SWINE FOCUS #002

Feeding wheat to pigs

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Summary

Wheat is a major crop in the United States and has a feeding value that is comparable with corn as an energy source for pigs. The concentration of energy in wheat is 91 to 97% relative to corn when fed to pigs. However, the concentration of standardized ileal digestible (SID) amino acids, particularly tryptophan, lysine, and threonine, is greater in wheat than in corn. Pigs fed wheat-based diets can grow as efficiently, and with similar meat quality as pigs fed corn-based diets when digestible energy and amino acids are equalized.

Wheat contains variable amounts of non-starch polysaccharides (NSP), mainly arabinoxylans, which can interfere with nutrient digestibility. However, the effects of wheat NSP appear to be less in pigs than in poultry. Recent reports suggest that differences in the digestible energy (DE) in wheat sources can be considerable. Thus, the concentration of energy should be accurately estimated through the use of prediction equations and gross chemical composition of wheat. Pigs tolerate a wide range of particle sizes of wheat, but a particle size of 500 to 1,000 µm is preferable. The digestibility of phosphorus is greater in wheat than in corn, but the digestibility of P is increased if diets are supplemented with a microbial phytase. Testing for mycotoxins, such as deoxynivanol and zearalenone, in stored wheat and measuring the total amount of damaged kernels and foreign materials should also be part of the evaluation of wheat intended for pigs.

Introduction

Wheat (*Triticum aestivum L.*) is a major crop grown in the United States with over 54 million acres planted in 2010 (USDA-NASS, 2010). Approximately 10% of the annual wheat production of over 2 billion bushels is used 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 regions in the U.S., wheat's greater concentration of amino acids can make it more attractive than corn, particularly in wheat-producing areas or in areas where corn is scarce.

Concentration and digestibilities of energy and nutrients in wheat

Composition. U.S. wheat grain can be classified into U.S. Grade No. 1 to 5 (USDA-FGIS, 2004) depending on the test weight (kg/hL), amount of damaged kernels, and concentration of foreign materials. It is expected that lower grades of wheat will have a lower concentration of energy and nutrients as a result of the diluting effect of the non-nutritive contaminants. Wheat contains slightly lower concentrations of starch and crude fat, but greater concentrations of acid detergent fiber (ADF) and neutral detergent fiber (NDF) than corn (Table 1). Wheat also has greater concentrations of crude protein and amino acids than corn (Table 2). While lysine and tryptophan are the two most limiting amino acids in corn-based diets fed to pigs, lysine and threonine are usually the first and second limiting amino acids in pigs fed wheat-based diets (Table 3).

Energy. Wheat has a lower concentration of digestible (DE), metabolizable (ME), and net (NE) energy, compared with corn (Table 4). Wheat contains 91 to 97% of the

Table 1. Composition of wheat and corn[1]

Item, %	Wheat	Corn
DM	87.20	86.27
Crude protein	12.39	8.01
Ether extract	1.89	3.78
Crude fiber	2.47	2.15
Starch	58.02	64.11
NDF	13.29	8.68
ADF	3.50	2.41

[1]Summarized from NRC (1998), Stein et al. (2001), Sauvant et al. (2004), and Pedersen et al. (2007).

Table 2. Concentration and standardized ileal digestibility (SID) of amino acids (AA) in wheat and corn, as fed basis[1]

