Review

Energy and protein requirements of pigs and the utilization of fibrous feedstuffs in Nigeria

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A sound nutrition programme, which allows the understanding of the interaction between nutrients and requirements for different levels of production, is essential for raising swine profitably. Nutrient requirement is that amount of each essential nutrient that will result in maximum production with a minimum of feeding. Hence, high quality feeds containing the essential nutrients in the amounts necessary to meet the animal's requirements must be provided, in order to attain an optimal rate and efficiency of growth from birth to market. The formulation of balanced diets that provide the correct amounts and proportions of these nutrients is essential to support the requirements for maintenance, growth and reproduction of the animal. It is only then that the feeding programme can be said to have a major impact on the performance and the overall profitability of the swine herd. The scarcity of conventional feeds has hindered the growth and development of the livestock industry in Nigeria. The general shortage of energy and protein feeds appear to be more severe for non-ruminants that depend to a great extent on compounded feeds, especially pigs, which are bulk feeders. There are a number of agro-industrial by-products, farm waste or crop residues that have been exploited as alternative feed sources for the high energy cereals. This has made a substantial contribution towards better and more economic feeding of non-ruminants. However, fibrousness, a feature of most locally available agro-industrial by-products and wastes has limited their use.

Key words: Feeding programme, balanced diets, fibrous feedstuffs.

INTRODUCTION

In recognition of the potential of pig as a prolific and fast growing animal, as well as a good converter of feed to meat, many Nigerian farmers have embarked upon intensive production of pigs. This is an effort geared towards increasing animal protein supply, at reduced cost for human consumption (Adesehinwa et al., 1998). Pig production represents the fastest means of correcting animal protein shortage in Africa. This is because, apart from their high rate of reproduction, poultry and pigs are characterized by the best efficiency of nutrient transformation into high quality protein (meat), although the cost of the transformation is very high (Tewe and Egbunike, 1988). Therefore, nutrient supply has to be judiciously manipulated to ensure the production of meat at economic rates. There exists in country some agro-industrial by-products and crop residues that can be used as total or partial replacements for the conventional ingredients in finished livestock feeds. Pigs are capable of converting these agro-industrial by-products or 'wastes' of all kinds (which will normally be discarded by humans) into wholesome animal protein useful to the human being.

The NRC (1988) recommendations of nutrient requirements, assumed to contain 90% dry matter and based on corn-soybean meal diet has been questioned in the tropics by the depressed feed intake, hence, depressed nutrient intake, resulting from the high ambient temperature and humidity prevalent in the tropical environment (Tewe and Adesehinwa, 1995a). Rao et al. (1976) concluded that animals in the tropics performed better when fed on an energy level 10% lower than the NRC recommendations. Fetuga (1984) in a similar study on energy, protein and amino acids requirements of pigs raised in the humid tropic concluded that a higher dietary protein is required.

Nutrient requirement was however reported (Conrad, 1984) to be such that it gives an account of the amount of each essential nutrient that will result in maximum pro-

duction with a minimum of over-feeding. He observed that these requirements must include a factor of safety so that normal variation in the composition and nutritive value of feeds and in the functional capacities of animals will never result in under feeding. It should be noted that the safety cannot be introduced until minimum requirements have been established. The minimum requirements of the essential nutrients have been report-ed for all classes of pigs both in the temperate regions (Cooke et al., 1972; Wylie and Owen, 1978) and the tropical areas of the world (Devendra and Parris, 1970; Fetuga, 1972, 1984; Babatunde et al., 1972; Dividich and Canope, 1978).

ENERGY REQUIREMENTS

The energy requirements of pigs are very variable. They are higher with increasing body weight, as basal metabolism and maintenance requirements are proportional to live weight as well as to growth rate (Serres, 1992). The more the animal grows, the more it requires energy to sustain this growth. From weaning until 20 kg, 1 kg of live weight represents about 3000 calories while at 90 kg, it is 5000 calories and it is beyond 6000 calories for fat pigs (Serres, 1992).

