Energy Sources for Swine Diets

Cereal Grains and Co-Products

The main energy sources for swine are the cereal grains corn, milo, wheat, barley, and their co-products. In cereal grains, starch and oil are positively correlated with energy values, whereas fiber is negatively correlated. The most common cereal grains and co-products used in swine diets are discussed in this fact sheet.

Selection of energy sources

The decision of selecting an energy source for swine diets must consider nutritional, economic, and logistic determinants, including: digestibility of energy and nutrients, variability in nutrient concentration, ability to consistently source a high-quality ingredient, availability of bin space in the feed mill, grinding capabilities, handling characteristics, cost, and production goals. **Table 1** presents the typical use of energy sources in swine diets considering some limiting factors.

Relative feeding value is often used to compare the value of a particular feed ingredient to the value of a standard energy source, typically corn. The relative feeding value considers the energy content and nutrient levels to evaluate the energy source.

Dietary energy formulation

There are two primary means to select ingredients when formulating the energy concentration in swine diets: allowing dietary energy to change as the ingredient is added or keeping dietary energy constant.

Formulating to allow dietary energy to change

Using this formulation method, dietary energy fluctuates as the energy source is included in the diet. In this case, a low energy ingredient decreases dietary energy and is often associated with lower growth rate and poorer feed efficiency. Cost of additional finishing space to achieve the same market weight or loss in revenue from lighter carcass weight must also be considered. The use of this formulation method is economically justifiable if the negative impact on pig value by lowering dietary energy is offset by savings in feed cost or improvements in income over feed cost.

Formulating to a constant dietary energy

Using this formulation method, dietary energy is kept constant as the energy source is included in the diet. In this case, a low energy ingredient is usually combined with a fat source or other high energy ingredient to maintain the same base energy concentration in the diet. The use of this formulation method typically maintains similar growth rate and feed efficiency. Thus, feed cost is an accurate estimate of ingredient value.

Cereal grains

Cereal grains typically provide most of the energy in swine diets. Usually, cereal grains have a relatively high concentration of starch, good palatability, and high digestibility. Corn is the leading cereal used in the United States and many pork producing countries. Corn contains a greater energy density than other cereal grains and is usually the standard to which other cereal grains are compared.

Corn

Corn is the most common cereal grain used in swine diets in the United States and many countries around the world. Corn contains relatively greater energy level than other cereal grains due to its high concentration of starch and oil, and low concentration of fiber.

Corn contains approximately 60 to 65% starch (NRC, 2012) with apparent total tract digestibility of around 90 to 96% (Rojas and Stein, 2015). Oil content is around 3.5% and fiber content is less than 10% NDF (NRC, 2012). These characteristics make the energy value of corn relatively greater than other cereal grains.

Crude protein (7 to 9%) and lysine content (0.25%) in corn is less than most other cereal grains (NRC, 2012), but standardized ileal digestibility of amino acids is relatively high, around 75 to 85% (Cervantes-Pahm et al., 2014). Phosphorus content in corn is approximately 0.25%, but standardized total tract digestibility of phosphorus is only 25 to 30% because at least 2/3 of the phosphorus is bound to phytate. The addition of exogenous phytase is a common practice in corn-based diets to increase phosphorus digestibility to around 45 to 60% (Almeida and Stein, 2012).

Improvements in genetic selection and modification have resulted in some corn varieties with enhanced nutrient profiles for use in swine diets. These corn varieties include nutrient dense, high oil, high lysine, and low phytate corn. However, the market availability of these corn varieties is typically limited.

Milo or Sorghum

Milo or sorghum is grown for human consumption, livestock feeding, and ethanol production in many countries around the world. Milo is an excellent energy source and can replace all or part of the corn in swine diets (Stein et al., 2016).

The concentration of starch and fiber in milo is very similar to that in corn, but milo contains slightly less oil than corn which results in an energy content of 98 to 99% relative to that of corn (Goodband et al., 2016). Because of this, pigs fed milo-based diets generally have similar growth rate but slightly poorer feed efficiency as those fed corn-based diets. A strategy that can improve feed efficiency and relative feeding value of milo to corn is fine grinding (Paulk et al., 2015).

