	−2,2984

* ME = ln (cumulative ME-intake) independant variable
** Mass = ln (live mass) dependant variable
*** Protein = ln (body protein) dependant variable

From Fig. 1 it is evident that the pigs in all the treatments deposited a maximum amount of protein at a live mass of approximately 45 kg after which there was a rapid decline in rate of protein deposition. The pigs in Treatment 2 deposited a maximum of 93,9 g per day at 45 kg while the pigs in Treatment 5 reached a maximum of 72,2 g per day at 45 kg live mass. After maximum deposition had been reached, the rate declined to such an extent that at 60 to 70 kg live mass, it equalled the deposition rate at 25 kg live mass. Mean N-retention figures at different live masses derived from the work of 18 researchers by Thorbek (1975) are presented in Table 3.

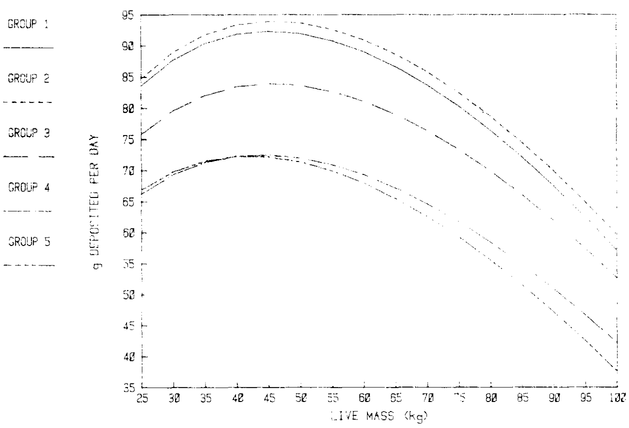

Fig. 1. *Protein gain per day at different live masses*

The results in Table 3 suggest that nitrogen retention peaks at between 70 – 90 kg live mass. Siebrits, Kemm & Ras (1981) fed pigs restrictively and found that daily protein deposition reached a maximum at a live mass of about 75 kg whereafter it declined. Oslage, Fliegel, Farries & Richter (1966), cited by Henry (1981) found protein retention in growing pigs to peak at a live mass of approximately 85 kg after which it declined. Hencken & Freese (1960) as cited by Henry *et al.* (1978) found nitrogen retention to reach a maximum at 40 kg live mass after which it remained constant. Whittemore & Elsley (1976) suggested that the daily rate of protein growth is relatively constant.

Ages of pigs at peak protein deposition in the 5 treatments are presented in Table 4.

Table 3

N-retention (g/day) from balance trials at different live masses (Thorbek, 1974)

Live mass (kg)	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
N-retention (g/day)	15	17	19	19	21	20	20	18
Variation	12–19	14–20	15–22	17–22	18–25	18–23	16–23	16–22

The age at which maximum protein deposition was attained differed between treatments, pigs in the treatment with the highest energy content being the youngest at 103 days as against the 130 days of Treatment 5 pigs.

The age differences at peak protein deposition are the result of growth differences between treatments resulting from the different dietary energy concentrations fed. Pigs, therefore, reached a live mass of 45 kg at a progressively later age depending on the reduction in dietary energy concentration. From the growth rates of the pigs on the different treatments at different live masses (Fig. 2) and the daily protein depositions of pigs on the different treatments at different ages (Fig. 3) it can be deduced that peak protein deposition takes place at a specific live mass rather than at a specific age and that the rate of protein deposition is therefore influenced by dietary energy intake. Thorbek (1977) found that by reducing ME-intake by 15%, the loss of urinary nitrogen increased from 47% to 60% of the digested nitrogen.

Protein conversion (g protein ingested per g protein deposited) differed widely between treatments as illustrated in Fig. 4. The differences between treatments remained constant throughout the growth period. Treatments 2 to 5 expressed as a percentage of Treatment 1 being respectively 107,2; 117,9; 132 and 150,8 per cent. Protein efficiency when expressed in g protein deposited per MJ ME-intake, however, differed only slightly between treatments throughout the entire growth period (Fig. 5).