Energy supplied to the animals may be measured as gross, digestible or metabolizable. The gross being that amount of energy liberated during complete combustion of the diet, which is of little practical value as a measurement. The digestible energy (DE) is that proportion remaining after digestion and may be estimated from the difference between energy of food ingested and energy of faeces voided. While, the metabolizable energy (ME) is the digestible less energy lost in the urine (Serres, 1992). Farrell (1978), Agricultural Research Council (1981), and Morgan and Whittemore (1982) suggested that DE is preferable in describing the energy content of swine feeds because DE is more easily and precisely determined than ME. The gaseous loss of energy in the digestive tract of swine is usually between 0.5 and 1.0% DE (Verstegen, 1971; Fuller and Boyne, 1972). The values are small and not measured hence they are ignored (NRC, 1988). The quality and quantity of protein in the diet was reported (May and Bell, 1971; den Hartog and Verstegen, 1984) to affect the relationship between ME and DE.

Metabolizable energy decreases if protein is of poor quality and with excess protein because the amino acids not used for protein synthesis are catabolized and used as a source of energy and the nitrogen is excreted as urea (NRC, 1988). The energy level of the diet must be related to other components. Longe (1988) reported that good diet formulation required that a balance be attained between the percentage crude protein and the number of energy units in the diets. This view was supported by Fashina (1991) who reported the existence of a relationship between the dietary energy and protein requirements

of pigs. Energy : protein ratios that deviate from those that will make animals perform optimally will therefore result in marked difference in performance (Longe, 1988).

The net energy (NE) is the best measure of energy available to an animal for maintenance and production (NRC, 1988), and it is lower than the ME because of losses associated with biochemical pathways within the animal (Serres, 1992). It defines the efficiency of utilization of the productive purposes. The NE value is influenced by the composition of the feedstuff, level of feed intake, balance of nutrients in the diet, age, breed, sex, body condition of the pigs, environmental conditions under which the animal is maintained, and percentage of energy retained as protein (Farrell, 1979; van der Honing et al., 1985).

The DE requirement of the growing pig was described by NRC (1988) as the sum of its requirements for maintenance, protein retention, fat retention and cold thermogenesis. Maintenance energy requirements include needs for all body functions and moderate activity and it is expressed on a metabolic weight basis. Although the mean energy cost per kg of protein or fat deposited are approximately equal (Wenk et al., 1980), 1 kg of lean muscle tissue is only 20 to 22% protein. Therefore, the energy cost for muscle production is considerably less than that for fat production (NRC, 1988). The cold thermogensis influences energy requirements when the ambient temperature is below the critical temperature (which is the point below which an animal must increase heat production to stay warm).

The energy content of the diet therefore generally controls the amount of feed consumed *AD LIBITUM* daily (ARC, 1981; Cole, 1984) and pigs will compensate for decrease or increase in the nutrient density of the diet by increasing or decreasing their feed intake. This compensation normalizes energy intake within limits (NRC, 1988). However, voluntary feed intake varies considerably from day to day and among individual pigs (Frank et al., 1983).

The metabolic utilization of the metabolizable energy or heat increment was reported by Noblet et al. (1994) to vary according to the diet's chemical characteristics and type of production (maintenance, growth, milk secretion, protein and fat deposition etc). The average efficiencies of utilization of the ME for these different purposes have been shown to differ markedly in swine: approximately 80% for fat gain (kg) or maintenance; 60% for protein deposition; 75% for weight gain (kg) during growth and 70% for milk (ARC, 1981; Noblet et al., 1990, 1991 and 1993).

PROTEIN REQUIREMENTS

In swine nutrition, a good quality protein is one that provides the ten essential amino acids required for the normal body function in the amounts and proportions necessary for the particular need of the pig (Adesehinwa

and Ogunmodede, 1995). Traditionally, swine diets are formulated on the basis of crude protein. This refers to the nitrogen content of the feedstuff x 6.25 (NRC, 1988). Amino acids are critical nutrients required by all classes of swine for the physiological processes of maintenance, growth, gestation and lactation (Fashina, 1991). Hence protein levels are established for the various weight classes of pigs so that the most limiting amino acid (lysine) will be present in adequate amounts (Adesehinwa and Ogunmodede, 1995).