Crude protein (9%) and lysine content (0.20%) are similar to corn (NRC, 2012). The concentration of some other amino acids, particularly threonine, tryptophan, and valine, is greater in milo compared to corn (Goodband et al., 2016), but standardized ileal digestibility of amino acids is slightly lower in milo than corn, around 70 to 75% (Cervantes-Pahm et al., 2014). The use of feed-grade amino acids allows to balance for amino acids while lowering the amount of soybean meal or other protein sources in milo-based diets. While generally not a concern in milo grown in the United States, the presence of tannins in milo must be considered, as tannins in concentrations greater than 1% negatively affect digestibility of amino acids (Stein et al., 2016).

Milo contains more saturated fatty acids and less polyunsaturated fatty acids than corn (Goodband et al., 2016). This characteristic may improve pork fat quality and decrease carcass iodine value and might allow for greater inclusion of co-products high in polyunsaturated fatty acids, such as distillers dried grains with solubles, compared to corn-based diets.

Wheat

Wheat is the traditional source of energy in swine diets in Canada, Europe, and Australia. Wheat is an excellent feed grain for swine, but usually is not competitively priced with corn in the United States. Wheat can replace all or part of the corn in swine diets without affecting growth performance (Stein et al., 2016).

The concentration of starch and fiber in wheat is similar to that in corn, but wheat contains significantly less oil (1.8%) than corn (NRC, 2012) which results in an energy content of 91 to 97% relative to that of corn (Stein et al., 2010).

Crude protein (14%) and amino acid content, particularly lysine (0.40%), threonine, and tryptophan, are greater in wheat than in corn (NRC, 2012; Rosenfelder et al., 2013). The standardized ileal digestibility of amino acids is relatively high and similar to that in corn, around 75 to 85% (Cervantes-Pahm et al., 2014). These characteristics reduce the amount of soybean meal or other protein sources and feed-grade amino acids in wheat-based diets. Phosphorus concentration and availability in wheat is greater than in corn due to the presence of endogenous phytase that improves phosphorus digestibility (Rosenfelder et al., 2013).

Based on the greater concentration of amino acids and phosphorus, wheat is generally given a relative feeding value greater than that of corn (approximately 105 to 110% of corn), but the energy content of wheat needs to be accounted for in wheat-based diets.

Wheat tends to flour when finely ground, which may reduce feed intake and increase the risk on gastric lesions. Thus, wheat should be coarsely ground to an average particle size of 600 μm (Stein et al., 2010).

Barley

Barley is grown mainly for malting or livestock feeding in the United States, Canada, Europe, and Australia. The nutrient composition varies among hulled and dehulled barley grains.

Barley contains lower concentration of starch (50%) and oil (2%) and greater concentration of fiber (18% NDF) compared to corn (NRC, 2012), which results in lower relative feeding value than that of corn (approximately 90 to 95% of corn) (Stein et al., 2016). However, there is significant variability in fiber concentration in barley varieties and, therefore, the replacement of corn by barley may not reduce growth performance under all circumstances (Woyengo et al., 2014).

Barley fiber is more fermentable than fiber from corn. The greater content of soluble fiber in barley increases hindgut fermentation and may improve gut health, but may also reduce feed intake and feces consistency in pigs (Wang et al., 2018).

Crude protein (11%) and lysine content (0.40%) are greater in barley than in corn (NRC, 2012), and standardized ileal digestibility of amino acids is similar to that in corn, around 75 to 85% (Cervantes-Pahm et al., 2014).

Oats

Oats is mainly grown for human consumption and only smaller quantities are used for livestock feeding.

Oats contains lower concentration of starch (39%) and greater concentration of oil (5%) compared to corn (NRC, 2012). The concentration of fiber (25% NDF) in oats is greater than that of corn or any other cereal grain (NRC, 2012).

Crude protein (11%) and lysine content (0.5%) are greater in oats than in corn. Oat protein contains a favorable amino acid profile and greater standardized amino acid digestibility compared to corn or any other cereal grain, around 80 to 90% (Cervantes-Pahm et al., 2014).

Although the amino acid profile is favorable, the high fiber content limits the application of oats in swine diets (Stein et al., 2016). Oats are most commonly included in initial nursery diets because the greater content of insoluble fiber may improve gut health and reduce post-weaning diarrhea in weanling pigs. Oats may also be included in gestation diets for sows.