Feed intake over the growth period, (Fig. 6) showed that the pigs in Treatment 5 (diet with lowest energy concentration) maintained the highest dry matter intake, but exhibited the fastest decline in intake after maximum intake (2,4 kg) was obtained at a live mass of 65 kg. The pigs in Treatment 1 had the lowest feed intake, with a peak intake of 2,07 kg per day at 75 kg live mass.

Energy intakes for the 5 treatments are presented in Fig. 7.

Although peak feed intake was the highest in Group 5 pigs they were unable to compensate for the low ME content (11,49 MJ/kg) of the diet (Fig. 7). The pigs fed diet 2 (15,57 MJ ME/kg), however, consumed so much more dry matter that they actually had a higher energy intake than pigs on Treatment 1. The fact that the pigs compensated for energy intake and that dietary protein content was almost constant (23%) resulted in higher protein intakes by the pigs fed diets containing sawdust. The peak daily protein intakes of the pigs in Treatments 1 to 5 were, respectively, 492, 541, 530, 500 and 555 g per day. When comparing the curves for feed and energy intakes (Figs. 6 and 7), pigs on Treatment 4 had a lower intake than pigs on Treatment 3, but pigs on Treatment 5 consumed the most.

Table 4

Ages of pigs in various treatments at peak protein deposition

Treatment	1	2	3	4	5
Age (days)	103	107	114	123	130
Live mass (kg)	45	46	46	44	42

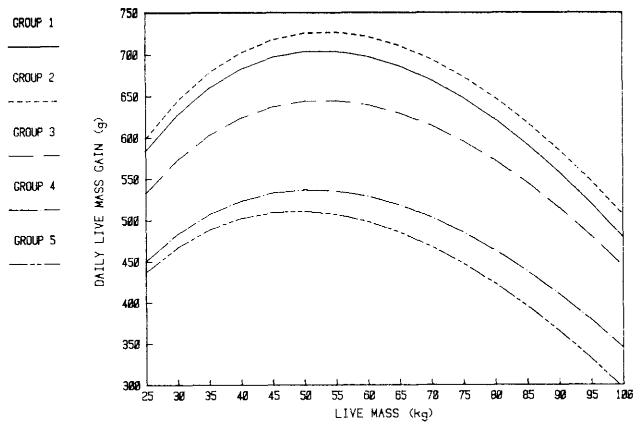

Fig. 2. *Average daily gain at different live masses*

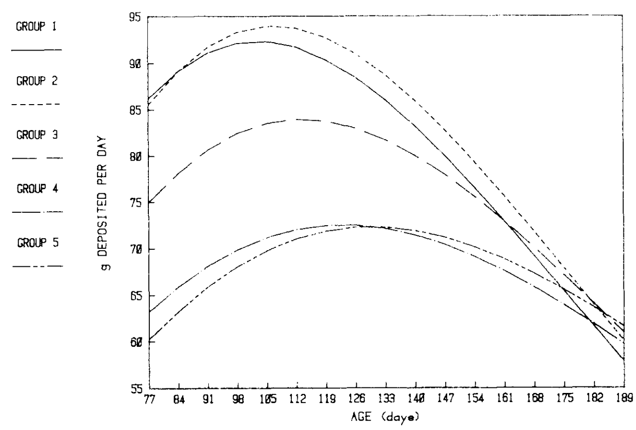

Fig. 3. *Protein gain per day at different ages*

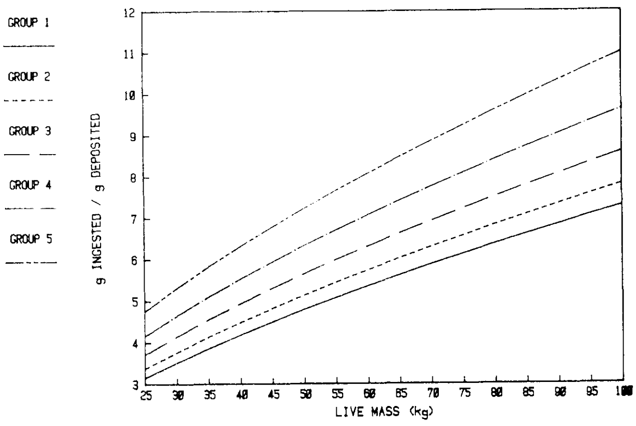

Fig. 4. *Protein efficiency (g protein ingested per g protein deposited) at different live masses*

