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Achieving feed efficiency targets with diverse ingredients

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Introduction

Wikipedia defines efficiency as the "extent to which time or effort is well used for the intended task or purpose… determined by the ratio of output to input". In swine production we are familiar with calculation of efficiency using feed as the input and unit of gain as the output (feed:gain or gain:feed). This ratio, while appropriate when comparing ingredients of similar energy content or perhaps the effectiveness of management changes is rarely a meaningful measure of the true cost of either inputs or outputs. The incorporation of economics into the efficiency equation improves efficacy of the target. Thus the definition of efficiency becomes the cost of gain (dollars spent/kg of gain) or return over feed cost (net return/cost of feed or incremental cost of feed).

Regardless of the definition, all involved in the swine industry are well aware of the importance, especially currently, of feed efficiency in their production systems. Feed, or more specifically, feed energy, represents the largest single variable cost of production. Supplying energy to the pig represents at least 85% of diet cost. The rising cost of feed, especially traditional grain based feeds, has producers and nutritionists formulating diets with a longer and more diverse list of ingredients. Although these ingredients supply nutrients other than energy; the provision of dietary energy to the pig is the greatest single cost in pork production and thus this discussion will focus on the inclusion of diverse ingredients as a source of energy.

The objective of this discussion is to examine the concerns and potential benefits when diverse ingredients are considered for inclusion in swine rations. It is not intended to be a listing of alternative ingredients. There are several good reviews discussing specific alternative ingredients for swine including a publication from the National Pork Board (`http://www.porkgateway.com`) and the National Swine Nutrition Guide (2010) which provides comprehensive feed tables.

Evaluating diverse feed ingredients

Ingredients added to a ration, primarily to supply energy, include grains (wheat, barley, oats, rye, sorghum, triticale) oilseeds (soybean, sunflower, canola), legumes (field peas, lentils), or they could be by-products of the milling, distilling, baking, or brewing industries which utilize these ingredients. Feeds, used primarily as protein sources, are derived from vegetable oil refining, rendering, meat processing or dairy industries. The decision to utilize a particular feed depends on several non-nutritive factors such as availability, transportation, ease of handling and storage costs. These costs need to be part of the efficiency equation, however, they are farm specific and will not be discussed further.

A purchase price can be estimated based on nutrient contribution and comparing this to a standard ingredient. Energy yielding nutrients are often compared to corn while oilseed meals or other protein-rich ingredients are usually compared to SBM (Table 1).

The advantage of the net energy (NE) over the digestible (DE) or metabolisable (ME) energy systems becomes more apparent with increasing diversity of ingredient incorporation into rations. This is especially relevant with ingredients that are high in crude protein or fiber. The DE and ME systems don't recognize the heat increment and overvalue ingredients high in fiber and/or crude protein (energy is required to remove excess nitrogen). As can be seen in Figure 1, the cost per Mcal varies greatly among ingredients. It is also important to note that the cost of energy among ingredients, or the ranking of ingredients according to the cost of energy, will vary depending on whether we characterize energy using a DE (or ME) or a NE system. This is shown in table 1 which describes the NE/DE ratio for growing pigs and in Figure 1 which shows the cost of a Mcal NE relative to the cost of a Mcal DE.

The utilization of diverse ingredients in ration formulation

The cost of dietary energy will have a dramatic influence on the feed cost per pig sold or pork produced. A producer must decide where to obtain this energy and how much energy to put into a ration. This latter question becomes more relevant with the incorporation of many of the non-traditional feeds which are often higher in fiber. Pigs will eat more of a high fiber diet and maintain growth rate,

Table 1: The energy or protein content of ingredients relative to either corn or soybean meal and the DE and NE (Mcal/kg) content in growing pigs and sows.

