ALTERNATIVE GRAIN SOURCES IN DIETS FED TO PIGS

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Abstract

Pigs may be fed diets containing barley, wheat, DDGS, or field peas as partially or fully replacements for corn. Barley and wheat may fully replace corn in diets fed to all categories of pigs without influencing pig performance. For barley, greater performance has been reported if included in diets fed to weanling pigs. Because of the greater concentration of amino acids and phosphorus in barley and wheat compared with corn less soybean meal and inorganic phosphorus is needed in diets containing barley or wheat compared with diets containing corn. Distillers dried grains with solubles (DDGS) may be included in diets fed to weanling, growing, and finishing pigs in concentrations of up to 30% without influencing pig growth performance. However, because of the reduction in carcass fat quality in pigs fed diets containing DDGS, a lower inclusion rate is recommended during the final 3 to 4 weeks prior to harvest. In diets fed to lactating sows, 30% DDGS may also be used, and DDGS can replace all the soybean meal in diets fed to gestating sows. Field peas may be included in diets fed to weanling pigs in amounts of 60% and in diets fed to growing and finishing pigs, field peas can replace all soybean meal. However, in diets fed to sows, only 24% field peas is recommended.

Key words: Barley, corn, distillers dried grains with solubles, field peas, pigs, wheat

Introduction

Although most pigs in the world are fed diets based on corn, pigs are capable or consuming a variety of grain sources. The most common alternative grains that are fed to pigs are wheat, barley, and field peas. Several co-products are also available for inclusion in swine diets the most common of which is distillers dried grains with solubles (**DDGS**). While there are many similarities among different sources of grain, there are also important differences that need to be taken into consideration when formulating diets containing these ingredients. It is, therefore, necessary that both concentrations and the digestibility of energy and nutrients be measured in each feed ingredient and that these values are used in diet formulations. The objective of this review is to describe the current state of knowledge about using alternative grains sources in diets fed to swine.

Wheat

Wheat (*Triticum aestivum L.)* is a major crop grown in the U.S. and approximately 10% of the annual wheat production of over 2 billion bushels is used as feed for livestock. Major classes of wheat are hard red winter, hard red spring, soft red winter, white, and durum wheat. While corn is the dominant grain source for pigs in most of the U.S., wheat contains a greater concentration of AA that makes it more favorable than corn, particularly in wheat-producing areas or in areas where corn is scarce.

Wheat contains approximately 10% less digestible and metabolizable energy than corn because of a greater concentration of NDF in wheat than in corn (NRC, 1998). The energy concentration in wheat is often associated with its test weight, and test weight is commonly used to grade different qualities of wheat. The expected test weight of wheat can range from 66.0 to 78.9 kg/hl based on wheat U.S. grade standards. However, the correlation between test weight and digestible energy concentration appears to be relatively low, with a correlation coefficient of only 0.54 based on 19 wheat samples. The concentration of DE appears to be more related to the concentration of specific NSP components such as xylose (Zijlstra et al., 1999). The concentration of DE in wheat can also be predicted from the concentration of NDF (Noblet et al., 1993).

The concentration of standardized ileal digestible amino acids is greater in wheat than in corn and the concentration of indispensable digestible amino acids is at least 5 percentage units greater in wheat than in corn (Stein et al., 2001; Pedersen et al., 2007b). Of special interest in the feeding of swine is the fact that the concentration of digestible Trp, Lys, and Thr in wheat is greater than in corn. Gestating and lactating sows can digest AA in wheat to the same extent as the AA in corn (Stein et al., 2001).

Wheat contains 0.35 to 0.39% total phosphorus, but 65-70% is in the form of phytic acid (Selle et al., 2000). Wheat has a greater intrinsic phytase activity than corn (Pomeranz, 1988), and the digestibility of phosphorus is greater. Improvement in phosphorus utilization in wheat-based pig diets supplemented with microbial phytase is well documented and up to 1,000 FTU of phytase may be used (Johansen and Poulsen, 2003).

