Minimizing & Managing Ingredients Variability

Denise Beaulieu, Ph.D. & Ken Engele, BSA
Prairie Swine Centre

Table 1. Cost per Mcal of ingredient and the opportunity cost associated with variable energy content.

Ingredient	$ / tonne[1]	DE, mcal/kg		$ / Mcal DE	Opportunity cost ($ per 370 Mcal)[2]	Reference[3]
Corn	360	Min	3.78	0.09		
		Max	4.03	0.10	3.70	NRC 2012
Corn DDGS	372	Min	3.87	0.09		
		Max	4.24	0.10	3.70	NRC 2012
Wheat	293	Min	3.70	0.07		
		Max	4.05	0.08	3.70	Zijlstra et al. 1999
Barley	257	Min	3.12	0.06		
		Max	4.29	0.08	7.40	NRC 2012
Field peas	257	Min	3.109	0.08		
		Max	4.56	0.11	11.10	Leterme et al. 2008

[1]Saskatchewan, Canada 2012.
[2]Difference between the minimum and maximum and assuming the grain contributes 50 % of the 735 Mcal required in grow finish (35 to 120 kg BW; Beaulieu et al. 2009).
[3]Reference of the DE minimum and maximum values (insufficient data to use NE).

An understanding of potential causes, implications and solutions to variation in nutrient composition of ingredients used for livestock feeds is essential for efficient pork production. It is relatively easy to calculate profit lost due to paying for nutrients not present or alternatively, not receiving full value for nutrients paid for. Costs however, are also associated with inefficient utilization of nutrients due to over-formulation, or growth and even health consequences due to under-formulation. The common practise of formulating diets with a safety margin to account for potential variation in nutrient content of ingredients adds cost to the final ration.

Feed manufacturers are expected to produce consistent diets from inconsistent ingredients. Increasing use of by-products, narrowing of margins or even losses and precision feeding technology requires a more thorough understanding of the nutrient content of ingredients.

Minimizing consequences of ingredient variability

Basic statistics informs us that 50% of the corn or wheat we purchase contains less than the average content of energy, lysine, Ca or any other nutrient. The decision to allocate resources to minimize the effects of ingredient variation assumes that 1) variation exists in nutrient content of the ingredients and 2) there are consequences to this variation which warrant the proposed expenditures.

Energy is the most expensive nutrient in swine production. Cost of the variation in NE content can be estimated by assigning a monetary value to the energy (ie. dollars per Mcal) and calculating the cost difference assuming the grain was purchased at a constant price, regardless of the energy content. An example, using the variation in the cost of DE is shown in Table 1. The potential difference in the cost of a Mcal, using current ingredient prices ranges from $ 0.01 for corn, corn DDGS and wheat to $0.03 per Mcal for field peas. While this doesn't seem like a lot; assuming that pigs require 735 Mcal DE to grow from 35 to 120 kg BW (Beaulieu et al. 2009) and the variable DE grain contributes 50% of this energy, a difference of only $0.01 per Mcal would result in a difference of $3.70 per pig.

Potential cost of ingredient variation in nutrient content increases with the cost of ingredients. Data in Table 2 was generated using the Prairie Swine Centre/George Morris Centre enterprise model in order to calculate overall changes in feed cost per pig assuming barley was purchased at a constant price despite varying DE content. The data for diet formulation and expected changes in performance due to changes in DE content of the diet were derived from Beaulieu et al. (2009). Even with relatively low feed costs (2006) the difference was almost $3.00 per pig. 2012 prices, however, the difference was over $5.00 per pig.

Table 2. Difference in overall feed cost per pig if purchased barley with a low or high DE content with various feed cost scenarios.

Feed Cost/pig	Variation in barley DE: Low DE barley	Variation in barley DE: High DE barley	Difference
$ 109.16 (2012)	$ -2.92	$ 2.59	$ 5.51
$ 85.44 (2011)	$-2.20	$ 1.96	$ 4.16
$ 65.98 (2006)	$-1.56	$ 1.39	$ 2.95

The above examples in Table 2 assume that a swine producer has purchased an ingredient or a diet based upon an assumed energy content, and received a diet with energy content lower than average, and in fact low enough to affect performance. Calculations and discussion above are focused on purchasing an ingredient which has an energy content below average or on the "left side" of the standard curve. In these examples, the "buyer" of the ingredient or diet is assuming the risk. A example of "risk versus rewards" including the perception of risk and ingredient diversification decisions is found in Figure 1 using mycotoxin contamination as an example.

