Final Report

Minnesota Pork Board Research Project

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I. Project Title: Ileal and total tract digestibility of fiber and starch in distillers dried grains with soluble by growing pigs

Principal Investigator: Dr. Jerry Shurson (in collaboration with Dr. Hans Stein and Pedro Urriola, University of Illinois)

Institution: Dept of Animal Science, University of Minnesota

II. Abstract

Competition between the ethanol and livestock industries has resulted in increased corn prices and the increase in U.S. ethanol production form corn has increased DDGS supply making the latter an attractive feed alternative for swine. Because DDGS has higher fiber content than traditional swine dietary ingredients, we investigated fiber content and digestibility of different sources of DDGS. Eleven growing barrows were surgically equipped with a T-cannula in the distal ileum and allotted to an 11 x 8 Youden square design with 11 diets and 8 periods. Pigs were fed 10 different diets using DDGS samples from 10 different ethanol plants, including 8 corn (C-DDGS), 1 sorghum (S-DDGS) and 1 corn-sorghum blend (CS-DDGS). Diets, ileal digesta and feces were analyzed for concentrations of crude fiber, acid detergent fiber (ADF), neutral detergent fiber (NDF), starch, total dietary fiber (TDF), insoluble dietary fiber (IDF), soluble dietary fiber (SDF), apparent ileal digestibility (AID) and apparent total tract digestibility (ATTD). Crude fiber in C-DDGS varied from 4.19 to 8.13%, whereas S-DDGS contained 6.63% and CS-DDGS contained 9.77%. In C-DDGS, concentration of ADF (7 to 16.7%) and NDF (27.7 to 44.1%) was not different from those in S-DDGS (11.0 and 41.9%, respectively), but was lower than CS-DDGS (25.0 and 41.9%, respectively). Concentrations of TDF were close to those of NDF and IDF in most samples, but SDF was low in all samples. Crude fiber AID for C-DDGS varied ($P < 0.01$) from 13.7 to 38.6% and was not different from S-DDGS and CS-DDGS. In DDGS, the digestibility of fiber is low, and in most sources, less than 50% of the non-starch polysaccharides (fiber) disappear with the passage through the intestinal tract, and more than 50% is excreted in the feces, indicating there are opportunities for enzymes or other additives to increase the digestibility of non-starch polysaccharides in DDGS.

III. Introduction

As ethanol production expands, the price of corn and other grains as well as the supply of distillers dried grains with solubles (DDGS) are increasing, which makes the latter an attractive alternative for swine diets. Unfortunately, optimal use of DDGS in swine diets is challenged by: 1) greater differences between GE and DE in DDGS compared to corn (Pedersen et al 2007); 2) variation in amino acid digestibility (Fastinger and Mahan 2006, Stein et al 2006); and 3) linear reduction of carcass yield with increased dietary DDGS (Whitney et al 2006). The high concentration of dietary fiber in DDGS is believed to be responsible, at least in part, for the suboptimal performance that is sometimes observed when pigs are fed diets containing this ingredient. Therefore, determination of fiber digestibility in DDGS is necessary to determine ways to optimize DDGS use in swine diets.

Dietary fibers are defined as the sum of oligosaccharides, non-starch polysaccharides (NSP), and lignin. These forms of carbohydrates are resistant to degradation by digestive enzymes in the pig's gastrointestinal tract, but are degraded by fermentation in the hindgut. There are several procedures used measure dietary fiber in feed ingredients including crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF; Grieshop et al 2001, Mertens 2003). However, these procedures have severe limitations when used to describe the feeding value of fiber for monogastric animals because they do not measure the water soluble NSP (Bach Knudsen, 2001). More recent methods for measuring dietary fiber are based on enzymatic-gravimetric and enzymatic-chemical procedures. The enzymatic-gravimetric method extracts low molecular weight sugars and lipids chemically, use enzymes to degrade protein and starch, then filtrates and corrects for residual protein and ash (Prosky et al., 1992). The residue is called "total dietary fiber" (TDF) and includes soluble and insoluble fiber, which gives a better description of the dietary fiber and its effects in the gastrointestinal tract (Bach Knudsen, 2001). In order to accurately describe the nutritional value of the fiber fraction in a feed ingredient, it is necessary to measure the concentration of TDF in the ingredient. It is believed that fiber has a lower digestibility than starch and reduces the digestibility of other nutrients, but there is no information on the digestibility of the fibers present in DDGS. These fibers can potentially be degraded by microbes in the small intestine or, more likely, in the hind gut producing short chain fatty acids (SCFA) that are easily absorbed and utilized by the animals. However, fermentation of fiber, depends on the physical and chemical composition of the fibers present in the feed ingredient and varies among feed ingredients.

