Minimizing Starch Consumption by Finishing Pigs: Demonstrated and Theoretical Approaches

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Summary and Implications

The connections and tensions among grain production, livestock feeding, and biofuel generation is well illustrated by conditions in Iowa during the early 21st century. The traditional conditions of abundant corn may not continue in the future. It is appropriate to discuss diets based on alternative energy feed sources for swine in Iowa, the leading corn, pig, and ethanol producing state. Because starch is used to make ethanol from corn, the objective of this analysis was to explore swine diets that minimize starch usage.

Consumer demand and resultant market prices will ultimately determine whether corn is used for producing ethanol or feeding pigs. For each market pig fed a typical corn-soybean meal diet from 18–127 kg, 262 kg of corn grain is consumed. Proven diets can reduce corn use by about 30% with theoretical diets potentially lowering corn use by 45%. Typical corn-soybean meal diets use starch to supply approximately 60% of the total NE. Proven diets can reduce starch use by 26% with theoretical diets potentially reducing starch use by 45%. Although some alternative feedstuffs can be incorporated into pig diets, the feasibility of expanding their use is uncertain. Effects on pork quality, feed delivery systems, feed storage and handling characteristics, and relative economics of alternatives remain to be explored further. Using bioenergy co-products can reduce corn feeding to pigs by 25% and has the potential to reduce corn feeding to pigs by about 35% to 45%.

Introduction

The connections and tensions among grain production, livestock feeding, and biofuel generation is well illustrated by conditions in Iowa during the early 21st century. Historically, feeding corn (*Zea mays*) to livestock, particularly pigs, was the primary method for Iowa farmers to increase the value of their crop. Perennial surpluses of corn lowered market prices of the crop and encouraged development of other markets such as ethanol production. Industrial production of ethanol began in 1978 and has experienced exponential growth since 2002. In Iowa, the primary feedstock for ethanol is corn, for every 1.0 L of ethanol produced, 2.4 kg of corn is used and 1.6 kg of dried distiller's grains with solubles (DDGS) is co-generated. Production of ethanol from corn grain results in removal of the starch and concentration of the protein, lipid, fiber, and ash fractions of the corn kernel. Iowa leads the United States in production of corn, pigs, ethanol, and biodiesel. Accordingly, Iowa also leads the U.S. in the production of co-products of these industries—swine manure, distiller's grains with solubles, and crude glycerol. The challenge for a successful swine industry is to create linkages that capture the advantages of each resource.

The traditional conditions of abundant corn may not continue in the future. It is appropriate to discuss diets based on alternative energy feed sources for swine in Iowa, the leading corn, pig and ethanol producing state. Because starch is used to make ethanol from corn, the objective of this analysis was to explore swine diets that minimize starch usage.

Materials and Methods

Nutritional comparisons of diets with alternative energy sources. Examining use of alternatives in pig diets allows for a comparison of corn grain use as well as the amount of starch provided. A formal starch requirement for pigs has not been defined. Starch-free diets are possible, however, under most production conditions they are not practical. Given the increased production of biofuels from traditional sources of starch in pig diets it is useful to examine alternative diets for starch content. Total levels of phosphorus fed the pig and thus potential for phosphorus excretion can also be determined.

The finishing phase of pork production requires the most feed. For our comparison we assumed a pig start weight of 18 kg and a finish weight of 127 kg. Feed consumption and diet formulation for the finishing period are based on recent work at the Iowa State University Swine Nutrition Farm, Ames, Iowa. Diet composition and feed consumption for 3 phases of growth were used to calculate an overall diet formulation and analysis for a corn-soybean meal reference diet. Table 1 presents this reference diet with 8 other diets containing alternative feedstuffs and providing a constant ratio of NE to standardized ileal digestible lysine. Production condition assumptions include high lean growth capacity genetics, thermo-neutral environment, a 1:1 ratio of barrows and gilts in pens sized to allow adequate pen and feeder space/pig, and a modest level of antigen exposure.

