ABSTRACT

In recent years, swine nutritionists have been spending increasingly more time investigating new approaches to diet formulation in order to address a continuing trend for increased feed costs. The use of alternative feedstuffs may reduce dependence on traditional ingredients like corn and soybean meal. While “alternatives” may provide feed cost savings, it is important to recognize the challenges that can accompany these opportunity ingredients. This paper will address some of the nutritional technologies that exist to maximize nutritional value of both alternative and traditional ingredients found in swine feed today.

INTRODUCTION

Co-products of the food, beverage and fuel industries are increasing in popularity as potential nutrient sources for livestock. These products are produced in large quantities in Ontario and are often available at a lower cost, relative to more commonly used feedstuffs like corn and soybean meal. In Ontario, the list of alternative feedstuffs can include dry co-products like dried distiller grains with solubles (DDGS) and wheat shorts and liquid co-products like condensed distiller solubles (CDS) and brewer’s yeast. While we often refer to these products as alternatives, rising demand for these types of ingredients has “commoditized” their pricing to some extent. With increased pricing due to demand, there is less margin for error when formulating diets with these types of ingredients. There is an ongoing quest by nutritionists and researchers to obtain the most value from these ingredients. Extra value may be found by adopting a number of nutritional technologies, including: new approaches to formulating energy and amino acid balances, incorporation of enzymes and fermentation of feedstuffs.

BALANCING ON AVAILABLE NUTRIENT BASIS

Net Energy Formulation

Determining energy content is often the biggest challenge when it comes to alternative feedstuff characterization. As co-products of the food, beverage and fuel industries, these ingredients can often have much of the major energy-yielding starch, sugars and possibly fat removed making it more difficult to predict the available energy content against better understood traditional ingredients. Predicting net energy (NE) from digestible nutrients including protein, fat, starch, sugar and remaining organic matter (fibre) offers a more comprehensive calculation of the “available” energy of an ingredient and allows for better prediction of animal performance de
Lange, 2008). There are tables available that estimate the digestibility of different nutrients within different feedstuffs available from the Centraal Veevoeder Bureau in the Netherlands (CVB, 2003). Different NE calculation equations have been developed, considering the heat increment associated with ingredient digestion, particularly fibre and protein effects on energy utilization in pigs (de Lange, 2008). In the instance of wheat shorts, digestible energy content could be calculated out as close to 80% of the value of corn but when considerations are made for the heat lost due to digestion of this higher fibre ingredient, the “available” net energy content may be calculated as being closer to 70% of the value of corn. NE offers little advantage over digestible and metabolizable energy systems when simpler corn/soybean meal diets are fed, however, the industry trend to feeding more alternative feedstuffs, and their associated complexity, definitely makes the case for this type of “available” energy calculation.

Digestible Amino Acid Formulation

For maximum cost benefit, producers should be taking advantage of synthetic amino acids and appropriate balances within feed that consider digestibility of ingredient amino acid (AA) content and requirements of different growth stages of animals. Before the dawn of digestible AA determination, rations were balanced on the basis of total AA content, and before that, crude protein (CP) content. Unfortunately, these systems were flawed and never addressed the real requirement for “standardized” ileal digestible (SID) AA.

An excellent example of understanding an ingredient’s contribution to SID AA content in feed would be DDGS. At first glance, DDGS may appear to be a higher value ingredient based on its CP content. However, despite being approximately 27% CP, the value of this protein could be considered relatively low when addressing the SID AA requirements of pigs, particularly the first limiting to performance (usually lysine). When compared to a commonly used protein supply, total lysine content as a percentage of CP in DDGS could be as little as half of the ratio that exists in soybean meal. Furthermore, digestibility of that lysine may be as low as 60% for DDGS, compared to 90% in soybean meal. This difference in digestibility is partly the result of heat damage during production/processing of DDGS (Fontaine et al., 2007). As such, increased use of synthetic amino acids, such as lysine-HCl, are crucial to maximizing the full potential of DDGS in swine diets.

Another aspect to consider when feeding higher fibre alternative ingredients to pigs is the impact of fermentable fibre on the pig’s intestine. Researchers demonstrated that microbial fermentation in the hindgut increased threonine-rich mucin secretions and as such, increased the requirement of the pig for this essential amino acid (Libao-Mercado et al., 2007; Zhu et al., 2005). As a result, it may be beneficial to formulate to a higher SID threonine to lysine ratio in pig rations containing higher levels of fermentable fibre.