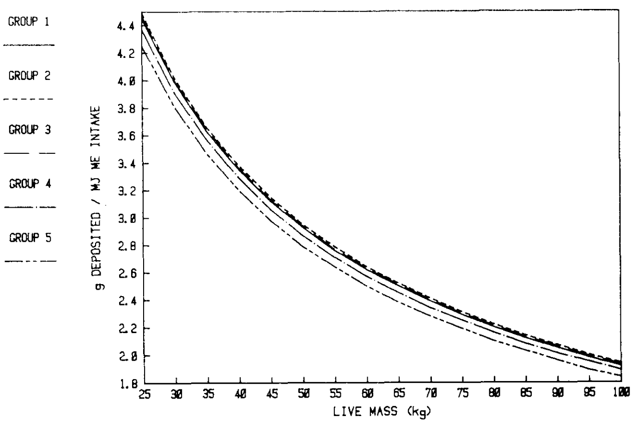

Fig. 5. *Protein deposited per MJ ME ingested at different live masses*

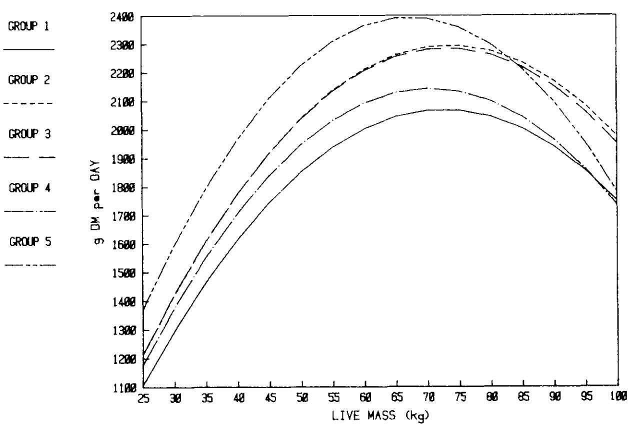

Fig. 6. *Feed intake at different live masses*

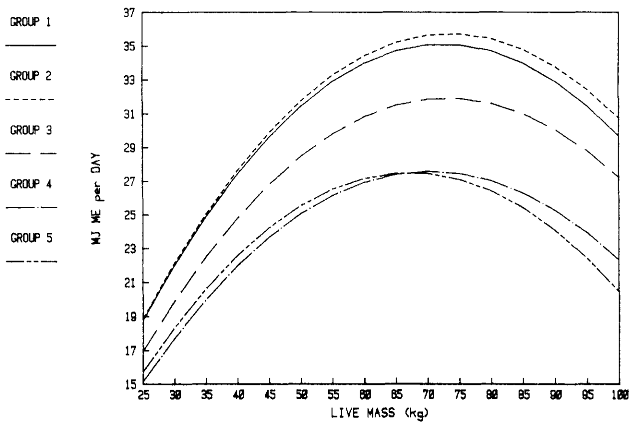

Fig. 7. *Daily metabolizable energy intake at different live masses*

Therefore, it can be postulated that when the dietary level of protein is sufficient the level of daily protein deposition will be positively correlated with daily energy intake. This is illustrated by the fact that the relative daily protein depositions (Fig. 1) followed the same pattern as relative energy intakes (Fig. 7) which in turn is substantiated by the fact that the amount of protein deposited per MJ ME-intake (Fig. 5) was almost the same for all the treatments. At 45 kg live mass, the amounts of protein deposited per MJ ME-intake for Treatments 1 to 5 were, respectively, 3,12; 3,15; 3,13; 3,06 and 2,98 g. The lower values calculated for Treatments 4 and 5 probably can be ascribed to the fact that protein had to be deaminated to provide energy which is in itself an energy consuming process (Thorbek, 1977).

