The application of the principles of nutrition to the feeding of breeding sows and the production of meat from growing pigs

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The causal relationship between feed supply and fat and lean growth is critical to effective determination of optimum feed supply to growing pigs. Although excessive fatness may be controlled by reducing feed intake, in early growth appetite limitation is such as to ensure a linear lean tissue growth response to increasing feed supply. For pigs of high intrinsic merit (entire males and animals of superior genotype), feeding to appetite may be justified until high livemass. The more likely the animal is to fatten, the earlier should restriction be imposed. For young growing pigs it is apparent that appetite is unnecessarily depressed in the commercial production environment. Studies of mass stasis and negative growth in newly weaned pigs have demonstrated a remarkable ability for fatty tissue catabolism. Experiments examining the responses of breeding sows to different levels of feeding in pregnancy and lactation point to the importance of maintaining sow body condition, and the unavoidability of some level of fat losses during lactation. The prediction of animal response to nutrient supply requires effective determination of the energy content of feed ingredients and compounded diets; the best prediction equations appear to favour the analysis of neutral detergent fibre rather than crude fibre.
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Die kousale verband tussen voedselvoorsiening en vet- en vetvrye groei is kritiek vir die effektiewe bepaling van optimum voervoorsiening aan groeiende varke. Alhoewel oormatige vetheid beheer kan word deur voedselinname te verlaag, word eetlusdemping op 'n vroeë leeftyd gebruik om 'n lineêre vetvrye weefselgroeirespons met toenemende voervoorsiening te verseker. Dit mag geregverdig wees om varke met hoë intrinsieke meriete (bere en diere met besondere genotipe) toe te laat om hul eetlus te bevredig, hoewel dit kan lei tot hoë liggaamsmassas. Dit is egter beter om diere wat meer geneig is om vet te word, op 'n vroeë stadium te beperk. Dit wil voorkom asof jong, groeiende varke se eetlus onnodig onderdruk word in die kommersiële produksieomgewing. Studies van massastase en negatiewe groei in pasgespeende varkies, het 'n merkwaardige vermoë getoon vir vetweefselkatabolisme. Eksperimente om die reaksie van teelsôe ten opsigte van verskillende voedingsvlakke gedurende dragtigheid en laktasie te ondersoek, het beklemtoon dat dit belangrik is om die sog se liggaamskondisie konstant te hou. Dit het ook die onvermydelike verlies van vet tydens laktasie uitgewys. Om die dier se reaksie op voedselvoorsiening te bepaal is dit nodig om die energie-inhoud van voerbestanddele en saamgestelde diëte deeglik te meet; die beste voorspellingsvergelykings is ten gunste van die bepaling van 'neutrale detergent vesel' eerder as ru-vesel.
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Introduction

Pig production is as much a business activity as a biological one; a proposition often forgotten when blueprints based upon biological targets such as feed conversion efficiency, growth rate, carcass quality, and piglets reared per sow per year are proffered by science for the use of practitioners. Neither may the industry best obtain answers to practical problems by undertaking practical experiments, nor is comparison of performance in factorial feeding trials likely to be the most effective guide to optimum diet by ration combinations for producer units. The alternative approach to the optimization of nutritional strategies is to put aside both the blueprint and the applied feeding trial approach, and to attempt to understand the causal forces of growth and lactational responses to nutrition. Once done, the system can be simulated and responses predicted, allowing pig producers to take entrepreneurial — rather than merely biological — decisions as to nutritional needs.

Protein supply

Daily lean tissue growth response to increasing protein supply is linear (Fowler, 1984) until either energy becomes limiting, or protein supply becomes excessive to the demands of the animal to achieve its maximum rate of daily lean tissue growth. The response to increasing protein concentration (that is a widening of the energy:protein ratio), may be depicted as in Figure 1. In the diagram the total amount of food supplied is assumed to supply adequate energy to maximize lean tissue growth. Levels of feed supply below this would cause lean tissue growth to plateau below the maximum, whilst feed supply above the optimum would maximize lean tissue growth at poorer (narrower) energy:protein ratios, but simul-