	Wheat			Corn		
	Total, g/kg	SID, %	SID AA, g/kg	Total, g/kg	SID, %	SID AA, g/kg
Crude Protein	117	87.0	102	77.8	77.45	60.3
Indispensable AA						
Arg	5.9	88.9	5.2	3.8	84.1	3.2
His	2.8	88.5	2.5	2.3	84.2	1.9
Ile	4.4	87.7	3.9	2.9	81.1	2.4
Leu	8.4	88.4	7.4	10.1	87.8	8.9
Lys	3.5	80.5	2.8	2.5	72.1	1.8
Met	2.1	88.6	1.9	1.7	85.9	1.5
Phe	5.8	89.2	5.2	4.0	85.0	3.4
Thr	3.7	82.5	3.1	2.9	76.2	2.2
Trp	1.6	87.4	1.4	0.6	74.2	0.4
Val	5.5	84.7	4.7	3.8	79.9	3.0
Dispensable AA						
Ala	4.4	79.9	3.5	6.1	83.2	5.1
Asp	6.2	83.2	5.2	5.3	80.8	4.3
Cys	2.9	91.0	2.6	1.9	81.1	1.5
Glu	34.9	91.2	31.8	5.2	82.9	4.3
Gly	5.0	88.2	4.4	3.1	73.6	2.3
Ser	5.4	88.7	4.8	3.8	83.9	3.2
Pro	11.9	70.1	8.3	7.1	74.8	5.3
Tyr	3.6	86.3	3.1	2.7	81.5	2.2

[1]Mean values from NRC (1998), Stein et al. (2001), Sauvant et al. (2004), and Pedersen et al. (2007).

Table 3. Limiting amino acids in common grains fed to pigs[1]

Limiting AA	Wheat	Corn	Sorghum	Barley
First	Lys	Lys and Trp	Lys	Lys
Second	Thr	Thr	Thr	Thr
Third	—	—	Trp	His

[1]Adopted from Lewis (1985).

Table 4. Energy concentration in wheat and corn, as-fed basis

Energy system	Wheat[1]	Corn[2]	Wheat, relative to corn
Digestible energy, kcal/kg	3374	3458	0.97
Metabolizable energy, kcal/kg	3240	3364	0.96
Net energy, kcal/kg	2315	2523	0.91

[1]Mean values from NRC (1998), Zijlstra et al. (1999), Wiseman (2000), and Sauvant et al. (2004).

[2]Mean values from NRC (1998) and Sauvant et al. (2004).

Source: Animal Science Image Gallery

Table 5. Conversion factors of energy system in common grains[1]

Energy system	GE to DE	DE to ME	ME to NE
Wheat	GE x 0.875	DE x .977	ME x 0.768
Corn	GE x 0.831	DE x 0.967	ME x 0.813
Barley	GE x 0.821	DE x 0.978	ME x 0.780

[1]Summarized from Noblet et al. (1994).

energy that corn contains when fed to pigs. The lower concentration of crude fat, greater concentration of NDF, and the presence of variable amounts of non-starch polysaccharides (NSP) in wheat may be responsible for the lower concentration of energy in wheat than in corn.

Variation in energy concentration. Wu and Ewan (1979) summarized data from 16 separate studies and reported that the coefficient of variation in the concentration of DE in wheat is only 2.6%. However, data from 17 more recent studies that were summarized by Kim et al. (2005b) indicated that the concentration of DE ranged from 3,177 to 4,761 kcal/kg DM. These results warrant a careful assignment of the energy value of wheat. The relatively wide range of DE in wheat may be partly attributed to differences in growing conditions and season (Van Barneveld, 1999), and the presence of variable amounts of total NSP in wheat.

Physical damage to wheat can reduce its bushel weight (Taverner et al., 1975). However, bushel weight does not always correlate to the concentration of DE in wheat (Christison, 1975).

The concentration of DE in wheat can be predicted from the concentration of CP and NDF in the grain (Zijlstra et al., 1999):

DE (kcal/kg DM) = 3584 + 38.3 x CP (% DM) - 16 x NDF (% DM).

The efficiency of conversion of gross energy in grains to DE, ME, and NE is different among grains (Noblet et al. 1994). However, the overall efficiency of converting gross energy in wheat to NE is similar to the efficiency for corn and slightly greater than for barley (Table 5).

Digestible nutrients. The concentration of standardized ileal digestible (SID) amino acids is generally greater in wheat than in corn (Table 2). The concentration of indispensable SID amino acids is at least five percentage points greater in wheat than in corn, mainly due to the greater concentration of SID tryptophan, lysine, and threonine in wheat. Thus, less soybean meal is needed when formulating wheat-based diets and the economics of using wheat in swine diets will partly depend on the cost of soybean meal and other protein sources.