From Fig. 1 the question arises as to why protein deposition declines after a maximum has been reached. Several investigators found nitrogen retention to be fairly constant after a maximum has been attained (Oslage & Fliegel, 1965 cited by Cöp, 1974; Thorbek, 1969; Homb, 1972; Wenk & Schürch, 1974). Fuller & Boyne (1971) and Wenk, Pfirter & Bickel (1980) found daily protein deposition to decline after a maximum has been reached. This apparent discrepancy may be due to the fact that different feeding regimes were used. Giles, Murison & Wilson (1981) observed that pigs fed restrictedly were able to increase their intakes throughout the live mass range whereas *ad libitum* intakes declined after a maximum was reached between 75 and 90 kg live mass. The A.R.C. (1967) cites a personal communication of W.E. Coey, who recorded reduced intakes by self-fed pigs after 73 to 81 kg live mass when given high energy diets. Reduced energy intakes (Fig. 7) together with reduced efficiencies (Fig. 5) caused reduced protein depositions beyond 45 kg live mass (Fig. 1). Should it be possible to increase energy intake along the entire growth phase, the decline in energetic efficiency (Fig. 5) could be offset and a constant protein deposition thus may be possible. Fuller (1976) reported a protein-sparing effect by adding carbohydrate (starch) to a diet. Therefore, the protein-sparing effect of additional starch could be attributed to a higher energy intake.

Conclusions

Reduced energy intake leads to leaner carcasses. This is illustrated by the total body protein for the 5 treatments at different live masses as presented in Fig. 8.

It is evident from Fig. 8 that pigs in Treatment 5 had the highest body protein content.

Feeding for leaner carcasses by reducing energy intake would limit protein deposition rates (Fig. 1) and protein turnover rates (Fig. 4). It would, therefore, be advisable to rather feed for optimal protein deposition than for maximal protein deposition. The only way to increase protein deposition without a deterioration in carcass quality (excess fat) would be by breeding leaner pigs (pigs with the ability to channel more feed energy towards protein deposition). Therefore, an experiment in which protein deposition of lean and obese pigs can be quantified should be performed.

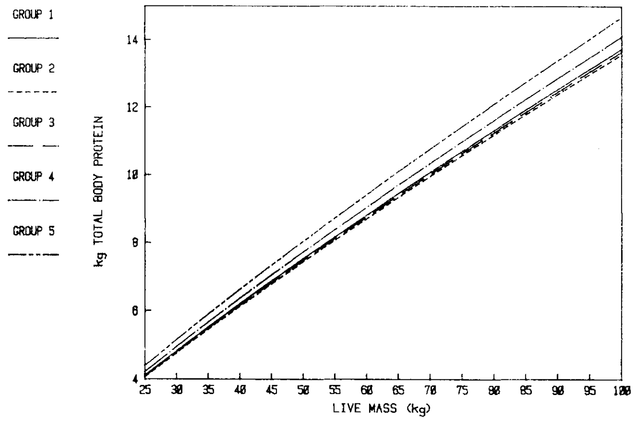

Fig. 8. *Total body protein at different live masses*

References

AGRICULTURAL RESEARCH COUNCIL, 1967. The Nutrient requirements of farm livestock. No. 3, Pigs. A.R.C. London.

COOKE, R., LODGE, G.A. & LEWIS, D., 1972. Influence of energy and protein concentration in the diet on the performance of growing pigs. 3. Response to differences in levels of both energy and protein. *Anim. Prod.* 14, 219.

Cöp, W.A.G., 1974. Protein and fat deposition in pigs in relation to body weight gain and feeding level. *Meded. Landbouwhogeschool Wageningen* 74–18.

FULLER, M.F., 1976. The effect of dietary carbohydrate on the utilization of protein by the growing pig. *Proc. Nutr. Soc.* 35, 149A.

