PRACTICAL ASPECTS OF IMPLEMENTING AN NE SYSTEM FOR SWINE

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INTRODUCTION

Feeding pigs is the single most expensive aspect of pork production accounting for as much as 70% of variable costs. Surprisingly, at least 50% of these feed costs can be attributed to providing energy to the animal, thus making energy financially the most important nutrient. As such, an investigation of the energy systems used to best meet the energy needs of the animal seems logical. Similar advancements for other nutrients, including protein, have previously been explored and are now largely accepted in North America. For example, many nutritionists have accepted and are formulating diets on the basis of standardized ileal digestible amino acids and the ideal protein concept, as opposed to total or apparent ileal digestible amino acids that were used in the past. Similarly, total phosphorus content has been gradually replaced with available phosphorus. However, for energy, many North American nutritionists continue to formulate diets using digestible or metabolizable energy systems (DE or ME) as opposed to more advanced systems, such as net energy (NE). Traditionally, potential reasons for the lack of use of a more advanced energy system include: 1) energy is a much more complex nutrient than others as it is derived from numerous dietary sources, 2) there is a lack of data about the energy contents of specific feed ingredients used in North America, 3) there is a lack of research data to support the use of advanced energy system, or 4) simply having comfort in using DE or ME systems (Patience et al. 2004; Patience and Beaulieu, 2005). However, more recently, concerted efforts have been put in place for technology adoption, including the development of complex feed tables that include NE values. The purpose of this paper is to identify the benefits of using an NE system, and then to provide an outline for implementing NE into commercial swine production.

BENEFITS OF USING NE

The NE system was developed to provide more accurate estimates of the "true" energy in an ingredient (and subsequent diet) that is going to be available for a pig to use for maintenance and product formation (i.e. growth, gestation, lactation, etc.). The main difference between the NE system and the DE and ME systems is that the NE system considers the amount of heat lost during digestion and subsequent deposition of nutrients in protein and adipose tissue. To illustrate this point, the DE, ME, and NE of several commonly used ingredients are reported in Table 1 as an index relative to a reference diet. When corn is compared with soybean meal, for example, their DE and ME index values are similar suggesting that they are relatively equal energy sources. However, when their respective NE index values are compared, it becomes apparent that there is a significant difference between the abilities of cereal grains and protein sources meal to provide retainable energy to the pig.

Table 1. Relative DE, ME, and NE values of selected feedstuffs[1]

Feedstuff	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
Soybean (full-fat)	116	113	108	72
Wheat bran	68	67	63	71
Distiller's Dried Grains	82	80	71	67
Soybean meal	107	102	82	60
Canola meal	84	81	64	60

[1]Source: Adapted Sauvant et al. (2004). Within each system, values are expressed as percentages of the energy value of a reference diet containing 68% wheat, 16% soybean meal, 2.5% fat, 5% wheat bran, 5% peas and 4% vitamins and minerals.

The advantages of the NE system and the amount of new research required to adopt the NE system have sometimes been overstated. The advantages of the NE versus the DE/ME system are not related to improvements in growth performance or feed efficiency (Frantz et al., 2004). Instead advantages of the NE system are related to: 1) ensuring consistent growth performance and likely carcass quality while making alterations in the macro-nutrient composition and thus NE content of feeds (Cadogan et al., 2005); 2) managing the risk of inclusion of alternative feedstuffs and co-products into swine diets (Smits and Sijtsma, 2007), and 3) reductions in feed costs per kg of feed or lean gain (Payne and Zijlstra, 2007). Energy is the main component of feed costs for swine, i.e., the greatest cost-pressure in swine feed is against energy content, and an accurate system to evaluate energy quality will thus play a role in managing feed costs (Zijlstra et al., 2001; Noblet, 2006). However, in addition to a focus to energy system used of diet formulation, large opportunities remain to be fulfilled practically to better manage dietary energy content (Patience et al., 2005) and reduce feed costs per unit of gain further.

A simple yet practical example of what this means for diet formulation using wheat-based diet is shown in Table 2 and for corn-based diets in Tables 3 and 4. The prices of the feeds in the proceedings are based on previous feedstuff prices and updated examples will be shown in the presentation. Diets formulated using NE are typically lower in crude protein (CP) than those using DE or ME, because the heat lost during catabolism and excretion of excess nitrogen is considered in the NE system. However, by employing the ideal protein concept and accounting for the standardized ileal digestible amino acids in the feed ingredients, the levels of the essential amino acids (Lys, Thr, Trp, Met, and Ile) are easily maintained. Hence, negative effects on animal performance would be not expected if dietary CP is reduced when diets are formulated for energy with the NE system, as has been reported by several research groups (Canh et al., 1998; Dourmad et al., 1993; Le Bellego et al., 2000, 2001; Kerr et al.. 2003; Patience et al., 2003).