Cereal grain co-products

Cereal grains are processed into products for human consumption or industrial application and the resulting co-products are used in livestock feeding. Cereal co-products tend to be more variable in nutrient concentration and digestibility and, therefore, their inclusion in swine diets may be limited. Distillers dried grains with solubles (DDGS) is commonly used in swine diets and is the primary co-product of ethanol production from corn, milo, or wheat. Corn co-products from the corn milling industry include corn gluten feed, corn gluten meal, and corn hominy feed. Wheat co-products are also included in swine diets and derived from the wheat milling industry.

Distillers dried grains with solubles (DDGS)

Corn DDGS is extensively used to partially replace corn in swine diets in the United States. Distillers dried grains with solubles is a co-product of fermentation during ethanol production, which results in removal of most of the starch in corn. As corn composition is approximately 2/3 starch and 1/3 other nutrients, it is generally assumed that the other nutrients are concentrated by approximately 3 times in DDGS compared to corn (Stein et al., 2016). The fermentation process also releases a large proportion of phosphorus bound to phytate, which greatly increases the digestibility of phosphorus in DDGS (Almeida and Stein, 2012). In contrast, the fermentation and drying processes negatively affect digestibility of most amino acids, particularly lysine (Kim et al., 2012). Also, if originally present in corn, mycotoxins are unaffected by the fermentation and drying processes and are concentrated in DDGS.

Corn DDGS contain similar concentration of metabolizable energy than corn, but net energy is variable. The concentration of oil may vary from less than 5% to more than 10% depending on the degree of oil recovery during processing. Production tools were developed to aid in determining the energy value of DDGS sources (KSU Energy Value of DDGS, **Figure 1**) and the economic dietary DDGS level in the grow-finish phase (DDGS Calculator).

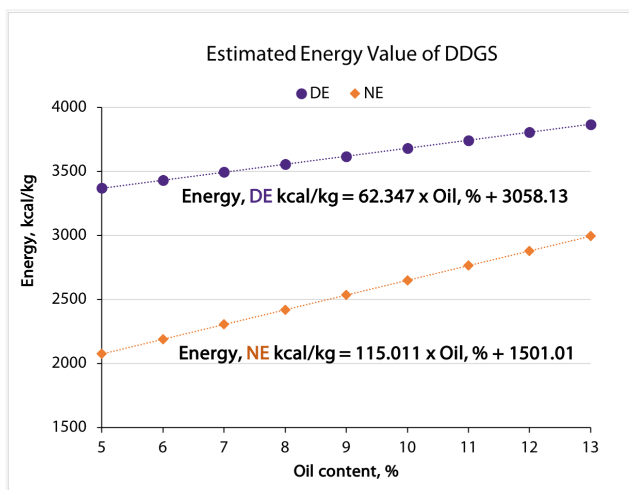

Figure 1. Equations to predict digestible (DE) and net energy (NE) values of DDGS varying in oil content. Every ±1% in oil content represents ±115 kcal/kg or ±52 kcal/lb of NE (KSU Energy Value of DDGS, Graham et al., 2014 doi:10.2527/jas.2014-7678).

Corn DDGS is rich in polyunsaturated fatty acids, which negatively affects pork fat quality and increases carcass iodine value. Carcass yield is also negatively influenced by the addition of DDGS in diets because of the high fiber content that increases gut fill and visceral weight. Adoption of a withdrawal strategy for DDGS prior to marketing is important to reduce the impact on iodine value and restore carcass yield (Asmus et al., 2014; Lerner et al., 2018).

Corn co-products

Corn co-products derived from the wet milling industry include corn gluten feed and corn gluten meal, whereas corn hominy feed is a corn co-product from the dry milling industry. The milling processes fractionate corn into its components to produce a variety of food products while the product streams are utilized in feeds.

Corn gluten feed is derived from the wet milling industry and contains many product streams from the milling process. Because of that, the composition of corn gluten feed is typically more variable than that of other corn co-products (Stein et al., 2016). Corn gluten feed contains very low concentration of starch and high fiber content, which results in lower energy value compared to corn (NRC, 2012).