Pigs fed wheat-based diets can gain as fast and as efficient as pigs fed corn-based diets. Wheat can be used in diets for young pigs without affecting subsequent performance (Rodriquez and Young, 1981) and in diets fed to growing-finishing pigs without affecting carcass quality, fatty acid characteristics of pork fat, or meat color (McConnell et al., 1975; Bell and Keith, 1993; Han et al., 2005). Thus, performance and meat quality of pigs fed a wheat-based diet is expected to be similar to pigs fed a corn-based diet when both diets are formulated to contain the same concentration of digestible energy and nutrients and wheat can replace all corn in diets fed to weanling, growing, and finishing pigs. It has also been reported that pigs prefer to eat wheat based diets over corn-based diets (Bruneau and Chavez, 1995).

In summary, wheat is a valuable energy source for pigs. Wheat has a greater concentration of digestible AA and digestible phosphorus than corn, but the concentration of digestible energy is lower than in corn. Growth performance and meat quality of pigs fed diets containing wheat is similar to pigs fed diets based on corn.

Barley

Barley can be two-rowed or six-rowed and hulled or hulless and the grain produced from these 2 sources of barley may have different nutritional profiles. However, the differences between different varieties of barley are usually smaller than the differences among barley grown at different locations. There can, therefore, be significant differences in the quality of barley that is used in the feed industry, and it is important the nutritional value of value is known before it is included in diets fed to pigs. The average nutritional composition of barley is shown in Tables 1 and 2 and the digestibility of amino acids are indicated in Table 3.

Barley contains more protein and amino acids than corn and barley protein is less limiting in lysine and tryptophan than corn protein is. However, barley also contains more fiber than corn, which reduces the energy concentration and there is less digestible energy in barley than in corn. The digestibility of amino acids in barley may be lower than in corn (Pedersen et al., 2007b). In contrast, the concentration and digestibility of phosphorus in barley is greater than in corn (Table 1; NRC, 1998).

Barley may be included in diets fed to all categories of pigs as the sole source of cereal grain. Diets containing barley will contain less digestible energy than diets based on corn, but pigs will usually compensate for the lower energy concentration by increasing the feed intake (Beaulieu et al., 2006). Barley is particularly well suited for inclusion in diets fed to weanling pigs, and weanling pigs fed diets based on barley usually have a better performance than pigs fed diets based on corn or wheat (Medel et al., 1999; Stein and Kil, 2006). Barley may also be used as the sole source of cereal grain in diets fed to growing-finishing pigs, and fat in pigs fed barley may be less yellow than in pigs fed corn (Carr et al., 2005). Barley may also be used as the sole source of cereal grain in diets fed to gestating and lactating sows without impacting animal performance.

Field peas

Field peas (*Pisum sativum L.*) have a nutrient profile that is intermediate between corn and soybean meal. Field peas have been grown for centuries in many parts of the world. Historically, field peas have been produced mainly for human consumption, but during the last 25 years, the industry has also found markets for field peas in livestock feeding. In North America, Australia, and Western Europe, the use of field peas in diets fed to swine has increased during this period. In the US, field peas have been included in diets fed to swine in the Pacific Northwest for several decades, but in the Midwest, where the majority of the pigs are produced, fewer field peas have been used.

The concentration of gross energy in field peas grown in the US is comparable to that in corn (Stein et al., 2004). Likewise, the digestibility of energy and the concentration of digestible energy in field peas are not different from corn. The value for DE in field peas grown in the US (3,864 kcal DE per kg DM) is also comparable to values reported for field peas grown in Canada (3,862 kcal DE per kg DM; Zijlstra et al., 1998) and in Europe (3,904 kcal DE per kg DM; Grosjean et al., 1998).