The actual change in diet formulation will depend on: (1) the main cereal grain and protein feedstuffs that are included in the original feed formulation, (2) the prices of the feedstuffs, and in particular the price ratios between the cereal grain and fat sources and between the protein feedstuffs and crystalline amino acid sources, (3) the entire matrix of feedstuffs used during least-cost diet formulation, and (4) the specific energy and amino acid levels used in the diet formulation. For example, the wider the range in the ingredient matrix for chemical composition especially for protein and fiber, for example, via the inclusion of additional by-products, the larger the importance of formulating diets using NE, SID AA and available P to ensure that a predictable growth performance is achieved.

Table 2. Example diets formulated using NE compared with ME

	25-50 kg body weight		50-75 kg body weight	
Ingredients, %	ME	NE	ME	NE
Wheat	58.44	69.78	77.96	78.44
Corn	--	--	3.82	3.39
Field peas	20.00	6.44	--	--
Soybean meal (48%)	11.17	9.33	8.42	8.37
Meat & bone meal (42%)	2.70	2.73	2.15	2.14
Canola meal (37%)	0.22	4.03	--	--
Tallow	5.00	5.00	5.00	5.00
Biolys®	0.53	0.77	0.80	0.80
L-Threonine	0.12	0.15	0.15	0.15
DL-Methionine	0.10	0.07	0.04	0.04
Other[1]	1.72	1.70	1.66	1.67
Calculated composition:				
ME, kcal/kg	3,370	3,354	3,390	3,390
NE kcal/kg	2,576	2,576	2,643	2,643
CP, %	18.8	18.14	16.1	16.1
SID Lys, %	1.00	1.00	0.88	0.88
SID Thr, %	0.62	0.62	0.55	0.55
SID Met+Cys, %	0.57	0.57	0.50	0.50
SID Trp, %	0.17	0.17	0.16	0.16
SID Ile, %	0.59	0.55	0.48	0.48
Cost per ton ($)	$181.33	$179.42	$178.27	$178.15

[1]Includes macro- and micro-minerals and vitamins

In the exercise for corn diets, all diets were formulated to meet the standardized ileal digestible Lys levels for each growth phase as determined by the NRC (1998) Computer Model and the standardized ileal digestible Met + Cys, Thr, and Trp ratios to Lys as suggested by Rademacher et al. (2001). For the NRC (1998) Computer Model, growth conditions were based on mixed-sex feeding and lean gain of 325 g per day. The ME diets were formulated to provide 3,370, 3,390, 3,410, and 3,430 kcal of ME per kg of diet for the grower 1, grower 2, finisher 1, and finisher 2, respectively, and these levels were based on recommendations from industry nutritionists. The NE content of each ME diet was determined during diet formulation, and then the NE diets were formulated to meet the same NE level as was provided by the ME diets with ME allowed to float.

The results of formulating the grower diets based on ME and NE are shown in Table 3. They indicate that corn usage was increased and soybean meal usage was reduced in the diets formulated on a NE basis. This decrease in soybean meal usage led to a concurrent decrease in the crude protein level of each diet, but the standardized ileal digestible amino acid levels were maintained with only slight increases in the supplemental amino acids. There also are economic benefits when the grower diets are formulated on a NE basis. Producers would save approximately $0.09 per ton of feed by formulating their diets on a NE basis in each growth phase.

Table 3. Results of formulating swine grower diets using ME compared with NE

Ingredient	Grower 1 using ME %	Grower 1 using NE %	Grower 2 using ME %	Grower 2 using NE %
Corn	69.71	70.72	73.12	75.41
Soybean meal (48%)	24.13	23.35	20.32	18.51
Tallow	2.79	2.50	3.13	2.50
Minerals & vitamins	2.99	3.00	3.04	3.06
Biolys®	0.30	0.33	0.28	0.36
L-Threonine	0.03	0.04	0.06	0.08
DL-Methionine	0.06	0.06	0.05	0.07
L-Tryptophan	--	0.004	--	0.009
Calculated Composition				
ME, kcal/kg	3,370	3,358	3,390	3,363
NE, kcal/kg	2,532	2,532	2,567	2,567
Crude protein, %	17.51	17.25	15.97	15.38
SID Lys, %	0.89	0.89	0.79	0.79
SID Thr, %	0.58	0.58	0.55	0.55
SID Trp, %	0.17	0.17	0.15	0.15
SID Met, %	0.31	0.31	0.29	0.29
SID TSAA, %	0.55	0.55	0.51	0.51
SID Ile, %	0.62	0.60	0.55	0.52
Cost ($/ton)	$102.17	$102.08	$99.55	$99.46
Savings ($/ton)		$0.09		$0.09