Ingredient	Value relative to corn[1]	DE, Mcal/kg[2]		NE, Mcal/kg[2]		NE/DE growing
		Growing	Sows	Growing	Sows	
Corn	100	3.39	3.54	2.65	2.72	0.78
Corn DDGS[2]	75-112	2.70	3.13	1.67	1.94	0.62
Corn DDGS[3]		3.64		2.37		0.65
Beet pulp	90-100	2.61	2.94	1.48	1.70	0.57
Barley	90-95	3.06	3.15	2.27	2.32	0.74
Brewers grain	110-120	2.37	2.58	1.48	1.60	0.62
Corn gluten meal	150-160	4.64	4.73	2.75	2.82	0.59
Fats and oils	210-220	7.98	7.98	7.12	7.12	0.89
Oats	80-90	2.63	2.80	1.91	1.98	0.73
Wheat	105-110	3.37	3.45	2.32	2.34	0.69
Wheat middlings	90-95	2.65	2.84	1.84	1.94	0.69
Peas	100-110	3.32	3.44	2.32	2.39	0.70
Soy hulls	60-65	2.01	1.00	2.75	1.43	0.50
	Relative to SBM					
Soybean meal	100	3.47	3.68	1.91	2.08	0.55
Canola meal	75-85	2.77	2.96	1.51	1.63	0.55

[1] Values from National Pork Board. Alternative Feed Ingredients in Swine Diets. http://www.pork.org/PorkScience/NutritionalEfficiency accessed 07/12 and Lackey, R. 2010. Byproduct Feed Ingredients for swine Diets. London Swine Conf. p. 135-146.

[2] Sauvant et al. 2004. Noblet 2007.

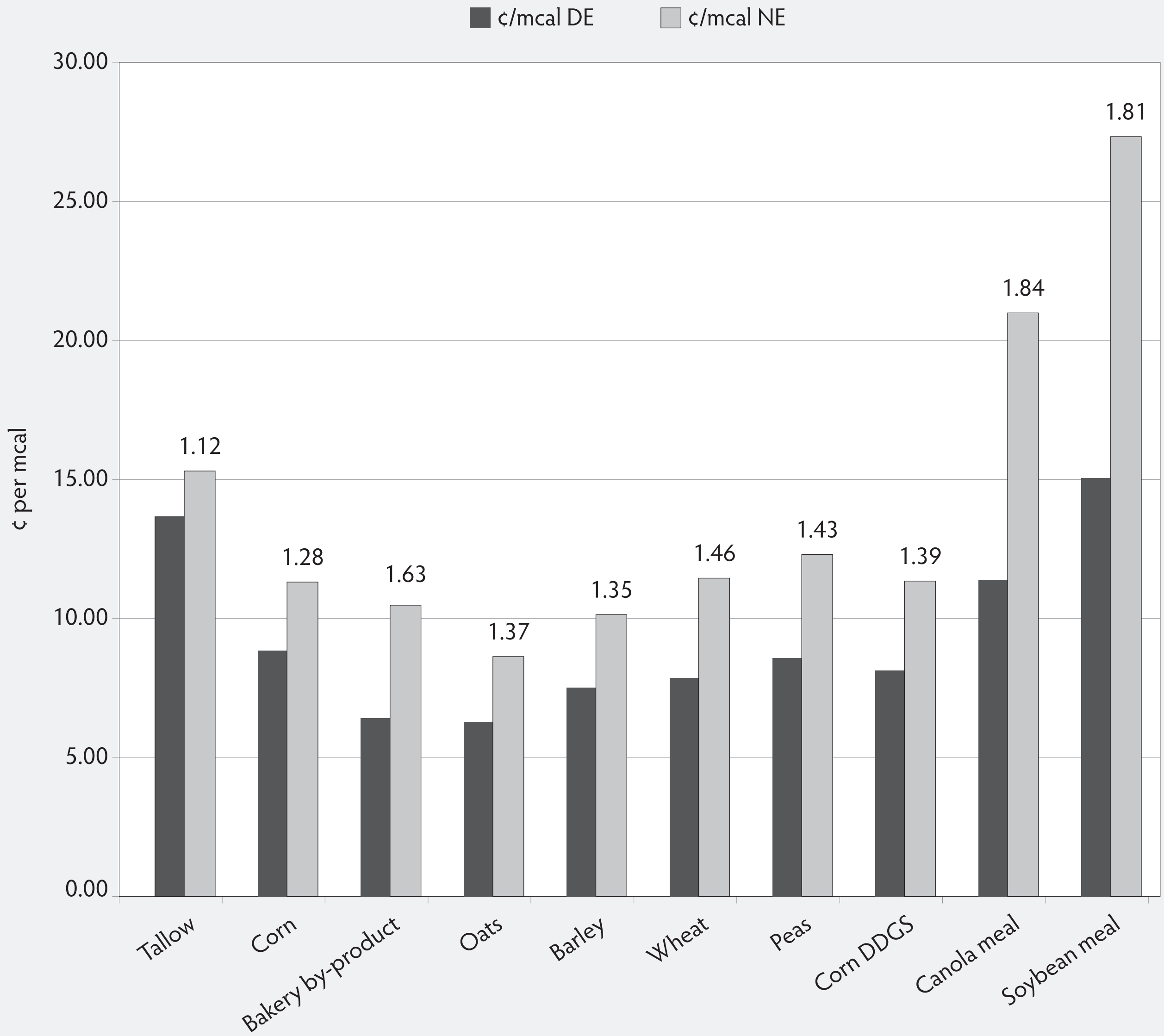
[3] Stein, H.H. and G.C. Shurson, 2009, National Swine Nutrition Guide 2010.