Field peas contain approximately 0.40% phosphorus (NRC, 1998; Stein et al., 2006a). Of the total concentration of phosphorus, 45 to 52% is bound in the phytate complex, and therefore, has a low digestibility by swine and poultry. However, the unbound phosphorus is highly digestible and the overall digestibility of phosphorus in US grown field peas fed to growing pigs is 55% (Stein et al., 2006a). However, the digestibility of phosphorus can be improved by 10 to 15 percentage units if microbial phytase is added to diets containing field peas (Stein et al., 2006a). Thus, the digestibility of phosphorus in field peas is considerably greater than in corn and soybean meal and the addition of field peas to diets will reduce the need for inorganic sources of phosphorus. The excretion of phosphorus in the manure will also be reduced if field peas are included in the formulas.

Field peas have a moderate concentration of crude protein. The pea protein has a relatively high concentration of lysine but low concentration of methionine, cysteine, and tryptophan compared with soybean protein. The ileal digestibility of most amino acids in US-grown field peas is comparable to the digestibility of amino acids in soybean meal (Stein et al., 2004). However, the digestibility of methionine, cysteine, and tryptophan in field peas is lower than in soybean meal and the digestibility of threonine tends to be lower in field peas than in soybean meal. The reason why certain amino acids have a lower digestibility than others may be related to their location within the pea seed. Albumin, which has a relatively high concentration of methionine, threonine, and tryptophan, is less digestible than other proteins in the seed (le Guen et al., 1995). This may explain why lower digestibilities for these amino acids have been reported.

The effect of thermal treatment on the ileal digestibility of amino acids has been investigated in a few experiments and improvements of 4 to 6 percentage units in the apparent and standardized ileal digestibilities for most amino acids have been reported as a result of extrusion (Stein and Bohlke, 2007). The amino acids that have the lowest digestibility in raw field peas (i.e., methionine, threonine, and tryptophan) have the largest improvement in digestibility upon thermal treatment.

Field peas may be included in diets fed to weanling pigs in concentrations of up to 60% if peas are introduced from 2 weeks post-weaning (Stein and Peters, 2008). Extrusion of field peas does not increase the productivity of weanling pigs fed field peas (Stein and Peters, 2008).

Field peas grown in the US have been included in diets fed to growing-finishing pigs (22 - 110 kg) at a level of 30% without any negative impact on pig performance, dressing percentage, or carcass composition (Stein et al., 2004). In a more recent experiment, field peas were included in the grower period (25 - 50 kg) at 66%, in the early finisher period (50 - 85 kg) at 48%, and during the late finishing period (85 - 125 kg) at 36% (Stein et al., 2006b). At these inclusion levels, all soybean meal in the diets was replaced by field peas. The performance of pigs fed these diets were compared to those of pigs fed a corn-soybean meal-based control diet or diets containing corn, soybean meal, and 36% field peas in all three phases. Results of this experiment showed that pig performance was not influenced by the inclusion of field peas in the diets. This was true for all of the three phases and overall for the entire experiment. Likewise, no negative effects of field peas were observed on carcass composition, carcass quality, or the palatability of pork chops or ground pork patties from pigs fed these diets (Stein et al., 2006b). It is, therefore, concluded that field peas may be included in corn-based diets fed to growing-finishing pigs at levels necessary to provide all the amino acids needed by the pigs.

There is only little research available on feeding field peas to sows. However, based on available data from Europe and North America it is concluded that field peas may be used in diets fed to gestating and lactating sows at an inclusion level of up to 20%. It is possible that greater inclusion levels may be used but at this point there is insufficient data to make conclusions about greater inclusion levels.

Distillers dried grains with solubles

Distillers co-products have been used in swine feeding for more than 50 years, but the emergence of the fuel ethanol and the bio-diesel industries during the last few decades has dramatically increased the total quantities of bio-fuels co-products that are available to the livestock and poultry industries. Recent technologies in the fuel-ethanol industry have allowed the industry to fractionate the corn before it goes into fermentation or fractionate the co-products after fermentation, which has resulted in a variety of different products being produced. Corn, wheat, barley, grain sorghum, or mixtures of these cereal grains may be used in the production of ethanol, but the co-products produced from each source of grain has a distinct composition and nutritional value.

