# Recent Developments in Net Energy Research for Swine

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## ▪ Introduction

The cost of feed is the most important cost of pig meat production (~60%) and the energy component represents the greatest proportion of the feed. Therefore, it is important to estimate precisely the energy value of feeds, either for least-cost formulation purposes or for adapting feed supply to energy requirements of animals. In addition, energy supply has an important impact on performance of animals. Evaluation of energy content of pig feeds is firstly and most commonly based on their Digestible Energy (DE) or Metabolizable Energy (ME) contents.

However, the closest estimate of the "true" energy value of a feed should be its Net Energy (NE) content which takes into account differences in metabolic utilization of ME between nutrients. In addition, NE is the only system in which energy requirements and diet energy values are expressed on a same basis which should theoretically be independent of the feed characteristics. The objectives of this review paper are to present the available energy systems for pig feeds with emphasis given to NE systems and to evaluate their ability for predicting pig performance. Methodological aspects of energy evaluation of pig feeds and complementary information have been considered in previous reviews (Noblet et al., 2003; Noblet and van Milgen, 2004; Noblet, 2006).

## ▪ Energy Utilization

For most pig diets, the digestibility coefficient of energy (DCe) varies between 70 and 90% but the variation is larger for feed ingredients (10 to 100%). Most of the variation of DCe is related to the presence of dietary fiber (DF) which is less digestible than other nutrients (<50% vs. 80-100% for starch, sugars, fat or protein) and reduces the apparent fecal digestibility of other dietary nutrients such as crude protein and fat. Consequently, DCe is linearly and negatively related to the DF content of the feed (Le Goff and Noblet, 2001). The coefficients relating DCe to DF are such that DF essentially dilutes the diet, at least in growing pigs. In other terms, even though DF is partly digested by the young growing pig, it provides very little DE to the animal. Digestibility of energy can be modified by technological treatments. Pelletting, for instance, increases the energy digestibility of feeds by about 1% (Noblet, 2006). However, the improvement is more important for some ingredients such as full fat rapeseed or (high oil) corn for which pelletting improves the digestibility of fat with subsequent marked differences in their DE value between mash and pellet forms (Noblet, 2006).

Energy digestibility is also affected by animal factors. In growing pigs, DCe increases with increasing BW (Noblet, 2006) and the largest effect of BW is observed when adult sows either pregnant or lactating and (close to) ad libitum growing pigs are compared (Le Goff and Noblet, 2001). The difference due to BW increase is most pronounced for high fiber diets or ingredients (**Table 1**). This improvement of energy digestibility with BW is mainly related to an improved digestive utilization of DF. The effect of feeding level on DCe is negligible even when lactating sows and gestating sows fed at very different energy supplies are compared. Little information concerning comparative digestibility in piglets and growing pigs is available. Considering that piglets are usually fed low-fiber diets for which the effect of BW is minimized, piglets can, from a practical point of view, be considered as growing pigs concerning the digestive utilization of energy.

**Table 1. Differences in energy values of ingredients between growing pigs and adult sows[a].**

| | DCe in growing pigs,% | Energy value in sows [a] | |
|---|---|---|---|
| | | DE | NE |
| **Wheat** | 87.6 | 102 | 101 |
| **Corn** | 87.9 | 104 | 103 |
| **Barley** | 80.7 | 103 | 102 |
| **Soybean meal** | 85.2 | 106 | 107 |
| **Canola Meal** | 67.5 | 108 | 108 |
| **Peas** | 88.0 | 104 | 103 |
| **Wheat bran** | 56.7 | 110 | 109 |
| **Distillers Dried Grains** | 65.9 | 116 | 115 |

[a] From Sauvant et al. (2004); the energy values in sows are expressed as percentage of the energy value in growing pigs

The ME content of a feed is the difference between DE and energy losses in urine and gases (methane). In growing pigs, average energy loss in methane is equivalent to 0.4% of DE intake and is 2-3 times this amount in adult sows. Energy loss in urine represents a variable percentage of DE since urinary energy depends greatly on the urinary nitrogen excretion. At a given stage of production, urinary nitrogen excretion is mainly related to the (digestible) protein content of the diet. On average, it represents about 4% of the DE value. However, this mean value cannot be applied to individual feed ingredients. The most appropriate solution is to estimate urinary energy (kJ/kg DM intake) from urinary nitrogen (g/kg DM intake) according to the following equation (in growing pigs, Noblet et al., 2004):

**Urinary energy = 192 + 31 x urinary nitrogen**

In practice, it can be assumed that dietary crude protein content is optimal relative to pigs protein requirements and urinary nitrogen represents then 50% of digestible nitrogen or 40% of total nitrogen, either for complete feeds or ingredients. These assumptions were used in INRA & AFZ feeding tables (Sauvant et al., 2004)