Wheat contains 0.35 to 0.39% total phosphorus, but 65 to 70% of the phosphorus is in the form of phytic acid (Selle et al., 2000). The phytate-bound phosphorus in wheat is poorly available to pigs because they do not produce sufficient intestinal phytase (Pointillart et al., 1984). The digestibility of phosphorus in wheat is, therefore, only around 43%, but this is greater than the digestibility of phosphorus in corn (Table 6). Wheat does contain endogenous phytase in the aleurone layer of the kernel (MacMasters et al., 1971), but this phytase is relatively inefficient in cleaving the phosphorus bound to phytic acid (Phillippy, 1999). Improvements in phosphorus utilization in wheat-based pig diets supplemented with microbial phytase have been reported (e.g. Nortey et al., 2007) and up to 1,000 FTU of exogenous phytase may be used (Johansen and Poulsen, 2003). Thus, the use of microbial phytase to improve phosphorus digestibility in wheat is recommended.

Table 6. Concentration and utilization of phosphorus and calcium in wheat and corn by pigs[1]

	Total P, %	Phytate P, as % of total P	P digestibility, %[2,3]	Total Ca, %
Wheat	0.34 (0.23-0.38)	56.7	42.7 (38.5-48.0)	0.05 (0.04-0.07)
Corn	0.25 (0.22-0.28)	80.0	24.3 (16.1-28.8)	0.02 (0.01-0.04)

[1]Summarized from Barrier-Guillot et al. (1996), NRC (1998), Spencer et al. (2000), Sauvant et al. (2004), Bohlke et al. (2005), Kim et al. (2005a), and Pedersen et al. (2007).

[2]Values are mean and range (in parenthesis).

[3]Apparent total tract digestibility.

Performance of pigs fed wheat

Pigs fed wheat-based diets can gain as quickly and as efficiently as pigs fed corn-based diets (Gill et al., 1966; Jensen et al., 1969; Han et al., 2005). Wheat can be used in diets for young pigs without affecting subsequent performance (Rodriquez and Young, 1981) and from the starter to the finisher phase 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 wheat-based diets is expected to be similar to that of pigs fed corn-based diets provided that both diets are formulated to contain the same concentration of digestible energy and nutrients. Growth performance is not different among pigs fed diets containing different wheat varieties (Zijlstra et al., 2002).

Source: National Pork Board

Wheat and corn

- Wheat contains less energy but more digestible amino acids and more digestible phosphorus than corn
- Wheat can replace all the corn in diets fed to all categories of pigs

Wheat can replace corn entirely in diets for all categories of pigs, as long as diets are balanced for amino acids and protein (Cromwell, 2002). However, a wheat-based diet can cause digestive problems in some pigs. Finely ground wheat can also lead to logistical problems in feeding;

it easily absorbs moisture and becomes wet, and it can bridge in self-feeders. For these reasons, some producers prefer to use corn or corn-wheat mixes. (Seerley, 1991).

Considerations on the use of wheat as feedstuff for pigs

Processing. Grinding of wheat improves the digestibility of energy and amino acids, and may improve animal performance (Wiseman, 1997). However, no optimal particle size of wheat for pigs has been established. Nursery and grower pigs fed wheat with a particle size of 860 to 1,710 μm did not show differences in weight gain. Performance was also similar for pigs fed wheat-based diets that contained particle sizes ranging from 500 to 3350 μm (Choct et al., 2004), but grinding of a wheat-based diet to a particle size of 500 μm, in combination with pelleting, slightly improved the SID of amino acids compared with a particle size of 1000 μm (Lahaye et al., 2008). Finely ground wheat-based diets may, however, increase the risk of gastroesophagial lesions (Erickson et al., 1980), may reduce feed intake as a result of increased dustiness, and requires additional electrical power during grinding. It is, therefore, recommended that wheat should be ground to an average particle size of 500 to 1000 μm.