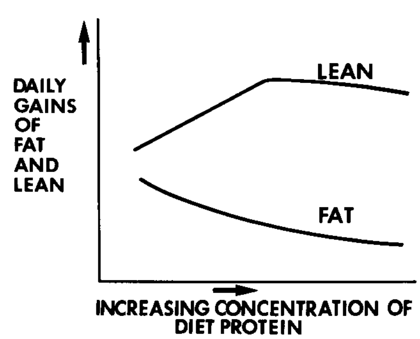

Figure 1 Influence of increasing concentration of protein in the diet (a widening of the ratio MJ DE:g CP) upon the daily gains of fat and lean tissues.

taneously produce greater amounts of fat in the gain (Whittemore, 1980). The figure shows how, at optimum level of total feed supply, diets that do not provide adequately for the requirement of ideal protein (Agricultural Research Council, 1981) fail to allow maximum lean tissue growth. Energy thus freed from protein synthesis is used for fat growth. Oversupply of protein consumes energy for deamination, bringing about a net reduction in the energy supply. The consequence of excess protein supply will therefore be a further diminution of fatness, and the achieved level of daily lean tissue growth may also be reduced consequent upon an inadequacy of energy. Optimum total feed supply is that which allows maximization of lean tissue growth, but does not exceed that requirement. Optimum energy:protein ratio is that which, at optimum level of feed supply, allows maximization of lean tissue growth but gives no encouragement to fat growth above that minimally required for physiologically normal positive growth.

Energy supply

The hypothesis for daily gains of fat and lean in response to daily feed supply shown in Figure 2 (Whittemore & Fawcett, 1976) implies that the attainment of maximum daily rate of lean tissue growth is primarily dependent on nutrient supply. That the intrinsic limits to lean growth rate are broadly similar over the whole of the 10 – 120 kg growth period for pigs has recently been confirmed by Tullis (1982). As food intake increases, daily lean tissue gains increase linearly to the point at which the maximum or plateau is reached. The slope of the response of lean tissue gains to daily feed supply in this nutritionally limited phase of growth is dependent on the amount of fat being laid down as a minimum requirement for normal growth. The height of the plateau for daily lean tissue growth rate and the ratio of fat to lean in nutritionally limited growth is dependent upon the sex and genotype of the pig. Variation in the steepness of the slope and in the height of the plateau has the effect of causing differences between pigs in growth responses to feed intake. The point at which the slope joins the plateau for daily lean tissue growth gives the feed intake level at which the pig will begin to fatten. The absolute amount of food relating to this point will also depend upon the amount of food used for maintenance, and the daily feed supply that relates to the beginning of the plateau will therefore increase as the pig grows. The point at the beginning of the plateau is critical for maximizing daily lean gains whilst minimizing the growth of fat. To the left of that point feed intake is inadequate to maximize lean tissue gains, whilst to the right of it feed intake is excessive with the consequence of surplus fat deposition. Pigs of higher merit will have higher potentials for daily lean tissue growth rate, the plateau will be raised and the point at which it will be reached will relate to a higher feed supply.

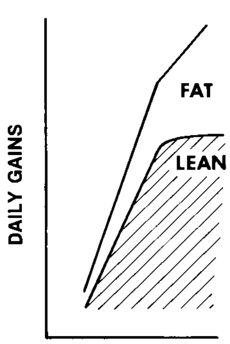

Figure 2 Growth responses to nutrient supply.

It is evident that young pigs may fail to reach their potential lean gains because of limited appetite; increasing feed intakes will invariably result in linear lean growth responses with no fattening in the case of young pigs. If, for pigs below 40 kg, the physical bounds of appetite restrict food supply to the nutritionally limiting range, then the reverse can often be the case above 40 kg, especially for castrated males or animals of low genetic merit. In these latter cases avoidance of fattening may be achieved by restricting the feed supply in such a way that it remains in the nutritionally limiting phase. Some particularly able strains, or genotypes with inherently low appetites may never eat enough to fatten before their slaughtermass is attained.

Early post-weaning growth

The foregoing propositions would appear to dismiss a strong relationship between the possibilities for lean tissue growth rate and livemass, whilst encouraging a view that lean growth is appetite driven in the young pig with a maximum distant from current achievement. Experiments with pigs grown from 6 – 24 kg (Tullis, 1982; Stamataris, 1985) indeed demonstrate that where appetite can be enhanced, growth rates of double the commercial standard or greater can be achieved. The unavoidable conclusion is that the growth of young pigs under present commercial husbandry conditions is unnecessarily retarded, and can be enhanced by the simple expedient of increasing feed intake. Daily feed intakes measured by Tullis (1982) are shown in Figure 3.