IV. Objectives

The objective of the present study was to measure the digestibility of fiber and starch in different sources of DDGS.

V. Procedures

Procedures for feeding, sample collection, and sample processing have been previously described (Urriola, 2006). Briefly, 11 growing barrows were surgically equipped with a T-cannula in the distal ileum and allotted to an 11 x 8 Youden square design with 11 diets and 8 periods. Each period lasted 7 days and pigs were fed a new diet in each period. Samples of feces were collected on day 5 and ileal digesta were collected on days 6 and 7. The 11 diets included a N-free diet, 8 diets containing corn DDGS, one diet containing sorghum DDGS, and one diet containing DDGS produced from a blend of corn and sorghum (Table 1). The DDGS was obtained from 10 different ethanol plants. All samples of DDGS, diets, ileal digesta, and feces were analyzed for concentrations of crude fiber, acid detergent fiber (ADF), neutral detergent fiber (NDF), starch, total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF). Apparent ileal digestibility (AID) and apparent total tract digestibility (ATTD) of each fiber measure were calculated as previously described (Urriola, 2006).

Data were analyzed using the Proc MIXED procedure of SAS (SAS Stat Inst. Inc., Cary, NC). Analysis of variance was used to compare results for the 8 samples of C-DDGS. Least squares means for each sample were compared using the LSD option. Contrasts were used to compare data for S-DDGS and CS-DDGS to data for C-DDGS. The pig was the experimental unit for all analyses and the means were considered different at $P < 0.05$.

Table 1. Ingredient composition (%) of experimental diets (as-fed basis).

Ingredient, % of diet	N-free	C-DDGS	S-DDGS	CS-DDGS
DDGS	—	66.7	66.7	66.7
Cornstarch	81	27	27	27
Soybean oil	3	1	1	1
Sucrose	9	3	3	3
Solka floc[1]	3	—	—	—
Limestone	—	1.35	1.35	1.35
Dicalcium phosphate	2.5	—	—	—
Chromic oxide	0.30	0.30	0.30	0.30
Salt	0.45	0.30	0.30	0.30
Vitamin premix[2]	0.10	0.10	0.10	0.10
Micromineral premix[3]	0.25	0.25	0.25	0.25
Potassium carbonate	0.30	—	—	—
Magnesium oxide	0.10	—	—	—
Total	100	100	100	100

[1]Fiber Sales and Development Corp., Urbana, OH.
[2]Provided the following quantities of vitamins per kg of complete diet: vitamin A, 10,990 IU as vitamin A acetate; vitamin D_3, 1,648 IU as D-activated animal sterol; vitamin E, 55 IU as alpha tocopherol acetate; vitamin K_3, 4.4 mg as menadione dimethylpyrimidinol bisulphite; thiamin, 3.3 mg as thiamine mononitrate; riboflavin, 9.9 mg; pyridoxine, 3.3 mg as pyridoxine hydrochloride; vitamin B_{12}, 0.044 mg; D-pantothenic acid, 33 mg as calcium pantothenate; niacin, 55 mg; folic acid, 1.1 mg; and biotin, 0.17 mg.
[3]Provided the following quantities of minerals per kg of complete diet: Cu, 26 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 0.31 mg as potassium iodate; Mn, 26 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 130 mg as zinc oxide.

VI. Results

Fiber Concentrations: Concentrations of the fiber components were similar in C-DDGS and S-DDGS, but CS-DDGS contained more fiber than all the other sources of DDGS (Table 2). The concentration of crude fiber in C-DDGS varied from 4.19 to 8.13%, whereas S-DDGS contained 6.63% and CS-DDGS contained 9.77%. Concentrations of ADF and NDF in C-DDGS varied from 7.0 and 27.7%, respectively, to 16.7 and 44.1%, and ADF and NDF in S-DDGS were also within this range (11.0 and 41.9%, respectively). However, CS-DDGS had much greater concentrations of ADF and NDF than all the other samples (25.0 and 41.9%, respectively). Concentrations of TDF were close to the concentrations of NDF in most samples, and also close to concentrations of IDF, but concentrations of SDF were low in all samples. Among the 8 samples of C-DDGS, the same sample (source 1) had the lowest concentration and sources 3 or 7 had the greatest concentration of all measures of non-starch polysaccharides except for SDF.