The results of formulating the finisher diets based on ME and NE are shown in Table 4. The finisher diets were very similar to the results from the grower diets as soybean meal usage was decreased in the NE diets, which was accompanied by an increase in corn and supplemental amino acid usage. These changes once again resulted in potential savings for a producer. During the finisher 1 phase, producers could save as much as $0.15 per ton of feed, but the potential for savings are even better in the finisher 2 as producers could save up to $0.69 per ton of feed by formulating their diets on a NE basis.

Table 4. Results of formulating swine finisher diets using ME compared with NE

Ingredient	Finisher 1 using ME %	Finisher 1 using NE %	Finisher 2 using ME %	Finisher 2 using NE %
Corn	77.78	81.27	82.81	87.55
Soybean meal (48%)	15.34	12.60	9.98	6.26
Tallow	3.47	2.50	3.79	2.50
Minerals & vitamins	3.10	3.13	3.17	3.21
Biolys®	0.25	0.38	0.23	0.40
L-Threonine	0.04	0.07	0.01	0.06
DL-Methionine	0.01	0.03	--	--
L-Tryptophan	--	0.01	--	0.02
Calculated Composition				
ME, kcal/kg	3,410	3,369	3,430	3,375
NE, kcal/kg	2,610	2,610	2,654	2,654
Crude protein, %	13.91	13.02	11.71	10.50
SID Lys, %	0.66	0.66	0.52	0.52
SID Thr, %	0.46	0.46	0.36	0.36
SID Trp, %	0.13	0.13	0.10	0.10
SID Met, %	0.23	0.24	0.19	0.18
SID TSAA, %	0.43	0.43	0.37	0.34
SID Ile, %	0.47	0.43	0.38	0.32
Cost ($/ton)	$93.61	$93.44	$87.65	$86.96
Savings ($/ton)		$0.15		$0.69

An additional indirect benefit to lower CP in the NE diets is that nitrogen excretion is decreased. According to Canh et al. (1998), each percentage point reduction in CP results in a 10% reduction in nitrogen excretion from the pigs. The decrease in nitrogen excretion results in decreased ammonia emissions and odor in the barns, which leads to improved animal performance. Canh et al. (1988) also indicated that water intake of pigs is reduced as dietary CP is reduced, which leads to less slurry volume. Finally, one more advantage to formulating diets using a NE system is that often the diet cost is decreased both on a per ton and a per pig bases (Patience, 2005; Payne, 2006). Of course, diet cost benefits will depend on the prices of each feed ingredient at any given time, but even if these cost advantages only occur 50% of the time, they would certainly be welcome.

IMPLEMENTING NE INTO COMMERCIAL PRODUCTION

Once a decision is made to look into using NE, the next question is how to proceed? A serious downfall of any energy system, including NE, is that most nutritionists have been and still are using the same energy values for their ingredients as they have been using for years. These energy values may have been developed within each company over the years or they could simply be average values from reference tables, such as those in the NRC (1998) or Sauvant et al. (2004). Of course, this may work for the NE as well, but it is certainly not the best management practice, because with every change in the crude nutrient (protein, fiber, fat, etc.) profile, there also is a change in the energy available from that ingredient. While the implementation of any new process can be a daunting task, below is a detailed guideline of how to proceed with implementing an NE system.

As with any nutrient system, the ideal first step is to develop some sort of database that will help nutritionists better understand the ingredients and their roles in animal diets. Practically speaking, a good place to start is by identifying the energy containing feed ingredients that would typically be used in the grow-finish diets.

There are several reasons for starting with the grow-finish diets including: the diets in these phases typically contain the least amount of ingredients and these diets make up the bulk of the feed that a pig will consume over its lifetime. Furthermore, while the concepts of NE certainly apply to all phases of growth, it is conceivable that each phase of growth would require a different set of mathematical equations as the animal's ability to extract nutrients, including energy, change as the animal grows. This concept is evident with the work of Noblet et al. (1994) as they suggest one set of NE equations for growing pigs and a completely different set of equations for breeding sows. The idea that the animal's ability to utilize nutrients differently as it grows applies to not only energy, but all nutrients. As with other nutritional advancements, such as digestible amino acids, the understanding of energy and NE is ever-evolving (De Lange and Birkett, 2005), but that should not be a reason to rule out using NE in today's commercial production scenarios.