Table 2 details calculated analysis and total consumption of diet components for the 9 diets presented in Table 1. Diet compositional analysis was calculated based on net energy. Diets similar to A through D have been proven to effectively support growth and development of pigs. Diets E through I are theoretical diets that remain to be tested under production conditions, but are presented for the purpose of comparison and discussion. It is assumed that pig growth is not compromised by any of the diets. It is also assumed that alternative grain starch sources (e.g. wheat, barley, etc.) would be of equal or greater price to corn starch in Iowa and thus were not considered as alternatives. Likewise, sugars and minor alternative feed energy sources, e.g. dried bakery product, were not included.

Results and Discussion

Demonstrated Diets. A typical corn-soybean meal diet fed to finishing pigs (Diet A) is approximately 50% starch by weight with more than 59% of the total NE provided by starch. In total, 262 kg of corn grain is consumed by each pig fed this diet from 18–127 kg. This diet would also provide 0.8 kg of unavailable phosphorus to the pig. Unavailable phosphorus is excreted by the pig. Although total P excretion includes unavailable P, available P that was not absorbed, and absorbed and biologically utilized P that was not recycled, unavailable P present in a diet will be used as a measure of total P excretion potential.

The maximal inclusion rate of corn DDGS in finishing pig diets has yet to be established. Given the variable nature of this co-product it is unlikely that a universal maximum exists, rather inclusion rates should be based on characteristics of the specific DDGS from a specific ethanol bio-refinery. Most modern ethanol facilities generate a DDGS product that allows for acceptable growth and performance at levels up to 20% DDGS in the diet with some reports of acceptable growth and performance at 30% DDGS inclusion. For this comparison a 25% inclusion rate of DDGS in a corn-soybean meal diet (Diet B) was considered. Diet B contains 37.2% starch, provides 44.5% of the total NE as starch, would require consumption of 192 kg of corn grain per pig, and provides 0.9 kg of unavailable phosphorus.

Crude glycerol is a co-product of biodiesel generation and is the 3-carbon backbone of a triacylglyceride. Crude glycerol is usually a viscous liquid and has been shown to have an ME for swine that is approximately equal to corn. Although this is a novel feedstuff, we have examined this product for use in pig diets. Based on our work with glycerol, a 10% inclusion rate in a corn-soybean meal diet is practical. Diet C with 10% glycerol contains 45% starch and supplies 59% of the total NE as starch. A total of 262 kg of corn grain and 0.8 kg of unavailable phosphorous would be consumed by a single pig over the defined growth period (18–127 kg).

Historic work reports that up to 15% raw beef fat may be hand fed to pigs in a mixed diet and support acceptable growth and performance. More recent reviews suggest 8% maximum inclusion rates of tallow with warnings that more than 5% may bridge feed. Historically the cost of animal fat has prohibited extensive use in pig diets and this is not expected to change in the near future. A corn-soybean meal diet containing 8% beef tallow was formulated (Diet D) to evaluate the possibility of minimizing starch in pig diets. Only 185 kg of corn grain is required to raise a pig to market on Diet D and only 0.6 kg of unavailable phosphorus would be fed. Less than 44% of total NE is supplied by starch, which comprises less than 42% of the total diet.

Theoretical diets. Research examining the effects of combining DDGS and crude glycerol in a corn-soybean meal diet has not been widely performed. Diet E was formulated to include 25% DDGS and 10% crude glycerol on the basis that those are the maximal practical inclusion rates for the individual feedstuffs. Starch accounts for 31% of Diet E and provides 42% of total NE. Corn grain is reduced to 186 kg, a 29% reduction compared to Diet A. Unavailable phosphorus is 0.9 kg for the entire growth period.