however, feed efficiency will decrease. Table 2 presents the results of an experiment conducted at the Prairie Swine Centre examining the response to decreasing the energy concentration in the diet (Beaulieu et al. 2009). Diets, fed in three phases from 35 kg to 115 kg BW, were based on wheat, barley, soybean meal, and canola meal. Lysine was formulated as a constant ratio with energy. Gain decreased and feed intake increased as the energy content of the ration decreased from 3.61 to 3.05 Mcal/kg. Feed efficiency, as expected, also decreased. Backfat increased and dressing percentage declined slightly with decreasing energy content of the diet. Carcass index and carcass value were not affected by the dietary treatments. Despite the increased days to market with the low energy diets, economic efficiency, expressed as returns over feed cost favored the low energy diet when this experiment was conducted and with a recent recalculation using current (2012) prices.

Table 3 and Table 4 shows the cost of these diets using current (July 2012) prices. For illustration purposes I've only shown the finishing diet in Table 3 (90 to 120 kg BW). The diets were re-formulated using a least-cost algorithm but with the same ingredients (wheat, barley, corn, soymeal, canola oil and amino acids) and restrictions imposed when the diets were formulated for the initial experiment. Performance differences between treatments therefore should be similar. Decreasing the DE (Mcal/kg) from 3.61 to 3.05 (Mcal/lb from 1.54 to 1.33) decreased the phase 2 diet cost by $107/tonne or almost $0.20 per kcal DE. The cost of the finishing diet decreased by $102/tonne. When these diets were reformulated using the comparable NE values (Sauvant 2004) a further decrease in diet cost was observed. This is especially notable in the high energy diets.

These diets were then reformulated with a slightly more diverse set of ingredients. Specifically, I included corn DDGS, peas, and canola meal to the matrix. The availability of these ingredients decreased diet cost by almost $30 tonne in the high energy diets or $10 per tonne in the low energy diets. Again a further decrease was observed in diet cost when these diets were formulated using the NE system (Table 3). Table 4 shows the diet formulations for

Figure 1: Cost per mcal DE or NE and the NE/DE ratio (number above bars) of ingredients utilized in diet formulation for swine. Costs based on SK. July 2012 ingredient prices (Cdn $).



the 3.47 Mcal/kg DE series of diets and the ingredient costs used for these calculations. Obviously, the diet formulation will vary with different ingredient costs, especially if the relative cost of ingredients changes (for example if the cost of wheat increases relative to corn). The illustration is provided to show improvements in cost efficiency achieved with a very modest increase in ingredient diversity and the additional benefits from using a NE system. Nutritionists with access to a wider array of ingredients would be able to show even greater benefits for cost reduction.