ENZYME USE

NSPases

Swine have a limited ability to digest certain types of carbohydrate fibre (Knudsen and Jørgensen, 2001). This includes readily abundant non-starch polysaccharides (NSP) that exists
in swine feed ingredients today (Barrera et al., 2004). Since pigs lack the endogenous enzymes that are required for digestion of this fibre type, they must rely on enteric fermentation to degrade NSP and oligosaccharides into sugars and high-energy organic acids (Black, 2000; Knudsen and Jørgensen, 2001). The extent of enteric fermentation in young, growing pigs is rather limited with fermentation being associated with heat production and gaseous energy losses, which reduces the useful energy supply to pigs (Black, 2000). Arabinoxylans (AX) are one type of this relatively undigested NSP fibre. AX are closely associated with plant cell walls, giving strength and rigidity to cellulose structure. Unfortunately, this same reinforcing trait characterizes AX fibre as an anti-nutritional factor – reducing animal performance. Some AX are soluble and thus, responsible for increasing the viscosity of gastrointestinal tract (GIT) digesta through increased water binding capacity. Increased digesta viscosity can impede digestion by reducing digestive enzyme contact with nutrients, as well as impairing nutrient absorption at the GIT mucosal level. Some AX are insoluble and thus, responsible for trapping nutrients in their fibre matrix making them unavailable to the pig through normal digestive processes.

One nutrition technology that is gaining popularity with swine nutritionists is the use of NSPase enzymes. Specific feed enzymes, including xylanases, have been designed to help maximize nutritional value of ingredients being used. While these enzymes can prove effective in the simplest of diets, their use is probably more justified with increased use of alternative, higher fibre ingredients like DDGS and wheat shorts. These ingredients can carry AX levels in excess of 15% compared to lower levels in corn and soybean meal with less than 5% and 2% AX, respectively. Nortey et al. (2007) proved xylanase supplementation significantly increased the digestible energy of diets containing high levels of wheat millrun (eg. wheat shorts). This increase in digestibility translated into as much as 3-7% improvement in feed conversion in pigs ranging from 40 to 70 kg body weight (Nortey et al., 2007). While not always clear, this energy uplift may be attributed to improved nutrient absorption (reduced viscosity effect in GIT) and liberation (release of nutrients from an insoluble AX fibre matrix).

**Phytases**

Phytases are becoming a relatively well understood anti-nutritional factor. Plant phytates have the ability to bind nutrients, particularly phosphorus, and keep them from being utilized by swine. Phytate-bound phosphorus found in commonly used swine feed ingredients can represent 50-80% of total plant phosphorus and can be dependent on ingredient, plant variety, soil type, environmental conditions and processing (Kirby and Nelson, 1988). Commercially available feed-grade phytase has been a widely used enzyme to address this naturally bound phosphorus and decrease dependence on inorganic phosphorus supplementation. While phytase enzyme is not a new addition to the list of swine feed technologies, there have been new approaches to addressing this enzyme’s use in swine feeds.

As mentioned, different ingredients contain different amounts of phytate-bound phosphorus. Some nutritionists have taken a cost savings approach whereby the quantity of enzyme supplementation is based upon the amount of available substrate. For instance, wheat shorts contain a higher level of phytate and as such, it may be intuitive to consider using more phytase enzyme in the feed formulation with higher inclusion rates of this ingredient. However, the time
allowed for the enzyme to liberate phosphorous is limited to a short period of time within the animal’s stomach and proximal small intestine. Due to the intrinsic nature of phytase, it may be possible to actually use less of the enzyme and still accomplish the same amount of phosphorus liberation due to higher amount of substrate available for hydrolysation. Phytase continually “frees-up” phytate-bound molecules one after another, not being consumed by the reaction itself. If there is more than enough phytate available, it stands to reason that the odds of the enzyme coming in contact with substrate increase, as well.

Another strategy that may address the quantity of phytase supplementation is to account for endogenous phytase that is already present in some feedstuffs. Ingredients like wheat and wheat co-products can contain higher levels of naturally occurring enzyme activity. While analytical techniques and grain growing/handling conditions create some difficulty to consistently predict endogenous phytase content in grain, wheat and wheat co-products can contain as much as 1193 and 4381 phytase units per gram, respectively (Eeckhout and De Paepe, 1994). In contrast, corn could be considered to have no enzyme activity with less than 100 phytase units per gram. Wheat based diets may be able to use a lower level of exogenous phytase incorporation.

The feeding value of some ingredients can be further improved by steeping in water with exogenous phytase enzyme before feeding. Niven et al. (2007) demonstrated that steeping high moisture corn with phytase rapidly hydrolysed almost all of the phytate bound phosphorus in just six hours. While practicality may not allow for entire grain portions of rations to be steeped for six hours before feeding, perhaps smaller portions can be and the resultant higher phosphorus availability can be accounted for during formulation.