Corn gluten meal is also derived from the wet milling industry and is considered a high protein co-product, containing around 60% crude protein (NRC, 2012). However, the amino acid profile in any corn co-product is similar to that of corn, which is not the ideal profile for swine (Almeida et al., 2011). Corn gluten meal is considered as a partial corn replacement due to its lower fiber content compared to other corn co-products (NRC, 2012).

Corn hominy feed is derived from the dry milling industry and contains a combination of corn bran, germ, and starch. Corn hominy feed is the corn co-product with the most similar composition to that of corn (NRC, 2012). The concentration of starch and oil is greater than any other corn co-product (NRC, 2012). Corn hominy feed is, therefore, considered suitable for use as a partial corn replacement in swine diets (Stein et al., 2016).

Wheat co-products

Co-products from the wheat flour industry are collectively known as wheat middlings, but sometimes are divided according to protein and fiber concentrations into wheat bran, wheat shorts, wheat red dog, and wheat mill run. The wheat milling process removes the starch from wheat, which results in co-products with lower energy density and higher protein and fiber content (Rosenfelder et al., 2013). The concentration of total fiber is usually between 25 and 35%, which may reduce growth performance and carcass yield with high inclusion of wheat middlings. Wheat middlings is often used as a fiber source in diets for gestating sows.

The low bulk density of wheat middlings increases the volume of the feed unless is in a pelleted form. Capacity of mixers, trucks, feed bins, and feeders must be considered when adding unpelleted wheat middlings or other ingredients with low bulk density to the diet, particularly at relatively high inclusion rates.

Co-products from food and pet food industries

Co-products from the food and pet food industries have an appealing nutrient profile and cost-effectiveness to be incorporated into swine diets. Bakery meal and pet food rations are the most common co-products available for use in swine diets. The main challenge lies on managing the variability in nutrient composition and the often high levels of salt, fat, and sugar in the products (Liu et al., 2018). Variability can be reduced by single-sourcing from one factory and making separate batches for each co-product. Even so, co-products should be regularly sampled and analyzed to maintain up-to-date nutrient values for use in diet formulation.

The nutrient values should be incorporated with caution into the diet formulator considering there is an analytical variability in addition to the variation in ingredient composition. In that sense, allowing a margin of safety for nutrient values is advisable. Also, the variability can be managed by adopting a conservative approach in diet formulation and setting the amino acids and phosphorus levels slightly above the estimated requirements.

Composition of food ingredients found in the USDA Food Composition Databases website can be used for a reference to estimate nutrient values.

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Table 1. Inclusion rates and limitations of common energy sources in swine diets

Ingredient	Swine diet[1] Nursery < 25 lb	Nursery > 25 lb	Grow-finish	Gestation	Lactation	Limitation
Alfalfa meal	**	5	15	25	**	High fiber
Bakery co-product	15	30	*	*	*	Variability
Barley	*	*	*	*	*	High fiber
Corn	*	*	*	*	*	None
Corn DDGS	20	20	40	40	10	High fiber, pork fat quality
Corn gluten feed	5	5	15	40	10	Variability, high fiber
Corn hominy feed	**	20	60	60	60	Low energy
Fat / Oils	5	5	5	**	5	Handling
Milo / Sorghum	*	*	*	*	*	None
Molasses	5	5	5	5	5	Feed processing
Oats	15	30	40	*	10	High fiber
Oat groats	*	*	*	*	*	None
Rye	**	10	30	20	10	Variability, anti-nutritional factor (ergot)
Soybean hulls	5	5	10	25	5	High fiber, low bulk density
Sugar beet pulp	**	5	15	50	10	High fiber
Triticale	20	30	*	*	40	Variability, high fiber
Wheat hard	*	*	*	*	*	None
Wheat bran	5	5	20	30	10	High fiber
Wheat middlings	5	10	35	*	10	High fiber, low bulk density
Whey, dried	40	30	**	**	**	High lactose
Whey permeate	30	25	**	**	**	High lactose

Adapted from National Swine Nutrition Guide (2010).

[1]Suggested maximum inclusion percentage rates for energy sources.

[*]No limitation for inclusion in the diet.

[**]Inclusion in the diet is not practical or economical.