FULLER, M.F. & BOYNE, A.W., 1971. The effects of environmental temperature on the growth and metabolism of pigs given different amounts of food. 1. Nitrogen metabolism, growth and body composition. *Br. J. Nutr.* 25, 259.

GILES, L.R., MURISON, R.D. & WILSON, B.R., 1981. Backfat studies in growing pigs. 1. Influence of energy intake on growth and carcass measurements at varying live weights. *Anim. Prod.* 32, 39.

HENRY, Y., DUEE, P.H. & SEVE, B., 1978. Construction of the amino acid requirement of the pig. 29th Annual meeting of the E.A.A.P., Stockholm, Sweden. 4–6 June 1978.

HENRY, Y., 1981. Variations of protein retention in the growing pig; consequences on the protein requirement. *Reprod. Nutr. Dévelop.* 21, 319.

HOMB, T., 1972. Proteinverwertung bei wachsenden schweinen 30–105 kg Lebendgewicht. *Z. Tierphys., Tierernähr und Futtermittelk.* 29. 123.

KEMM, E.H. & RAS, M.N., 1976. The protein and energy requirements of the pregnant gilt. II. Differences in the composition of the gilt body and her products of conception. *Agroanimalia* 8, 131.

LEWIS, D. & HARDY, B., 1970. The effect of dietary energy and protein on carcass composition in the growing pig. Ritena Conference: Majorca, May 1970.

LODGE, G.A., CUNDY, M.E., COOKE, R. & LEWIS, D., 1972. Influence of energy and protein concentration in the diet performance of growing pigs. 2. Differing nutrient density at a constant energy : protein ratio. *Anim. Prod.* 14, 42.

MEISSNER, H.H., 1977. An evaluation of the Roux mathematical model for the functional description of growth. Ph. D. Thesis, Univ. Port Elizabeth, S.A.

ROBINSON, O.W., 1976. Growth patterns in swine. *J. Anim. Sci.* 42, 1024.

ROUX, C.Z., 1974. The relationship between growth and feed intake. *Agroanimalia* 6, 49.

ROUX, C.Z., 1976. A model for the description and regulation of growth and production. *Agroanimalia* 8, 83.

ROUX, C.Z. & KEMM, E.H., 1981. The influence of dietary energy on a mathematical model for growth, body composition and feed utilization of pigs. *S. Afr. J. Anim. Sci.* 11, 255.

SIEBRITS, F.K., 1979. Die kwantifisering van effekte van nat teenoor droë voeding op die spekvark. M.Sc. (Agric) Thesis, Univ. Pretoria, S.A.

SIEBRITS, F.K., KEMM, E.H. & RAS, M.N., 1981. The effect of wet versus dry feeding and protein level upon the change in chemical composition of the growing pig. *S. Afr. J. Anim. Sci.* 11, 17.

THORBEK, GRETE, 1969. Studies on the energy metabolism of growing pigs. 4th Symp. on energy metabolism. Warsaw. *E.A.A.P. Publ.* 12, 281.

THORBEK, GRETE, 1975. Studies on energy metabolism in growing pigs fed different feed compounds. Efficiency of utilization of metabolizable energy for growth. *424. Beretning fra Statens Husdyrbrugs forsg Kbenbavn.*

THORBEK, GRETE, 1977. The Energetics of protein deposition during growth. *Nutr. Metab.* 21, 105.

WENK, C., PFIRTER, H.P. & BICKEL, H., 1980. Energetic aspects of feed conversion in growing pigs. *Livestock Prod. Sci.* 7, 483.

WENK, C. & SCHüRCH, A., 1974. Influence of the level of energy and protein in the feed on the energy metabolism of growing pigs. 6th Symp. on energy metabolism. Stuttgart. *E.A.A.P. Publ.* 14, 174.

WHITTEMORE, C.T. & ELSLEY, F.W.H., 1976. Practical pig nutrition. Suffolk: Farming Press Limited.