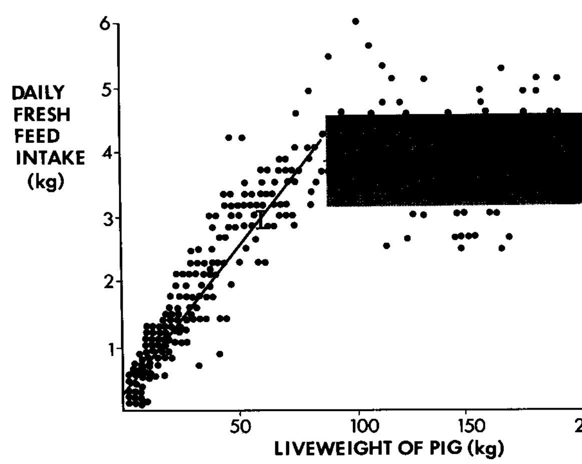

Figure 3 Feed intake of pigs in relation to live bodymass (Tullis, 1982).

Negative growth

Lipid catabolism and protein anabolism may occur simultaneously under nutritional stress such as occurs post-weaning in the young pig and during lactation in the breeding sow. In young pigs the post-weaning percentage of fat can be halved in 7 days (Whittemore, Aumaitre & Williams, 1978), whilst the livemass remains constant; the difference being made up by an increase in water content. Figure 4 shows the constancy of the proportion of protein in the empty body of baby pigs, whilst Figure 5 shows how, because of post-weaning fat catabolism, the proportion of lipid in the empty body is reduced dramatically, and remains so in consequence of the parallelism of subsequent response. In a study of the nature of negative growth immediately post-weaning (Whittemore, Taylor, Henderson, Wood & Brock, 1981), bodymass