Variation in ingredient quality, whether due to mycotoxin contamination (Figure 1), or reduced nutrient content produces two types of error associated with purchasing or selling these ingredients. If a good lot is rejected or a lot with a concentration less than the legal limit mycotoxin, or above average nutrient content) or priced below actual value then the seller is accepting the risk as they have lost potential income. Conversely if a bad lot is accepted and sold, the buyer is accepting the risk as contaminated feed may be incorporated into a diet or performance will not reach that predicted by the diet formulation. The limit assumes that there will be a difference in animal performance between animals fed diets based on a "good" or "bad" lot.

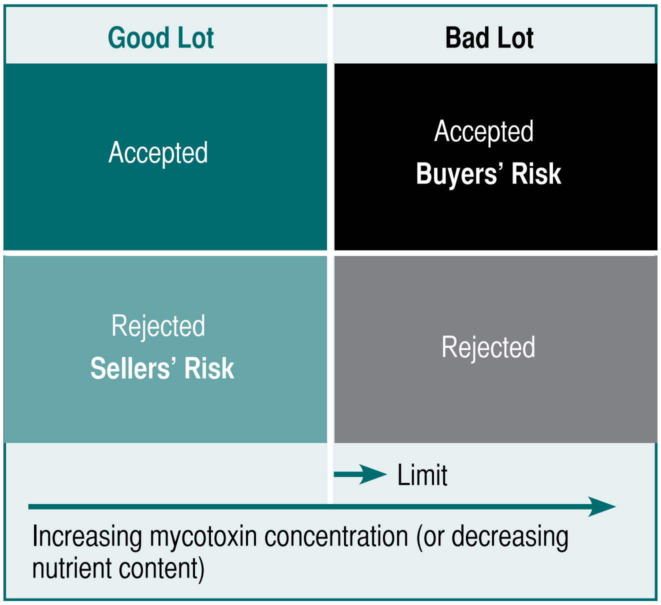

Figure 1. Risk assumed by sellers or buyers based on error. Source. Patience et. Al 2009

Reducing risk associated with ingredient variability by increased sampling and analyses (or can I use book values?)

It is intuitive that if one can accurately characterize nutrient content of ingredients the risks associated with their utilization is reduced, especially for the buyers. Ingredient variation may be due to real differences among the grains purchased, and it may also be an artefact of biases and inaccuracies in the sampling, sample preparation and analyses. Removing these sources of variation through improved sampling techniques to ensure that the sample accurately represents the load, and reducing in-lab and between lab sources of error can reduce this source of variation. These all have a cost associated with them, which must be assumed by buyers, sellers or both. Various industries (ie. corn DDGS) have recognized the importance of standardizing analysis of ingredients and by-products and the benefits to the entire industry. Statistical tools exist to aid in the development of sampling plans based on opportunity cost and risk (Whitaker et al. 2005). Increasing sample size or number and reporting an average result reduces risk to both buyer and seller. Conversely, when all samples are required to test above or equal (or below in the case of mycotoxins), the risk to the buyer is reduced, but the risk or cost to the seller is increased. This type of sampling plan is more common where the risk of accepting a bad lot is obvious and quantifiable.

An effective quality assurance program is a costly investment and questions must be asked regarding the proper allocation of resources. However, once properly established, the databases obtained allow important historical perspectives to be used and aid in the decision making process. This is analogous to the costly variation faced by livestock producers in terms of animal growth and as discussed by Patience and Beaulieu (2006) it is important to recognize within each facility what is normal variation which must be accepted and managed and when variation is a symptom of a problem which should be addressed. Consistent analysis of mixed diets leaving a mill will ensure standards are being met, and if a problem or errors exist in the production line. Frequent analysis and characterization of ingredients entering the mill can allow adjustments to ensure consistent mixed diet quality. Increases in ingredient variability above historical norms indicates a problem. Identification of the source of the problem (lab? supplier?) could allow this variation to be addressed.

Analyses are expensive and can be a source of variation. Moreover, chemical analysis of an ingredient often provides little information regarding the utilization of nutrients by the animal. Examples, of course, are energy, amino acids and P which rely upon animal experimentation or statistical correlation techniques which allow digestibility or availability to be approximated based on chemical constituents. Many producers and nutritionists rely upon tables of nutrient composition for ingredient composition and while most of these tables now contain an estimate of the variation associated with each mean, the lack of information is obvious.

(Minimizing & Managing ... continued on page 11

(Minimizing & Managing ... continued from page 3)

Table 3. Nutrient content and variation of ingredients in a typical swine finishing diet in Western Canada.

