The Net Energy System and Diet Formulation: An Overview

A. Denise Beaulieu, John Patience, and Temi Oresanya

Introduction

Energy is available to an animal following the breakdown of ingested feed. The energy is released as heat, or used for metabolic processes such as maintenance, growth or production. During the conversion of a feedstuff to useful energy, several losses occur (Figure 1). Typically, only about 50 to 60% of the total energy in common feed ingredients is actually available for use by the pig. The rest is lost due to incomplete digestion, the excretion of gases, and an inevitable loss of heat that occurs during normal metabolism.

Gross energy is the energy released following combustion of a feed sample. It provides little useful information about the value of this energy because it fails to account for that portion of energy that is unavailable to the pig. Digestible energy (DE) is that proportion of gross energy not lost in faeces. The metabolizable energy (ME) is the amount of DE not lost in the urine or as gas. Not all the ME is available to the animal for growth or production. A portion of the energy is lost as heat (heat increment, HI) associated with the normal processes of digestion and nutrient metabolism.

Net energy, the efficiency of use of ME, is therefore defined as energy retained in the body or as the ME minus the energy lost as heat. The NE is usually divided into energy for maintenance (NEm) and retained energy (RE) or the energy used for growth (NEg). Heat production is essential, but decreases the energy available for productive purposes and should be minimized. The NE system is superior to ME because the HI and the metabolic utilization of ME varies according to the diet chemical characteristics and the physiological state of the animal. We will now describe these in greater detail.

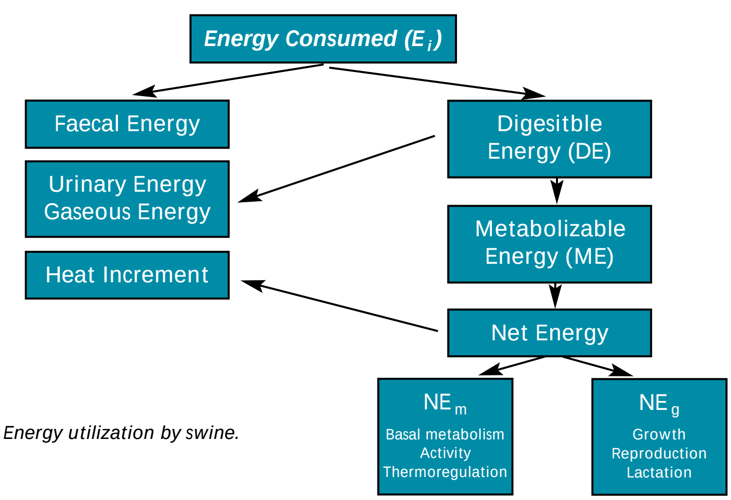

Figure 1: *Energy utilization by swine.*

Factors Influencing Net Energy

Animal Factors

Genotype. The efficiency of use of ME depends upon the protein:lipid deposition ratio. Pigs with a high lean growth rate potential respond to higher energy intakes by increasing lean rather than fat deposition. Increasingly, we are learning that a significant breed effect exists for the use of ME for maintenance. For example, in some breeds, the weight of the intestinal tract is higher, as a percentage of total body weight, than in other breeds. The amount of energy required for maintenance is believed to be closely related to the relative weight of the intestinal tract.

Physiological state

Figure 2 illustrates the portion of energy that is lost or used for various purposes by a growing sow or a sow at maintenance.

Maintenance. Maintenance is arbitrarily defined as the energy required to maintain body functions plus moderate activity in a thermoneutral environment. Although the net energy required for maintenance is higher than for growth, most net energy systems combine these two requirements into one number.

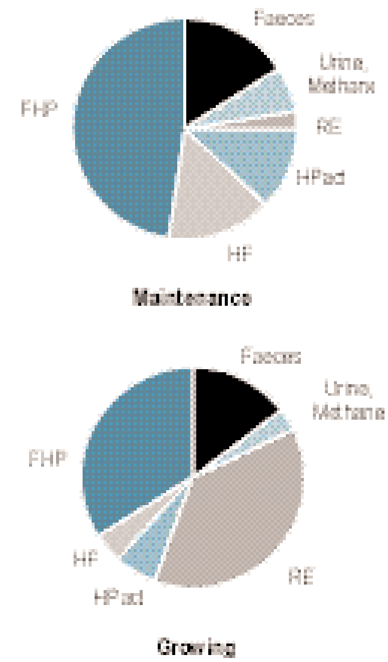

Figure 2: *The partitioning of gross energy in 200 kg sows at maintenance and growing pigs.*

Activity. Physical activity is an important contributor to energy requirements. Heat production associated with standing in sows (HPact: Heat Production for activity) was estimated to be four times greater than in other species. In individually reared or group housed young pigs, the HPact accounted for 47 or 59 kcal per day /kg $BW^{.60}$ respectively, or about 15 % of their total heat production.