FERMENTATION

Fermentation may be defined as the anaerobic conversion of carbohydrates into alcohols and acids by microbes (Davis et al., 1980). The advantages of feeding fermented complete feeds or individual components to pigs have been demonstrated in various studies. Benefits include increased growth performance along with decreased morbidity (Jensen and Mikkelsen, 1998; Scholten et al., 2002; Lindecrona et al., 2003). Unfortunately, anaerobic fermentation requires a certain amount of moisture; making traditional dry feeds exempt from fermentation benefits. With the advance of liquid feeding systems in the last 10-15 years and the use of liquid co-products and high moisture corn, Ontario swine producers have been realizing some fermentation benefits. Possible mechanisms for these benefits may include enhanced feeding value and improved gastrointestinal health in pigs.

Enhanced Feeding Value

Just as direct enzyme supplementation in swine feeds can improve the nutritional value of various feed ingredients, microbial fermentation can accomplish some of the same benefits through natural nutrient metabolism and enzyme production. Fermentation has been proven to reduce the amount of anti-nutritional phytate found in liquid feed, thus enhancing availability of phosphorus and other nutrients (Carlson and Poulsen, 2003). Many liquid co-products already contain significant amounts of highly available soluble phosphorus, however, for swine
producers not using these products and looking for more available phosphorus supplementation, they can turn their focus to an already widely used ingredient – high moisture corn (HMC). While HMC use is not limited to liquid feeding of pigs, many producers use liquid feeding systems to better manage delivery of this often “more-difficult-to-handle” feedstuff. Due to the ensiling process behind HMC preservation/storage in oxygen-limiting silos, it has been determined that beneficial microbes can increase the amount of soluble phosphorus during fermentation. Since, soluble phosphorus is inversely related to phytate-bound phosphorus, the 4-fold increase in soluble P during HMC storage can be assumed more available to the pig (Niven et al., 2007).

**Enhanced Gastrointestinal Health**

Fermentation of feed ingredients can influence the microbial ecosystem in the pig’s gastrointestinal tract through “probiotic” and “prebiotic” effects.

The proliferation of beneficial lactic acid bacteria (LAB) in fermented feed ingredients can lead to establishment of these organisms within the pig. The data in Figure 1 illustrate the establishment of healthier microbiota (e.g. LAB), based on a more favourable balance between LAB and enteropathogenic bacteria (e.g. total coliforms, TC), in pigs fed fermented liquid feed as compared to other types of feeding (Brooks et al., 2001). This competitive exclusion of enteropathogenic bacteria by LAB, could be considered a probiotic effect.

![Figure 1](image)

**Figure 1.** Balance between lactic acid bacteria (LAB) and total coliforms (TC) in the gastrointestinal tract of pigs for various types of diets (adapted from Brooks et al., 2001).

Fermentation products, such as organic acids, can benefit the pig through enhancing the digestive and absorptive capacity of the gastrointestinal tract (GIT). Organic acids like lactic acid (LA) and certain volatile fatty acids (VFA), may have physiological influences on immune function as well. Lactic acid, along with VFA, has been associated with enhanced digestion resulting from lower GIT pH and increased enzymatic secretions (Thaela et al., 1998; Scholten et al., 1999). Short chain VFA, and butyric acid in particular, are important for cell proliferation in the intestinal mucosa. Feeding butyric acid has been shown to increase villus height and reduce
crypt depth, thus increasing absorptive capacity of the GIT in starter pigs (Nousianen, 1991; Sakata et al., 1995).

With liquid feeding, many Ontario feed ingredients have the potential to be fermented. However, fermentation of all feed ingredients is not always advisable. When fermenting high value, high protein content sources like soybean meal, producers run the risk of reducing the nutritional value with degradation of amino acids into amines and ammonia which can decrease animal performance due to their toxic effect (Gaskins, 2001). A means to reduce fermentation of protein would be to ferment the carbohydrate portion of a diet separately, rather than the complete diet (Pedersen, 2001; Scholten et al., 2002). Close control of fermentation conditions is important. Several variables exist when implementing fermentation in commercial conditions. The use of commercial bacterial inoculants may reduce the growth performance variability that exists in pigs fed fermented feeds.

CONCLUSIONS

This paper addressed only a few of the nutrition technologies available for maximizing feedstuff value in swine feeding today. Others technologies not addressed may include, but are not limited to: metabolic modifiers, particle size, heat treatment, pelleting, palatants and preservatives.

Partnerships between producers and nutrition suppliers are the key to improving a farm operation’s bottom line. Producers should work with their advisors and nutritionist to maximize the nutritional value of feedstuffs used and to minimize potential profit leaks on their operation. While everyone may believe they are doing a good job, a good farm manager always strives for improvement.

REFERENCES