Amino acids are reported to be the chemical components of protein and are generally supplied to the pig from the crude protein in the diet (Fashina, 1991). Failure to supplement a low protein diet or feedstuff with sufficient amounts of high quality protein source was reported by Adesehinwa and Ogunmodede (1995) to result in poor growth, inefficient feed utilization, increased carcass fatness, general unthriftiness and or reduced reproductive performance. The capacity of the diet or feedstuff to provide sufficient indispensable (essential) amino acids and nitrogen for the synthesis of dispensable (non essential) amino acids determines the adequacy of the dietary protein level (NRC, 1988). Hence, the need for a nutritionally balanced ration in an economically viable pig production system (Adesehinwa, 1992).

Lower levels of dietary protein are required to maximize growth and efficiency of gain for a protein source with well balanced amino acid profile (Bender, 1975) in contrast to a protein source with poor amino acid pattern where more is required, to be efficiently utilized (Adesehinwa, 1992). Protein quality therefore becomes synonymous with amino acid balance. The amino acid requirements expressed as a percentage of the diet decrease as the pig becomes heavier, that is, the requirements are greatest during the rapidly growing stages of the young animal (Conrad, 1984).

The young animal was reported as not only growing at a more rapid rate as indicated by the percentage increase in the weight but that the proportion of the protein in the entire body weight is higher than during the finishing period. These changes in the rate of growth and body composition are the basis for recommending diffe-rent dietary protein levels to meet the amino acid requirements during the life of the pig (Fanimo, 1991). Fetuga (1984) reported the protein and amino acid requirements for the tropics to be higher than those recommended by NRC (1979) for the temperature zones. This view was also reported in an earlier work by Babatunde et al. (1972). The variation in the recommended protein and amino acid allowances for different classes of pigs was attributed in part to variations that exist in the protein sources or protein qualities used.

UTILIZATION OF ALTERNATIVE FEEDSTUFFS BY PIGS

Livestock production in Nigeria which had its boom in the

late 70s is now taking a downward trend because of the high cost of production. Commercial production takes two distinct forms or levels. There are large scale and small scale producers, each having its operational characteristics. However, for the successful take-off of either of the two scales of production, availability of feedstuffs in the right quality, quantity and price are very important.

The astronomic rise in the price of livestock feeds has recently reached an alarming proportion. Scarcity and outright non-availability of raw materials for feeds has hampered production and expansion of the livestock industry. Stock population decrease is being embarked on by some farmers in order to meet the increasing feed bills and in most cases terminating in outright withdrawal from production. This upward trend in feed cost is due largely to steep prices of and diversified use of maize, increasing prices of guinea corn, groundnut cake, soybean products and fish meal. These shortages have either kept most feed mills in the country idle or operating, well below production capacity. These increases in prices over the years have also resulted in increased prices of some livestock products.

Apart from the high prices, other factors include, astronomical and uncontrollable shortage of basal feed ingredient, the cereal grains; growing shortage of oil seed cakes which Nigeria used to produce and export in large qualities; adulteration of feed ingredients (particularly common with fish meal and groundnut cake, which suppliers now blend with brown sand and saw dust); lack of quality control body or the inefficiency of such body to monitor ingredient and finished feed composition and quality, and the seeming lack of government incentive to feed manufacturers or producers.

While the shortages of raw materials for livestock feeds production, particularly poultry and pigs are numerous, however, the emphasis seems to be on the shortage of grains (basal energy feed) and protein supplements which together constitute about 70-80% of finished products (Noblet et al., 1994). With the ban on their importation and the increasing demand for maize for industrial use as livestock feeds, beer production, baby foods, local consumption and staple food, the need to find substitutes to these items becomes urgent. Such substitutes must be readily available or should be produced in commercial quantities at lower cost. This in essence means shifting to ingredients for which there is less competition by other secondary industrial users and producers.