Table 5. Suggested action plan for implementing NE[1]

Step	Activity
1	Identify energy-yielding raw materials that will be used in grower-finish diet formulations
2	Collect required raw material samples for pre-determined length of time
3	Analyze raw materials for their nutrient content. These include but are not limited to: dry matter, crude protein, ether extract, crude fibre, acid and neutral detergent fibre, starch, sugar
4	Calculate DE, ME, and NE values for raw materials based on raw material analyses using currently available NE prediction equations
5	Compare calculated DE, ME, and NE values for raw materials with values currently being used in formulation software
6	Update nutrient matrices for energy-yielding raw materials in diet formulation software
7	Insert NE as a nutrient in grow-finish diets, and then reformulate all diets using current energy system (DE or ME)
8	Based on calculated NE from reformulated diets, remove former energy restrictions (on DE or ME) and place new nutrient restrictions on NE
9	Re-optimize all diets to balance on their NE content

[1]Source: Payne and Zijlstra (2007)

A suggested action plan for implementing the NE system is provided (Table 5). Once the energy-containing feed ingredients have been identified, then the next step towards creating a NE database would be to collect each ingredient over a defined period of time. Ideally, this collection would be in conjunction with an on-going quality control sampling protocol, such that it is as seamless as possible. As each ingredient is collected, it should be analyzed for its macronutrient composition, including, but not limited to crude protein, fat, and fiber, moisture, ash, acid and neutral detergent fiber, sugar, and starch. The reason for this is that the two most-widely used NE systems, which were developed by the French (Noblet et al., 1994; Sauvant et al., 2004) and the Dutch (CVB, 2003), are both solidly based on the macronutrient composition of the feed ingredients.

After analyzing the ingredients, the next step would be to incorporate the crude nutrient values into the NE equations so that a prediction of the NE content can be made. Concurrently, it would be beneficial to also calculate the DE and ME contents for each ingredient. The calculated DE and ME content of each feed ingredient would then be used as a means of verifying the calculated NE values and, perhaps more importantly, to verify the DE and ME levels that have are currently being used for each ingredient in the formulation software.

Next, the newly-calculated NE values should be incorporated into the formulation software, and if not already present, add NE into each grow-finish diet matrix. Rather than jumping directly into NE at this point, it seems logical to continue for some period of time formulating diets on a DE or ME basis with NE in the matrix, so that the resulting NE diet values can be monitored. The intention of this step is simply to give a nutritionist time to get comfortable seeing these new NE energy levels in diets before formulating to NE.

Finally, once the nutritionist has become comfortable with the NE levels, then the nutritionist should make the switch. Undoubtedly the NE levels of each diet will be smaller than what they were on a DE or ME basis, but remember, one of the greatest advantages of NE is that it accounts for all of the energy lost due to metabolic processes, thus the energy provided via NE is as close to exactly what the animal will have for maintenance and growth. With that in mind, the suggestion is to formulate each diet to meet the NE level that each diet contained when it was formulated to meet either DE or ME levels. This will allow for a smoother transition over to using NE, and it should give the nutritionist confidence about the energy levels that they are supplying to the pig. Although energy requirement data for growing pigs is sparse, regardless of type of energy system used, formulating the diet as indicated above should provide adequate levels of NE for pigs. As mentioned above, even when formulating diets on a DE or ME basis, ultimately, the intention was to provide enough retainable energy for the animal to perform optimally.

TAKE HOME MESSAGE

The implementation of a NE system is a major step forward from the use of the DE and ME systems. Combined with digestible amino acids and the ideal protein concept, a NE system will allow the nutritionist to formulate diets that provide the animal with the energy and amino acids that it needs for efficient and predictable growth and carcass performance. Additionally, by improving nutrient utilization and efficiency with the use of these systems, these systems promote better environmental stewardship for more sustainable pig production. While NE may not be the final advancement to be made in energy evaluation systems (De Lange and Birkett, 2005), it is definitely a start in the right direction.

LITERATURE CITED

Cadogan, D.J., Smith, C. and Henman, D.J. 2005. Net energy defines growth and carcass quality better than digestible energy. In Manipulating Pig Production X Proc. Tenth Biennial Conf. of the Australasian Pig Sci. Assoc., Christchurch, New-Zealand, Nov 27 to 30. pp. 271. APSA.

Canh, T. T., A.J.A. Aarnink, J. B. Schutte, A. Sutton, D. J. Langhout, and M.W.A. Verstegen. 1998. Dietary protein affects nitrogen excretion and ammonia emission from slurry of growing - finishing pigs. Livest. Prod. Sci. 56:181-191.