Table 2. Concentration (%) of non-starch polysaccharides in DDGS.

Fiber Type	Corn-DDGS								S-DDGS	CS-DDGS
	1	2	3	4	5	6	7	8		
Crude Fiber	4.19	6.13	6.77	7.36	6.50	6.36	8.13	6.31	6.63	9.77
ADF	7.0	11.6	10.8	12.9	9.74	10.3	16.7	12.1	11.0	25.0
NDF	27.7	40.7	44.4	43.5	37.4	39.5	44.1	40.1	41.9	47.9
IDF	26.4	38.8	37.3	35.6	33.6	36.4	38.5	35.7	40.4	43.5
SDF	4.73	5.0	2.36	8.1	5.1	7.6	6.36	8.54	4.58	5.98
TDF	31.2	43.8	46.3	43.7	38.7	44.0	44.8	44.3	45.0	49.4

Apparent ileal digestibility (AID): The AID of crude fiber in C-DDGS (Table 3) varied ($P < 0.01$) from 13.7 to 38.6%, and both S-DDGS and CS-DDGS had values for AID of crude fiber that were within the range and not different from the values observed for C-DDGS (31.7 and 34.7%, respectively). The AID for ADF and NDF in C-DDGS varied ($P < 0.01$) from 28.2 and 37.5% to 57.4 and 52.1%, respectively. The value for the AID of ADF in S-DDGS (36.5%) was greater ($P < 0.01$) than in C-DDGS, but this was not the case for the AID of NDF (45.5%) in S-DDGS. In contrast, the AID for ADF in CS-DDGS (34.1%) was not different from the values observed for C-DDGS, but the AID of NDF in CS-DDGS (50.4%) was greater ($P < 0.01$) than in C-DDGS. Values for the AID of IDF in C-DDGS varied ($P < 0.01$) greatly (from 4.8 to 33.6%) and the AID for IDF in S-DDGS (20.5%) was not different from the values in C-DDGS. In contrast, the AID of IDF in CS-DDGS (29.3%) was greater ($P < 0.01$) than the average values for C-DDGS. Values for the AID of SDF were greater than all other AID values and varied ($P < 0.01$) from 56.5 to 81.7% in the 8 sources of C-DDGS, and the values for S-DDGS and CS-DDGS (56.4 and 64.5%) were not different from the values in C-DDGS. For TDF, AID values in C-DDGS varied ($P < 0.01$) from 16.9 to 38.2% and for S-DDGS, an AID of 25.5% was observed, but this value was not different from the AID for TDF in C-DDGS. However, the AID for TDF in CS-DDGS (35.9%) was greater ($P < 0.01$) than the AID in C-DDGS.

Apparent total tract digestibility (ATTD): The ATTD for crude fiber in C-DDGS varied ($P < 0.01$) from 21.7 to 41.6% and the values obtained in C-DDGS were not different from the values for S-DDGS and CS-DDGS (51.2 and 45.1%, respectively). The AID for ADF and NDF in C-DDGS varied ($P < 0.01$) from 36.2 and 39.5% to 63.1 and 62.3%, respectively. Values for S-DDGS (64.3 and 65.8%) and CS-DDGS (56.5 and 60.8%) were not different from the values for C-DDGS. The AID for IDF, SDF, and TDF in C-DDGS varied ($P < 0.01$) from 14.2, 85.9, and 23.4% to 45.8, 95.3, and 55.0%, respectively. The values for S-DDGS (51.0, 91.3, and 56.4%) and for CS-DDGS (45.0, 91.1, and 52.0%) were not different from the values obtained for C-DDGS.

VII. Discussion

Concentrations of crude fiber, ADF, and NDF in C-DDGS are consistent with previous reports (Spiehs et al., 2002; Stein et al., 2006; Pedersen et al., 2007), but those of S-DDGS and CS-DDGS have not been previously reported. The concentration of all the fiber components in CS-DDGS was greater than in C-DDGS and S-DDGS except for SDF. It was expected that the values for CS-DDGS would be close to the values for the other two sources of DDGS, but that was not the case. Concentrations of IDF, SDF, and TDF in DDGS have not been reported and our data indicate that most of the non-starch polysaccharides are insoluble as indicated by the relatively high concentrations of IDF, and were close to the analyzed concentration of NDF.