ALTERNATIVE ENERGY SOURCES

Maize is a major grain crop grown in Nigeria and is used mainly in human foods as well as energy feed ingredient in animal production. Its use in the brewing industry and production of composite flours for confectioneries has robbed the livestock industry of its fair share of the total maize available in the country (Longe, 1988). This is re-

flected in the high prices of the finished feeds containing maize. Since the feed crisis of 1983, efforts have been made to seek alternative energy sources to maize, and some other conventional feed ingredients.

These alternative energy sources must be locally available, cheap and be able to replace a certain proportion, if not all of maize normally incorporated in diets of pigs without adverse effect on performance and product. Most of these energy sources, if not all, are agro-industrial by-products that are low in energy, high in fibre and bulky in nature. They were hitherto used as energy diluents in swine ration (Tegbe et al., 1995). Generally, except for rice offal and cassava peel meal, the crude protein content of most of the agro-industrial by-products are higher that that of maize. Their essential amino acid profiles also compare favourably with that of maize, thus showing that they could serve as sources of some essential amino acid in livestock feed (Tegbe et al., 1995).

Feed ingredients which have been successfully incorporated into the diets of pigs as alternative energy sources include wheat offal (Tegbe et al., 1984; Tegbe et al., 1986), brewers dried grains (Tegbe, 1983 and Tegbe, 1985a), rice offal (Tegbe et al., 1984 and Tegbe, 1985b), rice mill by-product (Attah et al., 1991), sorghum offal (Adesehinwa, 1992; Tegbe et al., 1995), cassava peel meal (Tewe and Oke, 1983; Nghi, 1986; Tewe et al., 1987; Iyayi and Tewe, 1988; Tewe and Egbunike, 1988; Tegbe et al., 1992a; Tewe and Adesehinwa, 1995a), palm kernel cake (Tegbe and Jegede, 1988; Tegbe et al., 1992b; Jegede et al., 1994; Tegbe et al., 1995) and maize offal (Tewe, 1988a; Longe and Fagbenro-Byron, 1990; Ande, 1992).

ALTERNATIVE ANIMAL AND PLANT PROTEIN SOURCES

The alternative animal protein sources are animal by-products obtained primarily from slaughter houses, surplus milk products and aquatic sources or wastes arising from animal production (Sonaiya, 1988). Virtually all these by-products can be used in the formulation of livestock feeds to supply protein or amino acids and minerals, in appreciable amount. They include meat and bone meal, blood meal, chicken offal meal, snail meal, prawn dust, shrimp meal, insect and fly larvae meal. Other animal protein sources available for livestock feeds include meat scrap, hatchery by-product meal and, feather and hair meal. The sources of plant origin include soybean meal, groundnut cake sunflower meal and rapeseed meal. Soybean meal is usually the most economical source of high quality plant protein available (Adesehinwa and Ogunmodede, 1995) because in terms of quality of amino acid content and ratio, it compares favourably with animal protein sources in most swine diets.

Most pig diets in the temperate countries have been al-

most exclusively based on maize and soybean meal, while in Nigeria, the diets have been largely based on maize and groundnut meal or cake. It is only in recent times that the extensive use of soybean meal became prominent in pig feeding. The depletion of a large number of commercial pig and poultry stock has be reported to be due to the scarcity and high cost of groundnut cake, soyabean and fish meals (Tewe, 1988b).

UTILIZATION OF FIBROUS FEEDSTUFF IN PIG NUTRITION

Various studies suggest that the pigs can utilize fibre for their growth, since fibre can be degraded by microbial fermentation. However, this process is reported to be confined to the lower part of the gastrointestinal tract and the products are volatile fatty acids, which can contribute significantly (5-30%) to the net energy requirements of pigs (Kass et al., 1980; Ehle et al., 1982; Rerat et al., 1987).