NSP. Wheat contains about 11% total NSP, 80% of which is insoluble NSP (Smits and Annison, 1996). While NSP limits the use of wheat in poultry rations, the effects of NSP in wheat on the digestibility of energy and nutrients and on the growth of pigs are not clear. The amount of soluble NSP in wheat (i.e., arabinoxylans and beta-glucans) is not correlated with the concentration of DE in wheat fed to pigs (Zijlstra et al., 1999), and different sources of wheat with varying concentration of NSP did not affect the growth and feed efficiency of pigs (Zijlstra et al., 2002). The effect of feeding wheat on digesta viscosity is also not a limiting factor in pigs as it is in poultry, because of the greater fermentative capacity of pigs compared with poultry. Pigs also have a longer retention time of digesta, allowing for better fermentation of NSP (de Lange, 2000). Supplementation of exogenous enzymes such as xylanase, beta-glucanase, amylase, pectinase, and cellulase to better utilize the NSP in wheat did not show clear benefits (Partridge, 2001).

Source: Matt Lavin (http://creativecommons.org/licenses/by-sa/3.0/)

Mycotoxins. Wheat grain can be infected with mycotoxins, such as deoxynivalenol and zearalenone. Infection can occur when wheat contains 20% moisture or more, and at a storage temperature of 70 to 85°F. Therefore, proper storage conditions should be observed when storing wheat for prolonged periods. Wheat should not contain more than 5 ppm deoxynivalenol if fed to pigs, and contaminated wheat should not exceed 20% of the diet (FDA, 2005).

Physical quality. The expected test weight of wheat can range from 50 to 60 lbs/bu or 66.0 to 78.9 kg/hl based on wheat U.S. grade standards. Damage to wheat kernels reduces the digestibility of energy and nitrogen (Taverner et al., 1975), and feeding weather-damaged wheat may reduce pig performance (Brewster et al., 1999). However, it is difficult to estimate the amount of DE in wheat with varying amounts of damaged kernels. A safe limit for wheat intended for livestock would be that the sum of the damaged kernels, foreign material, and shrunken and broken kernels should comprise no more than 20% of the total weight of the lot, which would correspond to U.S. Grade No. 5. When using out-of-grade wheat (i.e., > 20% combined damaged grain and foreign material, weight basis), it is advisable to analyze for chemical components that are indicative of its energy concentration, such as GE and NDF, and adjust the DE accordingly using prediction equations.

Economics of feeding wheat to swine

Table 7 shows the maximum price that can be paid for wheat at different costs of corn and soybean meal without increasing the cost of the complete diet if wheat is used instead of corn. Given constant soybean meal costs, the maximum price that can be paid for wheat increases $1.04/bushel for each $1/bushel the price of corn increases. Likewise, for every $50/ton increase in the price of soybean meal, the price of wheat can increase by $0.06/bushel without increasing costs relative to a corn-based diet. This is because when wheat is substituted for corn in the diet, less soybean meal needs to be fed. Before including wheat in diets fed to swine, producers are advised to make their own calculations based on local prices for corn, soybean meal, and wheat. The wheat price estimator found at http://nutrition.ansci.illinois.edu/feed-ingredients (Figure 1) can assist with these calculations.

Table 7. Maximum price ($/bushel) that can be paid for wheat at different costs of corn and soybean meal (SBM) without increasing cost of the complete diet [a, b, c]