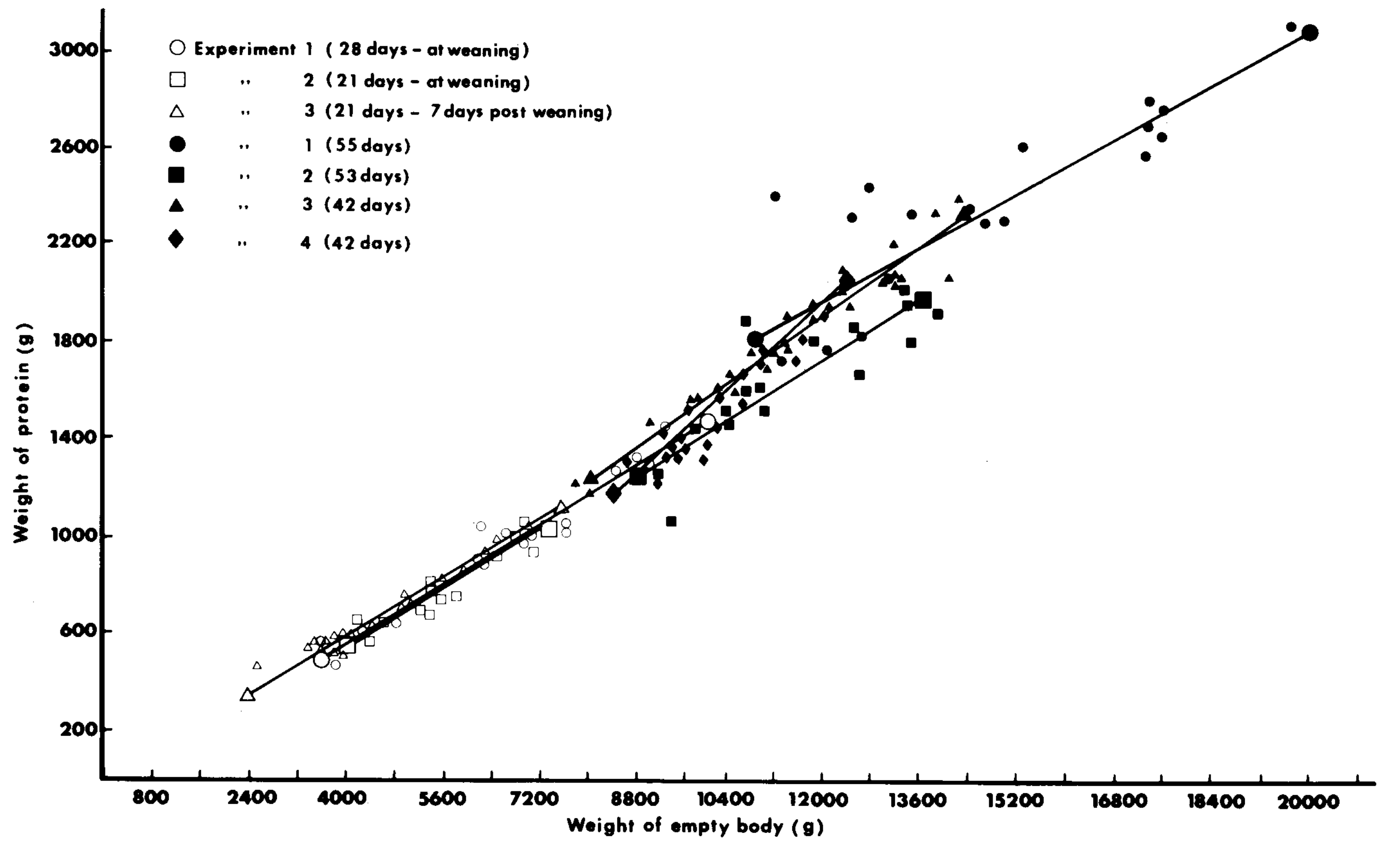

Figure 4 Protein content of the empty body of pigs.

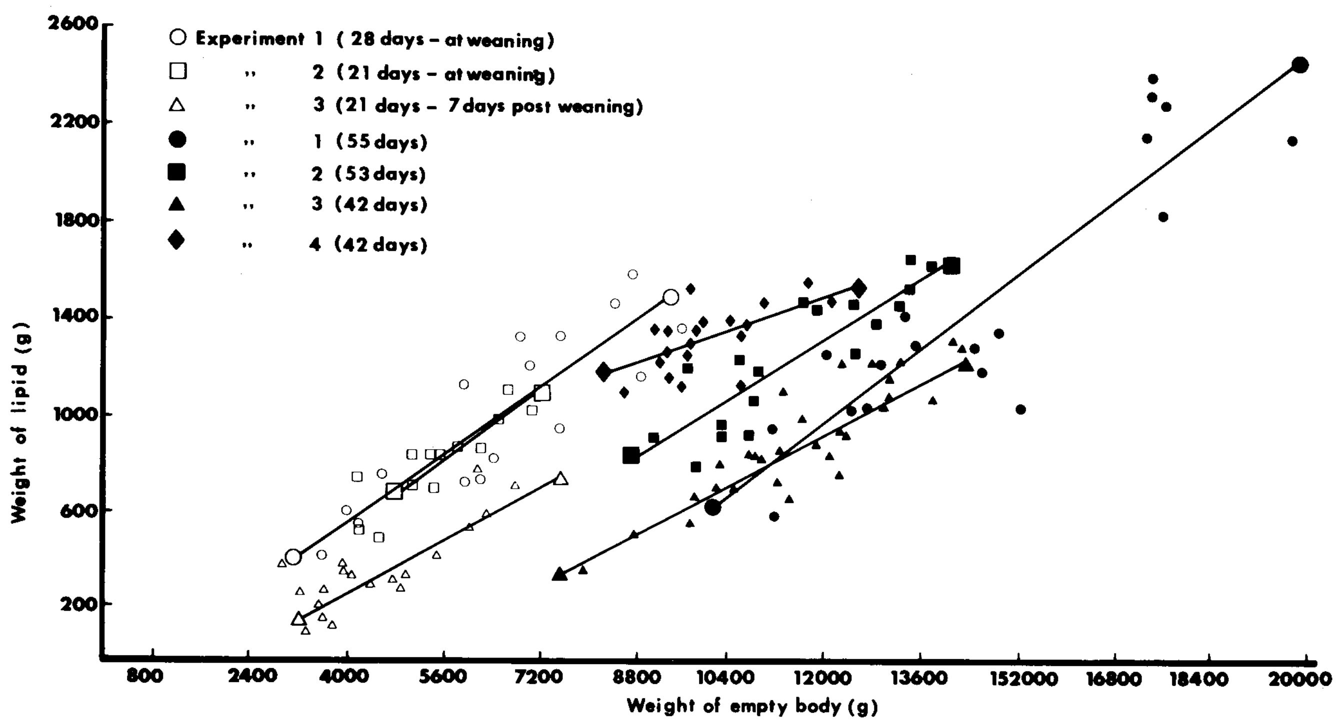

Figure 5 Lipid content of the empty body of pigs.

stasis concealed lipid losses of about 50 g daily and counter-balancing water gains. Lipid anabolism appears not to have begun until empty bodymass gains of 200 g or so were being achieved. At empty bodymass and gains ranging from 50–200 g daily, lipid catabolism was supporting protein anabolism. It is apparent from this experiment that, unless carefully nurtured, there is a high likelihood of young pigs falling into a state of fatty tissue catabolism.