Reducing the DE from 3.61 to 3.05 Mcal/kg in finishing (90 to 116 kg BW) meant an extra 1.5 days to market and 6.5 kg of feed. Cost of that gain however, was $6.00 less per pig (Cdn, 2012) on the low energy diets. Moreover, depending on the energy level, formulating with a more diverse set of ingredients and using the NE system could save another $5.00 per pig.

Variability

Concerns related to nutrient variability within ingredients increases as we utilize a greater number of ingredients within our formulation matrixes. For many of these ingredients the data base required to allow a good estimation of the energy content and confidence limits associated with that average is lacking. Moreover, when ingredients are derived as by-products from other industries there is the additional variability associated with the processing. Typically changes in processing procedures are made to improve the primary product and may be to the detriment of the feed by-products. A nutritionist may feel compelled

Production

Table 2: The performance of pigs consuming diets containing 3.61 to 3.05 Mcal DE/kg across 3 phases (35 to 116 kg BW).[1]

	DE content of diet, Mcal/kg						
	3.61	**3.47**	**3.33**	**3.19**	**3.05**	**SEM**	***P* < (linear)**
ME, Mcal/lb	**1.54**	**1.47**	**1.44**	**1.40**	**1.33**		
ADG, , kg/d	1.03	1.02	1.04	1.02	1.00	0.01	0.03
ADFI, kg/d	2.44	2.52	2.62	2.62	2.66	0.09	< 0.001
G:F (F:G)	0.44	0.42	0.41	0.40	0.39	0.0004	< 0.001
	(2.27)	(2.38)	(2.44)	(2.50)	(2.56)		
Gain, kg/Mcal	0.12	0.12	0.12	0.12	0.13	0.001	0.01
Dressing %	79.0	78.8	78.6	78.0	78.1	0.2	0.001
Fat depth, mm	19.4	18.6	18.3	17.8	16.8	0.5	< 0.001

[1] Beaulieu et al. 2009.

to use a larger "safety margin" with alternate ingredients. This cost and the cost of increased lab assays to maintain quality assurance must be factored into the overall cost of the ingredient.

Variability in ingredient energy content will affect final diet energy content and thus may affect feed efficiency when calculated as feed per gain. For example, the DE content of peas can vary by more than 500 kcal/kg (Table 5; Leterme et al. 2007). At a 40% inclusion rate, diet DE could change by up to 200 kcal/kg which in the example described in Table 2, would influence the feed/gain ratio by 0.06 to 0.1 points.

We purchase ingredients based on an assumed energy content. The incorporation of ingredients into our rations is largely dependent on the cost/tonne and the Mcal/kg or the cost/Mcal assigned to that ingredient. Variability in energy content, therefore, has a large effect on overall economic efficiency. The energy content of DDGS varies by more than 10% (Table 5; Stein and Shurson 2009). Even if we assume that the energy content of DDGS received by a mill varies by only 5% this is about 182 kcal DE/kg or $15 per tonne.

DDGS

Although the focus of this paper was not to discuss the merits of individual ingredients, DDGS deserves comment. For most producers, DDGS is no longer regarded as an "alternative ingredient" however it provides an excellent example of what we need to consider when increasing the number of ingredients in our formulation matrix. Similar to many other by-product ingredients, DDGS;

- has variable nutrient (energy) content
- is high in fiber
- is relatively high in CP
- inclusion may affect carcass composition (backfat and dressing %)
- cost depends on location
- nutrient content depends on location (plant age and processing)
- may require special handling

Carcass quality is negatively affected by the high unsaturated fat content of corn DDGS (Dahlen et al. 2011), and the high fiber content of wheat DDGS (Seneviratne et al. 2011). Effective strategies to mitigate carcass issues include removal from late finishing rations (Beltranena 2010) and/or the inclusion of other co-products, such as glycerol (Duttlinger et al. 2012), CLA (White et al. 2009) or choice white grease (Barnes et al. 2011). However, as the biofuel industry evolves, so do the co-products and the removal of oil from the DDGS is becoming common. While this may improve some of the handling and flowability problems associated with high oil DDGS (Saunders and Rosentrater 2009) and alleviate issues with unsaturated fat in the carcass, the resulting product is higher in fiber and lower in energy (Jacela et al. 2011). These factors must be taken into account if either feed or economic efficiency is to be maintained.