Net energy is defined as ME minus heat increment associated with metabolic utilization of ME and with the energy cost of ingestion, digestion and some physical activity. It is generally calculated as the sum of fasting heat production and retained energy (Noblet et al., 1994). The NE content, as a percentage of ME content (k), corresponds to the efficiency of utilization of ME for NE. The variations in k are due to differences in efficiencies of ME utilization between nutrients with the highest values for fat (~90%) and starch (~82%) and the lowest (~60%) for DF and crude protein. Measurements conducted in pigs which differed for their BW and the composition of BW gain suggest that the efficiency of ME for NE is little affected by the composition of BW gain, at least under most practical conditions. Similarly, the ranking between nutrients for efficiencies is similar in adult sows fed at maintenance level and in growing pigs. These results have been confirmed in recent trials (Noblet, 2006). Finally, the heat increment associated with protein utilization in growing pigs, either retained as protein or catabolized, is constant (van Milgen et al., 2001). This means that the NE value of dietary crude protein (CP) is not dependent on its final utilization, at least in growing pigs. Such information is not available in reproductive sows.

## ▪ Energy Systems

Apart from direct measurement on pigs, the DE and ME values of raw materials can be obtained from feeding tables (NRC, 1998; Sauvant et al., 2004). But the utilization of these tabulated values should be restricted to ingredients having chemical characteristics similar or close to those in the

tables. As illustrated in the previous section, DCe is affected by BW of the animals. It is therefore appropriate to use DE and ME values adapted to each BW class. However, from a practical point of view, it is suggested to use only two values, one for "60 kg" pigs which can be applied to piglets and growing-finishing pigs and one for adult pigs applicable to both pregnant and lactating sows. When the actual energy content of the feed is unknown, the possibility is to use prediction equations based on chemical criteria (Le Goff and Noblet, 2001) or estimates from near infrared or in vitro methods (Noblet and Jaguelin-Peyraud, 2006). Practical information for calculating energy values of pig feeds is available at the following website:
http://www.inapg.inra.fr/dsa/afz/tables/.

All published NE systems for pigs combine the utilization of ME for maintenance and for growth or for fattening. The system proposed by Noblet et al. (1994) and applied in the INRA & AFZ feeding tables (Sauvant et al., 2004) is based on a large set of measurements (61 diets). The NE prediction equations that have been generated from these measurements are applicable to ingredients and compound feeds and at any stage of pig production (Noblet, 2006). It is important to point out that different DE values or digestible nutrient contents should be used in growing-finishing pigs and adult sows with two subsequent NE values (**Table 1**). Reliable information on digestibility of energy or of nutrients is then necessary for prediction of NE content of pig feeds. In fact, this information represents the most limiting factor for predicting energy values of pig feeds. From that point of view, the lack of comprehensive information on effects of technology (pelletting, extrusion, enzymes addition, etc.) is a major limiting factor for obtaining accurate estimates of energy values for swine.

## ■ Comparison of Energy Systems

Assuming that NE represents the best estimate of the "true" energy value of feeds and according to differences in efficiencies of nutrients ME for NE, the energy value of protein-rich or fibrous feeds is overestimated when expressed on a DE (or ME) basis. On the other hand, fat or starch sources are underestimated in DE and ME systems (**Table 2**). With regard to NE for pigs, several systems have been proposed over the last 40-50 years. The INRA proposal (Noblet et al., 1994; 2004) is probably the most advanced system and it has been validated both by calorimetry measurements and growth trials (Noblet, 2006).

As previously mentioned, it is extremely important to use the same energy system for expressing the diet energy values and the animal energy requirements. From that point of view, the energy system in which the requirements are the most independent of diet characteristics should be the NE system. This is illustrated by several growth trials, especially conducted with variable dietary fat or CP levels that show that the energy cost of growth or the daily energy requirement are independent on diet composition when expressed on a NE basis. On the other hand, on DE or ME bases, the energy cost is decreased when CP content is decreased or fat content is increased (**Table 3**). This illustrates that DE and ME overestimate the energy value of protein and underestimate the energy value of fat. Therefore, unlike the NE system, the DE and ME systems are relatively unable to predict the performance of pigs.