Responses of breeding sows to feed supply in pregnancy and lactation

The ability of sows to lose fat and gain mass simultaneously (Whittemore, Franklin & Pearce, 1980) has been examined in a more recent experiment (Whittemore, 1985) shown in Figures 6 and 7. The similarity of fatness at weaning, achieved despite different fatnesses at farrowing, demonstrates the

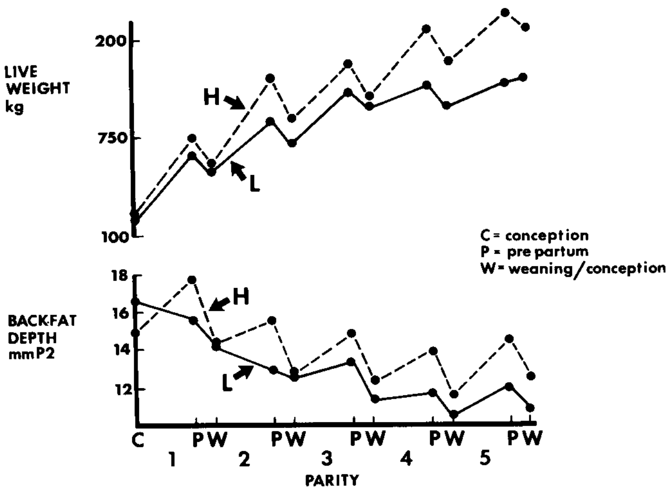

Figure 6 Changes in livemass and backfat depth of sows fed in pregnancy either to maintain body fatness (about 2,3 kg daily, H) or to lose fat rapidly (about 1,7 kg daily, L).

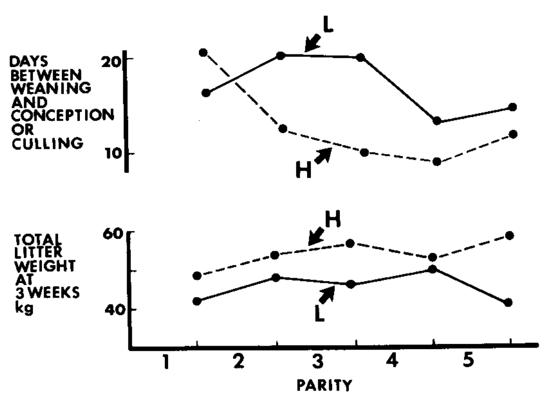

Figure 7 Influence of high (H) and low (L) feeding levels in pregnancy upon reproductive characteristics. See also Table 2.

Table 1 Measurements of backfat depth, livemass and reproductive performance over five parities for sows given three feeding levels in pregnancy

	Treatment (feeding level in pregnancy)			
Measurement	High	Medium	Low	sed
P2 at conception (mm)[b]	13,3	13,5	14,1	0,65
Mass at conception (kg)	151	144	136	2,7
Condition score at conception[c]	6,7	6,5	6,4	0,27
P2 at pre-partum (mm)[a]	15,5	14,4	13,6	0,73
Mass at pre-partum (kg)[a]	186	170	161	3,0
Condition score at pre-partum	6,8	6,4	5,8	0,28
P2 at weaning (mm)	12,7	12,1	12,0	0,69
Mass at weaning (kg)	168	162	152	3,0
Condition score at weaning	6,2	5,8	5,6	0,30
Number of pigs born alive	10,8	10,4	11,1	0,45
Mass of litter at 3 weeks (kg)	53,4	46,9	45,7	2,1
Weaning to conception or culling (days)	10,6	12,6	14,9	2,8

[b]Depth of backfat between exterior of the skin and the interface between the fat and lean layers 65 mm from the mid-line measured at the last rib position.
[c]On a 10-point scale 0 – 10, where 0 is very thin and 10 very fat.
[a]Measurement taken 2 – 4 days before parturition.