Fibrousness of feedstuffs (mostly of by-products of plant origin) is important in relation to their feeding value to pigs. The fibrous components of plant materials are cellulose, hemicellulose and lignin. The influence of crude fibre on organic matter digestibility varies from feed to feed, depending on the special characteristics of the crude fibre in individual feeds (Kidder and Manners, 1978). The fibrous portion of feed, being fairly indigestible to pigs, influences the digestibility of the other constituents by excreting a protective action, encasing these constituents in a digestion-proof shield, as it were. However, for efficient pig feeding, some form of physical treatment of cereal grains is essential to the breaking down of the fibre encapsulating the more soluble constituents so that digestive secretions can penetrate more completely (Kidder and Manners, 1978).

The addition of fibre to swine diets decreases the digestible energy (DE) and metabolizable energy (ME) concentration of the diet (Kennelly et al., 1998; Kennelly and Aherne, 1980) and often results in bulk feeds. Increased feed intake generally results as the pig attempts to maintain DE intake (Baird et al., 1975; Agricultural Research Council, 1981; Low, 1985). This could increase the length and weight of gastro-intestinal tract even when the fibre is eventually fermented (Stanogias and Pearce, 1985a and b). This change has been associated with physical properties of fibrous feeds such as its bulk (Longe and Fagbenro-Byron, 1990).

When dietary crude fibre exceeds 10-15% of the diet, feed intake may be depressed because of excessive bulk or reduced palatability (Braude, 1967). Low energy (as obtains for most high fibre diets) will support growth rates equal to those of pigs fed higher-energy diets at low temperature but usually depress the growth rate during periods of high temperatures (Coffey et al., 1982; Stahly, 1984).

Several researchers have tried to establish a relationship

between DE and the fibrous components of the diet (Drennan and Maguire, 1970; King and Taverner, 1975; Henry, 1977). Longe and Fagbenro-Byron (1990) later reported the apparent digestible energy to be influenced by the level of dietary neutral detergent fibre (NDF), while Henry (1977) showed it to have an inverse relationship to the fibre content, the former decreasing as the latter increases. However, the extent of the decrease in DE varied with the feedstuffs, depending on the composition of the cell wall constituents, particularly the ADF : NDF ratio (Pond, 1987).

Utilization of crude fibre by non-ruminant has been shown to vary considerably depending on the fibre source (Laplace and Lebas, 1981), degree of lignification (Forbes and Hamilton, 1952), level of inclusion (Farrell and Johnson, 1970; Just, 1979) and extent of processing (Saunders et al., 1969; McNab, 1975). The level of the fibrous feedstuff used in pig diets varies with the proportion of the cell wall constituents and it is generally thought that high fibre diet (>25% cell wall contents) will decrease growth efficiency in pigs (Longe and Fagbenro-Byron, 1990). Stahly and Cromwell (1986) reported that the digestibility of NDF is optimized in pigs fed diets containing 15% or less NDF.

Fibre utilization is also influenced by the physical and chemical composition of the total diet (Myer et al., 1975), level of feeding (Cunningham et al., 1962) age and weight of animal (Zivkovic and Bowland, 1970), adaptation to the fibre source (Pollman et al., 1979) and individual differences among pigs (Keys et al., 1970 and Farrell, 1973). When these factors are considered, it is not surprising that the digestibility of crude fibre has been shown to vary between 0 and 97% (Rerat, 1978) and that the literature contains conflicting reports about effects of crude fibre on the digestibility of nutrients (NRC, 1988).

There is disagreement concerning the influence of crude fibre on protein digestibility (NRC, 1988). Several reports suggest that when the source of crude fibre does not contribute significant amounts of protein in the diet, then an increase in the level of fibre does not affect protein digestibility significantly (Eggum, 1973; Kennelly and Aherne, 1980). Other researchers have observed, however, that an increase in the dietary level of fibre decreases protein digestibility (Kass et al., 1980; Frank et al., 1983). Just (1982) reported that an increase in dietary fibre by 11% depressed digestibility of gross energy by approximately 3.5%.