Distillers dried grains with solubles may be included in diets fed to pigs in all phases of production. The concentration of DE and ME in DDGS is similar to corn (Pedersen et al., 2007a). The concentration of phosphorus in DDGS is greater than in corn and the digestibility of phosphorus is much greater than in corn and the apparent total tract digestibility of phosphorus in DDGS is 59 (Pedersen et al., 2007a). Thus, less inorganic phosphorus in the form of dicalcium phosphate and monocalcium phosphate needs to be used if DDGS is included in the diet. The concentration of starch in DDGS is low (i.e., between 3 and 11%), but the concentration of fat in DDGS is approximately 10% and the concentration of ADF and NDF, in DDGS is approximately 3 times greater than in corn (9.9 and 25.3, respectively; Stein, 2007). The apparent total tract digestibility of dietary fiber is less than 50%, which results in low digestibility values for DM and energy in DDGS.

The digestibility of most amino acids in corn DDGS is approximately 10 percentage units lower than in corn (Stein et al., 2006c; Pahm et al., 2008). The lower digestibility of amino acids in corn DDGS compared with corn may be a result of the greater concentration of fiber in DDGS than in corn, because dietary fiber reduces amino acid digestibility. The variability in digestibility of amino acids among sources of corn DDGS is also greater than among sources of corn, which may be due to differences in production technologies and procedures among plants producing corn DDGS (Pahm et al., 2008). However, variability in digestibility of amino acids is not related to the region within the US where the DDGS is produced (Pahm et al. 2008).

The variability in the concentration and digestibility of lysine in corn DDGS is greater than the variability in digestibility of most other amino acids. The main reason for this variability is that some production units overheat the DDGS during drying, which results in the production of Maillard products resulting in low lysine digestibility (Pahm et al., 2008). The production of Maillard products results in a reduction in the total concentration of lysine as well as in the digestibility of lysine, but the concentration of crude protein is not changed. In non-heat damaged corn DDGS, the concentration of lysine as a percentage of crude protein is between 3.1 and 3.3%, but in heat damaged corn DDGS, this percentage can be as low as 2.10% (Stein, 2007). It is, therefore, recommended that the lysine concentration is measured before corn DDGS is used in swine diets, and only sources that contain at least 2.80% lysine, expressed as a percentage of crude protein, be used in diets fed to swine (Stein, 2007).

Some of the variability in amino acid digestibility, and lysine digestibility in particular, is caused by the addition of solubles to the distilled grain because the solubles contain some residual sugars that were not fermented into ethanol. The presence of these sugars will increase the likelihood of Maillard reactions occurring when the distilled grain is dried.

Nursery pigs from 2 to 3 wk post-weaning, and growing and finishing pigs may be fed diets containing up to 30% DDGS without any negative impact on pig growth performance.

Data from 25 experiments in which growth performance of growing-finishing or finishing pigs fed diets containing corn DDGS were compared with performance of pigs fed diets containing no DDGS have been reported. Average daily gain was improved in 1 experiment, reduced in 6 experiments, and not affected by treatment in the remaining 18 experiments (Stein and Shurson, 2009). The G:F ratio was improved in 4 experiments, reduced in 5 experiments, and not affected by dietary treatments in 16 experiments. Data for ADFI were reported only in 23 experiments and increased in 2 experiments, reduced in 6 experiments, and not affected by dietary DDGS inclusion in 15 experiments. However, carcass fat in pigs fed DDGS-containing diets has a higher iodine value than in pigs fed no DDGS. It may, therefore, be necessary to withdraw DDGS from the diet during the final 3 to 4 wk prior to harvest to achieve desired pork fat quality (Widmer et al., 2008).