Table 2 Fat and mass losses in lactation as a function of fat and mass gains in pregnancy, and readiness to rebreed as a function of absolute fat and mass

Fat loss (mm P2) pre-partum to 28-day weaning
= 2,5 + 0,3 × fat gain in pregnancy

Mass loss (kg) pre-partum to 28-day weaning
= 4,1 + 0,3 × mass gain in pregnancy

Log_e days weaning to conception
= 3,7 – 0,033 × fat at weaning (mm P2) – 0,008 × mass at weaning (kg)

Table 3 Fat and mass losses in lactation as a function of lactation feed intake

Mass loss (kg) post-partum to 28-day weaning
= 50,0 – 9,8 × feed (kg/day)

Fat loss (mm P2) post-partum to 28-day weaning
= 11,3 – 1,4 × feed (kg/day)

ability of the lactating sow to adjust to her perceptions of previous nutrient supply (Table 1). Fat and mass losses in lactation were strongly related to fat and mass gains in pregnancy (Table 2). The total litter mass at weaning was positively influenced by fat and mass losses, whilst absolute sow mass and fatness were positive influences upon readiness to rebreed.

In a recently completed experiment, studying response to level of feeding in lactation alone, simple linear regressions expressing mass loss and fat loss as functions of daily feed intake in lactation show that it would require about 5 kg of feed daily to prevent mass losses in lactating sows, but 8 kg daily to prevent fat losses (Table 3). While mass stasis in lactation may therefore be a feasible target, it appears that some fat losses in lactation cannot be denied. An extra kilogram of food daily will save about 10 kg of sow mass loss and about 1,5 mm of P2 fat loss. The weaningmass of piglets was positively related to sow feed intake, but the slope of the response was shallow. The relationship: Total dissected fat (%) = (0,92 P2) – 1,6; can be used to estimate absolute mass of fat lost over the lactation. Fat loss (kg) ≏ (0,3 mass loss) + 7,5. It was apparent that sows ingesting little food in lactation catabolized body tissue to maintain milk yield and litter growth; although they achieved this imperfectly, having lighter litters. Taking into account the need to subsequently replenish fatty and non-fatty tissues catabolized in lactation, an overall net balance may be calculated. The conclusion was that whilst in the short term animals fed lower amounts of food in lactation appeared to be the most efficient, overall those fed the highest levels of feed had the highest efficiencies of conversion of total food usage into piglet product. Notwithstanding the benefits of weaning in reasonable body condition upon rebreeding efficacy as demonstrated in the earlier experiment; it would also appear from the standpoint of efficiency that appropriate feeding strategy in lactation should tend toward *ad libitum*.

Feed evaluation

Effective prediction of responses to nutrients has the prerequisite of an ability to define nutrient supply. A recent review of energy evaluation of feeds and compounded diets for pigs (Morgan & Whittemore, 1982) concluded the need

Table 4 Equations to predict DE (MJ/kg DM) from the chemical composition of compounded feeds (g/kg DM)

Equation	rsd^d
$DE^a = 3{,}8 - 0{,}019\ NDF^b + 0{,}76\ GE^c$	0,38
$DE = 17{,}0 + 0{,}016\ EE^e - 0{,}018\ NDF$	0,44
$DE = 17{,}0 + 0{,}011\ EE - 0{,}041\ CF^f$	0,66
$DE = 18{,}0 + 0{,}016\ EE - 0{,}017\ NDF - 0{,}016\ Ash$	0,41
$DE = 17{,}5 + 0{,}016\ EE - 0{,}008\ CP^g - 0{,}033\ Ash - 0{,}015\ NDF$	0,32

[a]DE = Digestible energy; [b]NDF = neutral detergent fibre; [c]GE = gross energy; [d]rsd = residual standard deviation; [e]EE = oil by petroleum spirit extraction; [f]CF = crude fibre; [g]CP = crude protein.

for an improved methodology for the prediction of the energy value of compound food for pigs. Table 4 (Morgan, Whittemore, Phillips & Crooks, 1984) gives a selection of the more simple equations that may now be used with acceptable accuracy of prediction. Notable amongst the characteristics of these equations are their biological logic (despite their mathematical derivation), and the importance of neutral detergent fibre rather than crude fibre if effective prediction of DE for pigs is to be achieved.

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