Feeding high levels of DDGS to pigs has been associated with less firm pork bellies, an effect that has been attributed to the influence of corn oil found in DDGS. Fat firmness is influenced by the relative ratio of unsaturated fatty acids to saturated fatty acids (U:S) in the adipose tissue. Dietary fatty acids are known to directly influence fatty acid profile of pig adipose tissue. By lowering the U:S ratio of the total diet by adding 5% beef tallow, pork fat quality and pork belly firmness may be maintained at higher levels of DDGS. Diet F was formulated to include 25% DDGS, 10% crude glycerol, and 5% beef tallow in an attempt to minimize use of corn grain in the diet. Starch composes 26% of the total diet and supplies 32% of the total NE. Corn grain use is only 144 kg, or 55% of the amount used in the reference corn-soybean meal diet. Unavailable phosphorus is 0.8 kg.

As corn fractionization and biofuel production become more refined, it is expected that not only the starch but potentially the lipid, the fiber, or both fractions will be removed and used for fuel generation. Diet G, H, and I consider these possibilities. Nutritional values of the various co-products were calculated from compositional data of DDGS.

Diet G was formulated to contain 30% of a DDGS product. Nearly 34% of the total diet is starch with almost 43% of the total NE supplied by starch. Diet G uses 184 kg of corn grain and 0.9 kg of unavailable phosphorus would be fed per pig from 18 to 127 kg. Diet H was formulated to contain 30% of a lipid-free DDGS product. Starch makes up more than 34% of this diet while supplying 45% of the total NE. Two hundred kg of corn grain and 1.0 kg of unavailable phosphorus would be consumed by a pig fed this diet from 18 to 127 kg. Diet I was formulated to contain 30% of a lipid-free, de-fibered DDGS product. Nearly 34% of the total diet is presented as starch with slightly more than 41% of the total NE being supplied by starch. Diet I uses 183 kg of corn grain and supplies 0.9 kg of unavailable phosphorus per pig fed from 18 to 127 kg. Interestingly, using these potential DDGS products reduces soybean meal use and relies on additional amino acid supplementation (shown as Other in Table 1). In other words, the concentrated proteins found in DDGS and other ethanol co-products can be used to meet some, but not all, the amino acid needs of the pig.

Overall Diet Discussion. Diet F requires the least amount of corn grain to feed a pig from 18–127 kg, but that diet is more than 40% corn grain. The higher levels of unavailable phosphorus presented in Diets B, E, F, G, H, and I compared with the reference corn-soybean meal diet may result in greater potential for phosphorus excretion and negative environmental consequences. These diets may be an opportunity for effective phytase use. Although theoretically possible, elimination of starch from pig diets does not appear to be practical at this time. Other sources of energy are likely to be priced relative to starch sources, particularly corn grain in Iowa, and the physical characteristics of fats, oils, and crude glycerol limit their inclusion in pig diets using existing equipment. Although refinement of mixers, feed delivery systems, and pig feeders in response to available feedstuffs are likely to continue, this is a relatively slow process and will limit the use of dietary alternatives to starch in pig diets for the near term.

Acknowledgements

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Table 1. Formulation and calculated analysis of different diets providing constant Net Energy: Standardized Ileal Digestible Lysine ratio.[1]