Growth. Unlike the net energy used for maintenance (NEm) which is a non-productive use of energy, the producer is interested in the net energy used for gain, (NEg) which includes the energy required for growth – and the accompanying protein and lipid deposition – reproduction, lactation and work. There are various estimates in the literature of the energy cost per gram of protein or lipid deposited. The energy cost of protein deposition ranges from 7 to 15 Mcal ME/kg and the estimates for fat deposition range from 12 to 16 Mcal ME/kg. Interestingly, the energy required to deposit a gram of protein is not much different than that required to deposit a gram of fat. However, since protein deposition is also associated with a substantial amount of water, and lipid has little associated water, "lean" gain is more efficient than "fat" gain.

Pregnancy and Lactation. Weight gain during gestation is required for growth of the reproductive tissues, storage of body reserves and possibly growth of the gilt or sow to mature size. Because the composition of this gain changes as pregnancy advances, the use of ME during pregnancy also changes. More than 75% of the energy intake by pregnant sows is needed to meet the maintenance requirement. The efficiency of use of ME for milk synthesis is about 0.71, regardless of whether the energy is derived from the diet or body reserves.

Dietary Factors

The heat increment of animals on different diets with the same DE or ME is not constant, and thus the NE varies between diets. Table 1 demonstrates how the rankings of feed will vary depending on the energy system used. It is clear from this table that DE and ME tend to overestimate the true value of ingredients high in protein (eg. soybean meal), and tend to underestimate the value of ingredients low in protein (eg. barley).

Fibre. The efficiency of use of ME for NE is low when the ME comes from crude fibre. The chemical constituents of fibre that negatively affect NE are poorly understood.

Protein. High dietary CP is associated with an increased energy demand required for the deamination of excess amino acids, for the synthesis and excretion of urea and urine, for protein turnover, etc. Growing pigs fed a 17.8% CP diet required 100 kcal more ME per day to obtain similar energy retention to pigs fed a 15% CP diet. When diets are formulated on an equal ME basis, lower CP results in higher energy gain as fat due to increased NE of the low CP diet (Table 2). This is one of the key reasons why net energy is considered a superior system for diet formulation. Indeed, in Europe, the NE system has become the industry standard.

Practical Application of the NE System

The useof ME for NE is affected by the chemical composition of a diet and the use of nutrients for productive purposes. Research evaluating the NE values of feedstuffs is extremely expensive and time-consuming since the NE value of a feed depends on both the nutrient composition and the productive function of the pig. Prediction equations must be validated with several groups of animals at different stages of production. It is therefore a more complex system to implement than DE or ME. The NRC (1998) has included estimates of the NE content of feedstuffs, but requirements are based on DE or ME.

The following equation developed by Noblet in France (1994), has been widely cited as a way of estimating the net energy content of common ingredients :

NE (kcal/kg DM) = 0.703 x DE + 1.58 x EE + 0.47 x ST – 0.97 x CP – 0.98 x CF where DE is in kcal/kg DM and chemical characteristics are in g/kg DM.

Conclusions

The NE system of evaluating the energy content of the diet considers the metabolic use of nutrients and is thus the "preferred" energy system for formulating diets. Although the above statement has been recognized for decades, the NE system is only slowly being implemented for use in practical diet formulation for swine in North America. As more information becomes available on the NE content of common ingredients, and as we learn more about how animals use dietary energy under practical conditions, the NE system will become much more common.

Net energy, a superior system for diet formulation, is becoming the industry standard in Europe, but is still being evaluated for use in North America.

Acknowledgements

Strategic program funding provided by Sask Pork, Alberta Pork, the Manitoba Pork Council and the Saskatchewan Agriculture and Food Development Fund.

Table 1. A comparison of the rankings of feed by energy system. Wheat has been arbitrarily assigned a value of 100 (based on NRC 1998)

Feed stuff	DE	ME	NE
Wheat	100	100	100
Corn	104	101	115
Barley	90	86	111
Soybean meal	103	94	93
Canola meal	85	78	78
Animal fat	210	202	211
Canola oil	230	221	230

Table 2. The NE content of high and low CP diets formulated with different ingredients (PSC 2002)

Ingredients [a](%)	High CP	Low CP
Wheat	60.4	33.3
Soybean meal	24.2	19.9
Barley	11.2	40.3
Canola oil	1.0	3.0
Crude Protein	21.0	18.6
Starch	48.0	46.3
Ether extract	2.72	4.64
Crude Fiber	3.07	3.67
DE	14.23	14.23
ME	13.3	13.4
NE	10.15	10.32
NE/DE	0.71	0.73