**Table 2. Relative DE, ME and NE values of ingredients for growing pigs[a]**

| | DE | ME | NE | NE/ME,% |
|---|---|---|---|---|
| Animal fat | 243 | 252 | 300 | 90 |
| Corn | 103 | 105 | 112 | 80 |
| Wheat | 101 | 102 | 106 | 78 |
| Barley | 94 | 94 | 96 | 77 |
| Reference diet | ***100*** | ***100*** | ***100*** | ***75*** |
| Pea | 101 | 100 | 98 | 73 |
| Wheat bran | 68 | 67 | 63 | 71 |
| Distillers Dried Grains | 82 | 80 | 71 | 67 |
| Soybean meal | 107 | 102 | 82 | 60 |
| Canola meal | 84 | 81 | 64 | 60 |

[a] From Sauvant et al. (2004). Within each system, values are expressed as percentages of the energy value of a diet containing 68% wheat, 16% soybean meal, 2.5% fat, 5% wheat bran, 5% peas and 4% minerals and vitamins. The DE, ME and NE contents of the reference diet are 13.71, 13.16 and 9.94 MJ/kg, respectively.

## ▪ Energy Requirements

Energy requirements are expressed on different bases. In ad libitum fed pigs, they consist mainly in fixing the diet energy density according to regulation of feed intake (appetite), growth potential of the pig, climatic factors or economical considerations. In restrictively fed growing pigs or in reproductive sows, it is necessary to define feeding scales according to expected performance. In more sophisticated or more theoretical approaches (factorial approach or modeling approach), it is necessary to determine the components of energy requirements (maintenance, growth, milk production, thermoregulation, etc). Whatever the level of approach, most trials and recommendations in the literature were conducted according to DE and ME estimates for feeds and conclusions were then expressed as DE or ME values. Most of these recommendations were obtained with rather conventional feeds, i.e. cereals-soybean meal based diets whose efficiency of ME utilization in growing pigs was close to 74% (**Table 3**); this latter value also corresponds to the average efficiency obtained on 61 diets by Noblet et al. (1994). The proposal is then to estimate the diet NE recommendations (diet energy density, daily energy requirements, components of energy requirements, etc.) as present DE or ME estimated requirements multiplied by 0.71 or 0.74, respectively. This proposal is applicable at any stage of pig production, including pregnant or lactating sows, since NE value is calculated for any stage from one single set of equations obtained in growing pigs (Noblet, 2006). This approach can be modulated under extreme practical conditions for which the k value of the commonly used diet is markedly different (<72 or >76% for k) from these average efficiencies. It must be pointed out that the k values are much less variable for complete feeds than for ingredients.

**Table 3. Performance of growing-finishing pigs according to energy system and diet characteristics [a]**

| **Energy System** | **DE** | **ME** | **NE** |
|---|---|---|---|
| **Trial 1: Added fat (%)** | | | |
| 0 | ***100*** | ***100*** | ***100*** |
| 2 | 100 | 100 | 100 |
| 4 | 99 | 99 | 100 |
| 6 | 98 | 98 | 100 |
| **Trial 2: Crude protein content (30-100 kg)** | | | |
| Normal | ***100*** | ***100*** | ***100*** |
| Low | 96 | 97 | 100 |
| **Trial 3: Crude protein content (90-120 kg)** | | | |
| Normal | ***100*** | ***100*** | ***100*** |
| Low | 97 | 98 | 100 |

[a] Energy requirements (or energy cost of BW gain) for similar daily BW gain and composition of BW gain; values are expressed relative to the energy requirement (or energy cost of BW gain) in the control treatment (considered as 100; values in bold characters); from Noblet (2006) and unpublished data.

## Conclusions

This review indicates that energy value of pig feeds can be measured according to different criteria (DE, ME or NE). The most advanced and practically applicable energy evaluation system appears to be the NE system proposed by Noblet et al. (1994) for which energy values of most ingredients used in pig diets are available (Sauvant et al., 2004). In addition, these authors have proposed energy values that are different for growing and adult pigs. This system has been widely used in Europe and internationally in many major feed companies. This review also indicates that the relative energy density or the hierarchy between ingredients depends on the energy system with considerable variations between ingredients or compound feeds when either fat or crude protein contents deviate from values in standard diets. Even if it has not been considered in detail in this review, the change from DE or ME systems to a NE system is usually associated with a shift in diet composition with lower crude protein contents and slightly higher fat levels. From that point of view, formulating according to a NE concept produces more environmentally friendly diets. This review also shows that significant improvements in prediction of energy value of pig feeds will come from an improved knowledge of energy and nutrients digestibility, which depends on chemical characteristics of the feed, (bio)technological treatments and animal factors. Unfortunately, current information is insufficient to take this systematically into consideration and it should be a promising area for future research. Finally, for least cost formulation purposes, reliable (i.e., related to animal performance) nutritional values must be used. It is then highly suggested to combine efficient protein – digestible amino acids - and energy – net energy - systems. Under such circumstances, the feed cost of production should be minimized.

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