	Diet[2]								
Ingredient	A	B	C	D	E	F	G	H	I
Corn	78.00	58.00	70.00	65.00	48.00	41.00	53.00	53.40	53.00
Soybean meal	19.90	14.00	18.00	24.00	12.90	15.80	13.00	11.50	13.00
DDGS (0% starch)[3]		25.00			25.00	25.00			
DDGS – CF[4]							30.00		
DDGS – EE[5]								30.00	
DDGS – (CF +EE)[6]									30.00
Crude glycerol			10.00		10.00	10.00			
Beef tallow				8.00		5.00			
L-Lysine	0.06	0.40	0.02	0.13					
Dical	1.10		0.97	1.85					
Limestone	0.72	2.60	0.65	0.05	2.40	2.20	3.00	3.00	3.00
Other	0.22		0.36	0.97	1.70	1.00	0.93	2.10	0.86
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1]Based on reference corn-soybean meal diet fed in 3 phases from 40–280 lb.
[2]Diet A = reference corn-soybean meal diet.
[3]DDGS dried distillers grains with solubles.
[4]DDGS-CF DDGS with fiber removed.
[5]DDGS-EE DDGS with lipid removed.
[6]DDGS-(CF + EE) DDGS with fiber and lipid removed.
Diet B = corn-soybean meal diet with 25% DDGS (0% starch).
Diet C = corn-soybean meal diet with 10% crude glycerol.
Diet D = corn-soybean meal diet with 8% beef tallow.
Diet E = corn-soybean meal diet with both 25% DDGS (0% starch) and 10% crude glycerol.
Diet F = Diet E + 5% beef tallow.
Diet G = corn-soybean meal diet with 30% DDGS (0% starch) – CF.
Diet H = corn-soybean meal diet with 30% DDGS (0% starch) – EE.
Diet I = corn-soybean meal diet with 30% DDGS (0% starch) – (CF + EE).

Table 2. Calculated analysis[1] and consumption[2] by feed component of different diets providing constant Net Energy: Standardized Ileal Digestible Lysine ration.[1]

	Diet[3]								
	A	B	C	D	E	F	G	H	I
Calculated Analysis									
Crude protein, %	15.39	18.17	13.84	16.26	16.48	17.23	19.94	19.28	21.18
Crude fiber, %	2.91	4.24	2.62	2.87	3.96	3.98	1.95	4.92	1.95
Ether extract, %	3.26	4.66	2.93	2.86	4.27	4.07	5.45	2.19	2.21
Starch, %	50.00	37.18	44.87	41.67	30.77	26.28	33.97	34.23	33.97
NE, Mcal/kg of diet	2.45	2.42	2.20	2.76	2.12	2.35	2.36	2.20	2.38
SID Lys, g/kg of diet	6.52	6.44	5.86	7.36	5.65	6.24	6.28	5.86	6.33
Total phosphorus, g/kg diet	3.47	4.60	3.12	3.52	4.27	4.27	5.09	5.00	5.09
Available phosphorus, g/kg diet	1.20	2.10	1.08	1.35	2.01	2.03	2.46	2.43	2.46
Unavailable phosphorus, g/kg diet	2.27	2.50	2.04	2.17	2.26	2.24	2.63	2.57	2.63
Total consumption for finishing phase									
NE, Mcal	822	822	822	822	822	822	822	822	822
Feed consumption, kg	336	340	374	298	388	350	348	374	345
Starch, kg	168	126	168	124	119	92	118	128	117
% of total NE from starch	59.3	44.5	59.3	43.7	42.0	32.5	42.7	45.2	41.2
Corn, kg	262	197	262	185	186	144	184	200	183
Unavailable phosphorus, g	762.7	850.0	763.0	646.7	876.9	784.0	915.2	961.2	907.4

[1]Estimated analysis of diet based on net energy values.
[2]Feed consumption and estimated energy and nutrient consumption based upon 30 pigs (mixed barrows and gilts) fed 0% crude glycerol for 138 d.
[3]Diet A = reference corn-soybean meal diet.
Diet B = corn-soybean meal diet with 25% DDGS (0% starch).
Diet C = corn-soybean meal diet with 10% crude glycerol.
Diet D = corn-soybean meal diet with 8% beef tallow.
Diet E = corn-soybean meal diet with both 25% DDGS (0% starch) and 10% crude glycerol.
Diet F = Diet E + 5% beef tallow.
Diet G = corn-soybean meal diet with 30% DDGS (0% starch) – CF.
Diet H = corn-soybean meal diet with 30% DDGS (0% starch) – EE.
Diet I = corn-soybean meal diet with 30% DDGS (0% starch) – (CF + EE).