To our knowledge, there is no published data for AID and ATTD of non-starch polysaccharides in DDGS. The results reported here show that the greatest digestibility among the non-starch polysaccharides is that of SDF. The reason for this observation is that SDF contains components that will solubilize in the liquid environment of the intestinal tract, and approximately 60% will be absorbed in the small intestine, with an additional 30% that will be fermented in the hindgut to produce short chain fatty acids, so the overall disappearance is very high. However, insoluble non-starch polysacchrides are much less digestible than the soluble portion and while ileal digestibility for IDF was only around 20% for most DDGS sources, the total digestibility was between 40 and 50% for most sources. This observation suggests that non-starch polysaccharides of IDF are resistant to enzymatic hydrolysis and microbial fermentation in the hindgut of the pig. The feeding value of this fraction is, therefore, is very low and it is likely that the low digestibility of IDF in DDGS is the reason for the low digestibility of DM and GE in DDGS that has previously been reported (Pedersen et al., 2007). The digestibility of TDF is a combination of the values for SDF and IDF, and the AID and ATTD for TDF are, therefore, slightly greater than the AID and ATTD for IDF.

Table 3. Apparent ileal digestibility (%) and apparent total tract digestibility (%) of starch and dietary fiber in diets based on distillers dried grains with solubles (DDGS) fed to growing pigs.

Item	C-DDGS								S-DDGS	CS-DDGS	Contrasts		SEM	P-value
	1	2	3	4	5	6	7	8			S vs. C DDGS	CS vs. C DDGS		
Ileal digestibility														
Crude fiber	13.7	19.2	42.8	35.3	34.0	36.2	38.6	30.7	31.7	34.7	0.07	0.95	5.50	<0.01
ADF	35.0	28.2	47.0	40.0	32.6	40.8	57.4	41.4	36.5	34.1	<0.01	0.12	4.02	<0.01
NDF	41.7	37.5	52.1	48.8	45.7	45.1	49.9	37.9	45.5	50.4	0.18	<0.01	4.22	<0.01
IDF	5.9	9.0	33.6	26.	13.	21.1	27.7	4.8	20.5	29.3	0.14	<0.0	6.94	<0.0

				7	9							1		1
SDF	81.7	62.1	70.2	56.5	59.6	63.8	65.9	63.4	56.4	64.5	0.59	0.73	3.63	<0.01
TDF	29.0	19.6	38.2	32.8	21.8	28.3	33.4	15.9	25.5	35.9	0.30	<0.01	5.91	<0.01
Total tract digestibility														
Crude fiber	37.6	38.0	50.6	21.7	48.1	36.3	41.6	39.9	51.2	45.1	0.88	0.76	4.00	<0.01
ADF	63.1	51.8	62.2	36.2	54.7	53.7	60.7	53.7	64.3	56.5	0.13	0.64	4.08	<0.01
NDF	61.0	54.3	60.7	39.5	62.3	51.6	59.3	51.5	65.8	60.8	0.42	0.06	3.58	<0.01
IDF	37.1	30.9	45.8	14.2	41.7	29.3	41.3	28.6	51.0	45.0	0.30	0.05	4.24	<0.01
SDF	95.3	92.7	92.1	85.9	92.6	89.4	90.9	90.6	91.3	91.1	0.78	0.59	1.47	<0.01
TDF	55.0	41.1	52.8	23.4	49.5	39.4	48.8	39.2	56.4	52.0	0.49	0.06	4.58	<0.01

Although the analyzed concentrations of crude fiber, ADF, NDF, and IDF were different within each source of DDGS, AID and ATTD for each of these components were low and in many cases relatively similar to those of IDF. This suggests that regardless of which measure for non-starch polysaccharides in DDGS is used, the digestibility values that can be measured are low. In most sources of DDGS, less than 50% of the non-starch polysaccharides disappear during the passage through the intestinal tract and more than 50% is excreted. This indicates that there is ample substrate for enzymes or other additives that may be used to increase the digestibility of non-starch polysaccharides in DDGS to improve energy value, improve dry matter digestibility, and reduce fecal excretion.

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