Longe and Fagbenro-Byron (1990) in their studies on fibrous waste and by-products for pig feeds in Nigeria concluded that fibre sources in general, may be best suitable for adult pigs. This, they attributed to their requirement for lower dietary energy to obtain a desirable carcass lean: fat at slaughter. This agreed with the significant potential for fibre degradation in the pig large intenstine (Varel, 1987). The appreciable contribution to the total digestible energy (Rerat et al., 1987) encourages giving serious consideration to these fibrous materials and their potential as feed resources in pig production. Though,

Longe and Fagbenro-Byron (1990) did not fail to add that the economics of production will need to be considered also in determining the suitability of fibrous materials as feed ingredients. However, high fibre diets were reported to be associated with some cardiovascular risks such as low density lipoprotein and total cholesterol (Ande, 1992) and reduction in blood glucose and serum insulin concentrations (Dodson et al., 1981).

NUTRIENT DIGESTIBILITY IN PIGS

The pig is used to convert a variety of foods/feeds into meat for human consumption. The efficiency with which this conversion is carried out is of crucial importance to the pig industry. The efficiency of the conversion is dependent on the digestibility of the feeds and their constituents (Kidder and Manners, 1978). The proximate analysis of the feedstuffs provides vast amount of data on the crude composition of the feed (dry matter, ash, organic matter (dry matter minus ash), crude protein (N x 6.25), ether extract, crude fibre and nitrogen free extractives) (Church, 1991). The measurement of the inputs and outputs of these components in feeds and faeces determine the extent of digestibility of the components.

The concept of nutrients digestibility assumes that the feed residues found in faeces are merely the result of inefficient digestion and nothing else (Kidder and Manners, 1978). However, they reported that the position is more complex, because faeces contain undigested feed residues, unabsorbed digestive secretions, intestinal cells which are continually being sloughed off, as well as dead micro-organisms and the products of microbial fermentation. The unabsorbed residues of secretions and cellular debris, predominantly proteineous in nature are of endogenous nitrogen source.

Generally, the digestibility measurements are reported in terms of apparent digestibility. This is so because, it is difficult to devise appropriate corrections for the amount of digestive secretions and other waste products which are irretrievably mixed with the undigested feed residues of which the faeces are largely composed (Kidder and Manners, 1978; Church, 1991). The coefficient of apparent digestibility of dry matter provides a valuable index of the overall digestibility of the diet. However, a more complete picture of digestibility is obtained with the apparent digestion coefficients of the individual nutrient (crude protein, ether extract, crude fibre, ash and nitrogen free extractives) contained in the diet or feedstuffs.

ENERGY PREDICTION IN PIG DIETS

The cost of feed represents over 70% of the total cost of pig production (Frape and Tuck, 1977; Adesehinwa and Ogunbodede, 1995; Tewe and Adesehinwa., 1995), the energy component being the greatest proportion (Frape and Tuck, 1977; Noblet and Perez, 1993; Noblet et al.,

1994). Therefore, it is important to know precisely both the energy requirement of the pigs and the energy value of feeds. The types of pig feeds used in the tropics vary greatly, and since many by-products are used in place of cereals, the variation in nutritive values between and within feeds may be considerable (Lekule et al., 1990).

The evaluation of the energy content of feeds is usually based on their digestible or metabolisable energy values (NRC, 1988; INRA, 1989; Noblet and Perez, 1993). The energy value of feed ingredients or feeds enables the predictability of the amount of pig meat produced from a given feed and allows the achievement of the least-cost formulation of diets of given energy densities (Frape and Tuck, 1977). This assists the pig producer to produce a uniform carcass quality at a feed cost commensurate with maximum profit.

The determinations of the metabolisable energy values are time-consuming and expensive, and the chemicals required are not readily available in many laboratories in the developing countries (Lekule et al., 1990). Hence, the apparently digested energy of feeds may be assessed from faecal output by crude chemical analysis of feed and faeces for crude protein, ether extract, crude fibre and nitrogen free extractives. The summation of these values, each multiplied by its characteristic coefficient yields a value representing the heat of combustion of the apparently digested product of 1 kg dietary dry matter (Frape and Truck, 1977).