Ingredient	%[1]	$/mt[2]	Mcal/kg	Lys	Met	P
Wheat	24	293	3.800 ± 0.15	4.8 ± 0.04	2.5 ± 0.02	4.0 ± 0.03
Barley	25	257	3.150 ± 0.35	4.8 ± 0.05	2.0 ± 0.03	3.9 ± 0.04
Peas	30	257	3.504 ± 0.23	16.3 ± 0.18	2.1 ± 0.03	4.2 ± 0.06
Corn DDGS	10	372	3.355 ± 0.17	8.6 ± 0.08	6.2 ± 0.08	5.6 ± 0.11
Canola meal	8	320	3.779 ± 0.02	10.1 ± 0.05	3.8 ± 0.05	7.0 ± 0.14

[1]Diets contained mineral and vitamin premixes, limestone, lysine and threonine but it was assumed these ingredients did not alter the variation of the above nutrients in the final ration.
[2]Saskatchewan 2013.

For example, the NRC Nutrient Requirements of Swine (2012) has no estimation for the variation in energy content within different classes of wheat. The DE content of corn and corn DDGS is based upon 4 and 11 observations, respectively. Interestingly, data for AA availability is generally more complete, however ingredient composition and utilization was identified by the committee as a priority area for future research (NRC 2012). The relevance of "book values" for either nutrient content or the variation associated with reported averages has to be considered by each individual mill or producer. Local conditions can significantly affect nutrient content.

In a study conducted several years ago, (but probably still relevant, especially with changing climates) Suleiman and co-workers (1997) showed, using a large number of samples of barley grain, alfalfa and silages grown in Alberta, that the current NRC dairy (1989) values did not accurately predict nutrient content. The average concentration of Ca was 100% and CP 30% higher than the NRC values while Cu and Zn were only 18 to 40% of reported values. The authors concluded that, in Alberta, locally derived nutrient values should be used for ration (dairy cattle) formulation and moreover, the high CV's observed indicated that frequent analysis was required (Suleiman et al. 1997).

Prioritizing analyses however, can significantly reduce associated costs. This can be accomplished by calculating the contribution of each ingredient to nutrient variation and then, based on ingredient cost, the cost of the variation (Duncan 1988). Variation of nutrients in a ration can be estimated from variation of each ingredient by (Duncan 1988):

$SD = \sqrt{}(X^1S^1)^2 + (X^2S^2)^2.....(XnSn)^2$

SD = SD of the nutrient in the ration
Sn = SD of the nutrient in the nth ingredient
Xn = fraction of total nutrient contributed by the nth ingredient

Table 4. Cost of nutrient variation in a Western Canadian swine finishing diet, 2013.

Restriction	Cost of unit/$mt[1]	SD[2]	Cost of variation, $/mt[3]
DE, Mcal	0.079	0.12	0.009
Lysine, g/kg[4]	0.040	0.06	0.002
Methionine, g/kg[4]	0.110	0.02	0.002
Phosphorus, g/kg[4]	0.063	0.003	0.0002

[1]Only considering ingredients in Table 5.
[2]Standard deviation of the nutrient in the finished feed calculated as described above.
[3]SD time the cost.
[4]Total amino acids and phosphorus.

The contribution of each ingredient to final nutrient variation in a swine finishing diet was calculated using the data in Table 3. This calculation considers the cost of the variation in each nutrient, not the cost of the nutrient per se. Synthetic amino acids and minerals were assumed to have a negligible variation and were thus not included. As illustrated in Table 4, the cost of variation in energy is 3 to 4 times the cost of variation in other nutrients. Expending analytical dollars on the energy content of energy supplying ingredients would yield the highest return.

Logistical considerations

Table 4 indicates that variability in the cost of energy contributed more to the cost of variation in an example swine finishing diet than variation attributable to lysine, methionine and phosphorus combined, implying that analyzing high energy yielding nutrients for energy content would be a judicious use of resources to minimize ration costs associated with variation. However as well known by feed mill managers and producers mixing their own diets on farm, analyzing an ingredient and then segregating it until the results of the analysis are returned is very seldom a practical option. Advances in near-infrared spectroscopy (NIRS) however, are allowing the prediction of several nutrients, including energy (Zijlstra et al. 2011), rapidly enough that the use of these instruments may effectively mitigate some of the logistical problems of trying to adjust ration formulations to attain a consistent nutrient profile. Development and maintenance of calibration curves for various ingredients, however, remains an industry challenge.

The Bottom Line

The variation in ingredients available for use in livestock rations is real, of economic importance and unlikely to decline. The cost and risk associated with this variation depends among buyers and sellers. Understanding the source of the variation is important. If the perceived variation can be attributed to sampling or laboratory technique it can be reduced. If the variation is real it must be managed.

Reference for this article can be obtained by contacting Prairie Swine Centre at denise.beaulieu@usask.ca