The maintenance of either feed or economic efficiency requires a thorough understanding of the product being purchased and adaptation as it changes. More frequent testing and diet reformulation is typically required to maintain quality assurance standards with increased diversity of ingredients.

Table 3: The cost of diets formulated using either the DE or NE energy systems and the inclusion of corn DDGS, peas or canola meal to the matrix. The diet formulated in column 1 is the finishing diet used in the experiment illustrated in Table 2.

			Formulation criteria[1]			
			DE	**NE**	**DE**	**NE**
Energy, Mcal/kg			**3.47**	**2.40**	**3.47**	**2.40**
SID lysine, g/Mcal			**2.44**	**2.80**	**2.44**	**2.80**
	$/tonne[2]	**Limitations**				
Ingredients						
Wheat	265		87.5	22.3	27.1	13.3
Barley	230			65.1		2.3
Corn	298					18.9
Soymeal	529		8.3	7.1		
Canola oil	1590		1.7	2.9	1.07	
Limestone	140		0.87	0.83	1.00	0.97
Mono dicalcium P	850			0.53	0.60	0.07
Lysine	2950	max 0.3	0.30	0.30	0.02	0.01
Threonine	3400			0.07	0.08	0.01
DL-methionine	5250			0.003		
Corn DDGS	296	max 30			30.0	23.7
Peas	285	max 40			40.0	40.0
Canola meal[3]	316	max 10				
$ tonne			329	320	303	294

1 Diets formulated to meet the indicated DE or NE and lysine/energy ratio with the indicated ingredients. Other amino acids formulated as a ratio with lysine. Minerals and vitamins added to meet requirements.

2 Saskatchewan (Cdn) prices, current July 2012.

3 Included in the matrix, did not enter the formulas.

Table 4: Diet cost of diets formulated with varying DE or equivalent NE content and the inclusion of corn DDGS, peas or canola meal.

	Barley, wheat and soymeal				
DE, Mcal/kg	**3.61**	**3.47**	**3.33**	**3.19**	**3.05**
Cdn/tonne	$367	$329	$297	$279	$265
NE, Mcal/kg	**2.40**	**2.35**	**2.30**	**2.25**	**2.20**
Cdn/tonne	$320	$305	$290	$277	$265
	Above with corn DDGS, peas and canola meal				
DE, Mcal/kg	**3.61**	**3.47**	**3.33**	**3.19**	**3.05**
Cdn/tonne	$340	$303	$280	$266	$256
NE, Mcal/kg	**2.40**	**2.35**	**2.29**	**2.25**	**2.20**
Cdn/tonne	$307	$294	$278	$267	$258

Table 5: Variation in the energy content of corn DDGS and peas.

		Corn DDGS[1]		
		Growing pigs		
DE, Mcal/kg	Average	3.64		
	Min	3.47		
	Max	4.04		
		Field peas[2]		
		25 kg pigs	50 kg pigs	Gestating sows
DE, Mcal/kg	Average	3.71	3.92	3.70
	Min	3.23	3.18	3.44
	Max	4.30	4.55	4.05
NE, Mcal/kg	Average	2.57	2.71	2.55
	Min	2.22	2.28	2.34
	Max	3.08	3.08	2.82

[1] Stein and Shurson, 2009.
[2] Leterme et al. 2007.

Summary

The utilization of a diverse array of ingredients to formulate rations for pork production should improve economic efficiency and will become even more important as primary grains are being utilized for other than feed purposes. Benefits of a net energy system become more apparent with increased diversity of ingredients in our diet. Producers must consider potentially negative impacts on carcass quality, increased uncertainty or variability in the energy content of some of these ingredients and increased costs associated with quality assurance, transportation and storage.

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