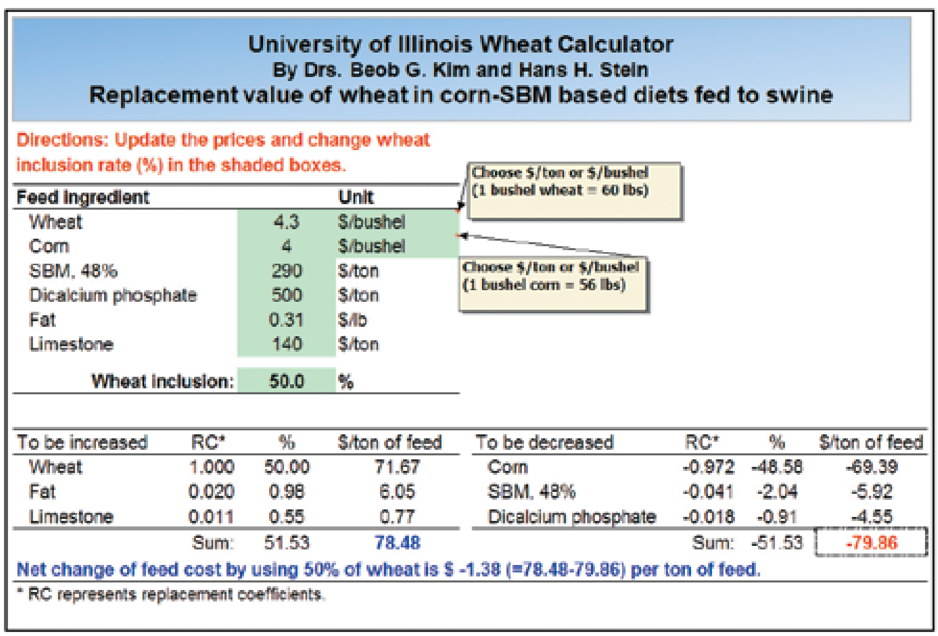
	Corn, $/bushel			
SBM, $/ton	3.0	4.0	5.0	6.0
200	3.23	4.27	5.31	6.35
250	3.29	4.33	5.37	6.41
300	3.35	4.39	5.43	6.47
350	3.41	4.45	5.49	6.53
400	3.47	4.51	5.55	6.59

[a] Calculations based on soybean meal containing 47.5% crude protein.

[b] For each combination of costs for corn and soybean meal, the price indicated for wheat will result in identical diet costs for a corn-soybean meal diet and a wheat-soybean meal diet. Total diet costs will be reduced if wheat can be purchased at prices that are less than indicated in the table.

[c] One bushel of corn = 25.45 kg; one bushel of wheat = 27.22 kg; one ton of soybean meal = 907 kg.

Figure 1. Spreadsheet for calculating the cost of replacing corn with wheat in a diet


University of Illinois Wheat Calculator
By Drs. Beob G. Kim and Hans H. Stein
Replacement value of wheat in corn-SBM based diets fed to swine

Directions: Update the prices and change wheat inclusion rate (%) in the shaded boxes.

Feed Ingredient		Unit
Wheat	4.3	$/bushel
Corn	4	$/bushel
SBM, 48%	290	$/ton
Dicalcium phosphate	500	$/ton
Fat	0.31	$/lb
Limestone	140	$/ton
Wheat inclusion:	50.0	%

Choose $/ton or $/bushel (1 bushel wheat = 60 lbs)

Choose $/ton or $/bushel (1 bushel corn = 56 lbs)

To be increased	RC*	%	$/ton of feed	To be decreased	RC*	%	$/ton of feed
Wheat	1.000	50.00	71.67	Corn	-0.972	-48.58	-69.39
Fat	0.020	0.98	6.05	SBM, 48%	-0.041	-2.04	-5.92
Limestone	0.011	0.55	0.77	Dicalcium phosphate	-0.018	-0.91	-4.55
	Sum:	51.53	78.48		Sum:	-51.53	-79.86

Net change of feed cost by using 50% of wheat is $ -1.38 (=78.48-79.86) per ton of feed.

* RC represents replacement coefficients.

Value of wheat

On a per bushel basis, the value of wheat is 4% greater than the value of corn

Conclusions

Although corn is the most common cereal grain used in swine diets in most regions of the United States, wheat can also be used. The relatively high concentration of amino acids in wheat compared with corn makes wheat an attractive alternative to corn, especially if prices of protein are high. The energy content of wheat can vary, but in general wheat is lower in energy than corn and diets should be formulated accordingly. Wheat can substitute for all the corn in diets fed to all categories of pigs.

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