CVB. 2003. The Livestock Feed Table. Centraal Veevoederbureau, Lelystad, Netherlands.

De Lange, C. F. M. and S. H. Birkett. 2005. Characterization of useful energy content in swine and poultry feed ingredients. Can. J. Anim. Sci. 85(3):269-280.

Dourmad, J.Y., Y. Henry, D. Bourdon, N. Quiniou and D. Guillou. 1993. Effect of growth potential and dietary protein input on growth performance, carcass characteristics and nitrogen output in growing-finishing pigs. Pages 206-211 in: Nitrogen Flow In Pig Production and Environmental Consequences. M.W.A. Verstegen, L.A. den Hartog, G.J.M van Kempen, and J.H.M. Metz, eds. Pudoc. Wageningen, The Netherlands.

Frantz, N.Z., Tokach, M.D., Steidinger, M.U., Dritz, S.S., Derouchey, J.M., Goodband, R.D., Nelssen, J.L. and Usry, J.L. (2004). Effects of increasing crystalline amino acids and the subsequent change in diet net energy on growing pig performance. Journal of Animal Science. 82 (Suppl. 2):60.

Kerr, B. J., L. L. Southern, T. D. Bidner, K. G. Friesen, and R. A. Easter (2003b): Influence of dietary protein level, amino acid supplementation and dietary energy levels on growing-finishing pig performance and carcass composition. J. Anim. Sci. 81: 3075-3087.

Le Bellego, L., J. van Milgen, M. Rademacher, S. van Cauwenberghe and J. Noblet. 2000. Utilization of low heat increment diets at high ambient temperatures in growing pigs. J. Anim. Sci. 78(Suppl. 1):186.

Le Bellego, L., J. van Milgen, S.Dubois and J. Noblet. 2001. Energy Utilization of low-protein diets in growing pigs. J. Anim. Sci. 79:1259-1271.

Noblet, J., H. Fortune, X. S. Shi, and S. Dubois. 1994. Prediction of net energy value of feeds for growing pigs. J. Anim. Sci. 72:344-354.

Noblet, J. 2006. Energy systems for pig feeds. In Proc. Pre-Symp. Workshop 'Net energy systems for growing and fattening pigs', May 24, Vejle, Denmark. pp 30-39. CVB and INRA.

Patience, J. F. 2005. Netting Pig Profit with Net Energy. National Hog Farmer, November 15, 2005

Patience, J. F., and A. D. Beaulieu. 2005. The Merits, Benefits, and Challenges of Adopting the Net Energy System in a North American Context. Minnesota Nutrition Conf., September 20-21, 2005.

Patience, J. F., A. D. Beaulieu, R. T. Zijlstra, D. A. Gillis, and J. L. Usry. 2003. The performance of grower-finisher pigs fed diets formulated to meet amino acid requirements but with declining crude protein content. Monograph No. 02-03. Prairie Swine Centre Inc., Saskatoon, Canada. 15 pp.

Patience, J. F, A. D. Beaulieu, R. T. Zijlstra, T. Oresanya and R. Mohr. 2004. Energy systems for swine: A critical review of DE, ME and NE. Proceedings Midwest Swine Nutrition Conference. Indianapolis, Indiana. August 31, 2004.

Patience, J.F. (2005). Netting pig profit with net energy. National Hog Farmer, Nov. 15, 2005.

Payne, R. L. 2006. The Net Energy System in Swine – How can it help you? Feedstuffs, March 27, 2006.

Payne, R. L. and ZIJLSTRA, R. T. (2007). A guide to application of net energy in swine feed formulation. In: Proc. 2007 Banff Pork Seminar. Advances in Pork Production. 18:159-165.

Rademacher, M., W. C. Sauer, and A.J.M. Jansman. 2001. Standardized ileal digestibility of amino acids in pigs. The new system. Degussa AG, Feed Additives Division, Hanau, Germany.

Sauvant, D., J. M. Perez, and G. Tran. 2004. Tables of composition and nutritive value of feed materials. INRA, Paris, France.

Smits, C. and Sijtsma, R. 2007. A decision tree for co-products utilization. In Proc. 2007 Banff Pork Seminar. Advances in Pork Production. 18:213-221.

Zijlstra, R. T., Ekpe, E. D. and Patience, J. F. (2001). Variation in nutritional value of western Canadian feed ingredients for pigs. In Proc. 22nd Western Nutrition Conference, Saskatoon, SK, Canada. pp. 217-225.