Results of 5 experiments in which corn DDGS was fed to lactating sows have been reported (Stein and Shurson, 2009). Inclusion rates of corn DDGS in these experiments were up to 15, 20, or 30% and no negative effects of including corn DDGS in diets fed to lactating sows were observed in any of these experiments. There was no influence of corn DDGS on milk composition, apparent nitrogen digestibility, or nitrogen retention. However, sows fed diets containing 20 or 30% corn DDGS had lower values for blood urea nitrogen than sows fed the control, which indicates that these sows were fed diets with a better amino acid balance compared with sows fed the control diet. It also was observed in one experiment that sows fed diets containing corn DDGS had improved weight gain in lactation and reduced wean to estrus intervals, but these effects were not reported in the other experiments. In diets fed to gestating sows, no soybean meal is needed if DDGS is used because DDGS may replace all the soybean meal in these diets.

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Table 1. Energy and nutrient concentration in corn, soybean meal (SBM), corn distillers dried grains with solubles (DDGS), field peas, wheat, and barley, as-fed basis[1]

Item	Corn	Corn DDGS	Field peas	Wheat	Barley
Dry Matter, %	87	88	91	86	87
DE, kcal/kg	3,544	3,643	3,519	3,450	3,050
ME, kcal/kg	3,458	3,429	3,407	3,305	2,910
Crude Protein, %	7.2	27.5	20.0	12.4	12.4
Crude Fat, %	2.9	10.2	1.2	1.8	1.8
ADF,%	2.3	9.9	9.2	2.69	7.4
NDF,%	6.7	25.3	13.0	9.01	17.6
Calcium, %	0.02	0.04	0.07	0.04	0.06
Phosphorus, %	0.20	0.61	0.44	0.48	0.35
ATTD, P[2]	19.3	59.0	55.0	50.0	30.0

[1]Data from NRC, (1998), Stein et al. (2004; 2006a,b), Stein (2007), and Pedersen et al. (2007a,b).

[2]ATTD = apparent total tract digestibility.

Table 2. Amino acid concentration in corn, corn distillers dried grains with solubles (DDGS), field peas, wheat, and barley, as-fed basis[1]

Item	Corn	Corn DDGS	Field peas	Wheat	Barley
Arg	0.40	1.16	1.96	0.57	0.66
His	0.24	0.72	0.53	0.29	0.29
Ile	0.31	1.01	0.96	0.43	0.44
Leu	1.09	3.17	1.69	0.83	0.87
Lys	0.26	0.78	169	0.36	0.49
Met	0.21	0.55	0.25	0.21	0.21
Cys	0.20	0.53	0.24	0.27	0.24
Phe	0.41	1.34	1.09	0.53	0.64
Tyr	0.20	1.01	0.77	0.27	0.31
Thr	0.28	1.06	1.18	0.33	0.42
Trp	0.07	0.21	0.18	0.16	0.11
Val	0.41	1.35	1.06	0.55	0.63

[1]Data from Stein et al. (2006b), Stein (2007), and Pedersen et al. (2007b).

Table 3. Standardized ileal digestibility (%) of crude protein and amino acids in corn, corn distillers dried grains with solubles (DDGS), field peas, wheat, and barley[1]

Item	Corn	Corn DDGS	Field peas	Wheat	Barley
Crude protein	79.9	72.8	79.9	85.6	77.9
Arg	84.5	81.1	92.8	87.7	81.2
His	82.0	77.4	88.3	85.7	77.1
Ile	77.8	75.2	83.4	83.7	75.6
Leu	85.2	83.4	85.7	85.7	77.0
Lys	68.5	62.3	88.1	75.1	71.7
Met	82.8	91.9	77.9	86.0	78.4
Cys	77.4	73.6	67.3	85.8	74.1
Phe	81.6	80.9	86.9	86.2	78.1
Tyr	76.9	80.9	84.7	81.0	74.1
Thr	71.8	70.7	80.2	79.1	69.6
Trp	69.8	69.9	75.4	86.3	79.2
Val	76.0	74.5	78.2	80.7	73.6

[1]Data from Stein et al. (2004), Stein (2007), and Pedersen et al. (2007b).