As consequence of the cost of biological determinations and because of the inherent variability between samples of the same ingredients, a number of equations have been derived to predict the digestible and metabolisable energies from easily determined chemical characteristics of the diets. It should however, be noted that these equations are based on some referenced sample feedstuffs. Morgan et al. (1975b) predicted the following equations:

$$DE = 0.460CP + 0.625EE + 0.377NFE - 21.05 \ (R^2 = 0.95)$$

$$ME = 0.416CP + 0.605EE + 0.367NFE - 20.06 \ (R^2 = 0.94)$$

Where DE is the digestible energy, ME is the metabolisable energy, CP is the crude protein, EE is the ether extract and NFE is the nitrogen free extractives. However, it was reported that the starch content of the nitrogen free extract decreases as the fibre contents increase (Nielsen, 1970). In the contribution of Lekule et al. (1990), they showed the crude fibre to have the highest correlation to the ME content and the relationship was shown as:

$$ME \ (MJkg^{-1} \ DM) = 16.81 - 0.031CF \ (gkg^{-1}DM) \ (R^2 = 0.68)$$

Where CF is the crude fibre and DM is the dry matter.
The high correlation has also been shown by Just et al.

(1984), Fernandez and Jorgensen (1986) and Morgan et al. (1987), among others. The best equation with two variables was reported by Lekule et al. (1990) as:

$$ME \ (MJkg^{-1}DM) = 16.34 - 0.034CF \ (gkg^{-1}DM) + 0.003CP \ (gkg\text{-}1DM0 \ (R^2 = 0.73)$$

While they reported the best three-variable equation as:

$$ME \ (Mjkg^{-1} \ DM) = 3.36 + 0.016CP + 0.029EE + 0.013SC \ (R^2 = 0.83)$$

Where SC is soluble carbohydrate
Noblet and Perez (1993), in their study later predicted thus:

$$DE = 4151 - 12.2Ash + 2.3CP + 3.8EE - 6.4CF \ (R^2 = 0.89)$$

$$ME = 4168 - 12.3Ash + 1.4CP + 4.1EE - 6.1CF \ (R^2 = 0.88)$$

The digestible energy of feed is by no means recoverable in useful animal products (Frape and Tuck, 1977). Some workers, therefore, advocated the determination of metabolisable energy, which is that, available to the tissue for productive use. In pig, methane losses are small for normal diets, about 0.01 of the digestible energy (Bowland et al., 1970) and therefore, in practice, the metabolisable energy is simply assumed to be that portion of the digestible energy not lost in the urine (Frape and Tuck, 1977; Serres, 1992). Urinary nitrogen losses were reported to increase as dietary protein is raised, so that high protein ingredients are likely to incur a greater handicap than cereals in the computation of their metabolizability. Thus, metabolisable energy is affected by dietary protein level and by the way it is utilized and so, it is not a constant characteristic of an ingredient.

Metabolisable energy may, therefore, be calculated from the proximate composition of digestible dietary components as in the equation above, or as a proportion of the digestible energy: approximately 0.98DE for cereals and 0.95DE for protein concentrates (Frape and Tuck, 1977). Morgan et al. (1975a) allowed for variation in protein intake, thus:

$$ME = DE \ (0.997 - 1.88 \ x10^{-4}CP_1) \ (R^2 = 0.88)$$

Where CP_1 is crude protein in g/kg dietary dry matter. While, Lekule et al. (1990) predicted:

$$ME \ (MJkg^{-1}DM) = 0.08 + 0.96DE \ (MJkg^{-1}DM) \ (R^2 = 0.96).$$

The relationship was found to be very close and of the same magnitude as that found by Just (1982). The energy value of the diet could then be used to predict the amount of pig meat (pork) to be produced from a given

amount of feed (which is an inverse of the amount of feed consumed per kg liveweight gained) or to achieve the least-cost formulation of diets of given energy densities.

This is the major determinant of the nutritive value of a feedstuff and its assessment is therefore of great importance for diet formulation. This is of special practical importance in the developing countries where determination of proximate components in feed and feces are relatively more feasible compared to the use of sophisticated gadgets, required in other methods of energy value determinations, which are not available.

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