REMOVAL OF FIBER FROM DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS) TO INCREASE VALUE

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ABSTRACT. *This study was undertaken to investigate the possibility of using air aspiration to remove fiber from distillers dried grains with solubles (DDGS), produced from fuel ethanol and beverage alcohol cereal grain dry–grind processes. The aspirated fraction was called "aspirated DDGS" and the remaining fraction (original DDGS without the aspirated fraction) was called "residual DDGS." Aspirated DDGS fractions were analyzed for individual and total phytosterol composition. Phytosterols are high–valued nutraceutical compounds that can be recovered from grain fiber fractions. The residual DDGS (original DDGS after the removal of fiber) was analyzed for fat, protein, neutral detergent fiber, acid detergent fiber, and ash content. The study showed limited success in removal of the fiber from the original DDGS fraction. Fiber content was only slightly enriched in the aspirated DDGS fraction compared to the residual DDGS fractions. Slightly better results (in terms of fiber enrichment) were seen with DDGS samples from certain dry–grind plants compared to the DDGS samples from other plants. These differences could be due to the differences in the milling/processing conditions of the plants. Although slight enrichment of fiber was obtained in the aspirated DDGS fraction as compared to the original DDGS, no significant enrichment of the phytosterols was noticed in the aspirated DDGS fraction. Due to aspiration, slight enrichment of oil and protein was observed in the residual DDGS fraction compared to the original DDGS. The increased oil and protein and decreased fiber content of the residual DDGS could result in increased market value of the residual DDGS.*

Keywords. *Distillers dried grains with solubles, Corn fiber, Phytosterols, Dry–grind ethanol, Aspiration.*

In a conventional dry–grind process, various cereal grains (corn, wheat, sorghum, rye, etc.) are used as raw materials for fuel ethanol or beverage alcohol production. In the U.S., however, most of the dry–grind plants use corn. Cereal grains contain approximately 60% to 70% starch and approximately 30% to 40% non–starch (protein, fiber, and oil) materials. During processing, grains are ground to reduce particle size and then mixed with water and thin stillage to produce a slurry, which is cooked. The starch in the slurry is liquefied, saccharified, and fermented to produce ethanol. After removal of ethanol by distillation, the remaining non–fermentables are dewatered and dried to produce distillers dried grains with solubles, or DDGS. The DDGS is the coproduct of the conventional dry–grind ethanol process and is sold as a feed product, mainly for ruminants.

Cereal grains are known to contain unique compounds called phytosterols. In corn, there are three mains types of phytosterol classes: ferulate phytosterol esters (FPE); free phytosterols (St), and fatty acyl phytosterol esters (St:E) (Moreau et al., 1996). Phytosterols can lower serum cholesterol levels in laboratory animals and, therefore, can potentially be sold as high–valued nutraceuticals (Moreau et al., 1998). Most of the phytosterols found in cereal grains are associated with the cell wall and fibrous tissue. In a conventional dry–grind ethanol plant, cell wall and fibrous tissue material ends up in the DDGS fraction.

Removal of fiber from the DDGS in a dry–grind ethanol plant has three potential benefits: (1) it adds another coproduct to the process which can be used for the recovery of high–valued phytosterols, corn fiber gum (Doner and Hicks, 1997) and other bio–based products; (2) it increases the percentage of protein and fat in the resulting DDGS; (3) it reduces the amount of fiber in the DDGS. The latter two effects may allow the dry–grind ethanol producers to sell DDGS as a more lucrative non–ruminant feed.

The objectives of this study were: (1) to determine the phytosterol composition of the aspirated fiber fraction that can be recovered from DDGS, (2) to determine the effect of fiber removal by aspiration on composition of resulting DDGS, and (3) compare the results between fuel ethanol and beverage alcohol plants.

MATERIALS AND METHODS

DDGS samples (approximately 10 to 15 kg) were obtained from three U.S. dry–grind ethanol plants in the Midwest. Two of the dry–grind ethanol plants used 100% corn as their feedstock, and one plant used 70% corn and 30% wheat flour slurry. Three DDGS samples were also obtained from three dry–grind beverage alcohol plants in the U.S. and Canada.

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Beverage alcohol plants typically use corn (80%), rye (10%), and malted barley (10%) as their feedstock.

A 1.0 kg representative sample of DDGS was placed on a 20–mesh (840 micron) screen and aspirated with an air jet at a pressure of approximately 2.8 atm using a procedure very similar to that of Eckhoff et al. (1996) to aspirate pericarp fiber from the germ fraction in the laboratory corn wet–milling procedure. The aspirated material was called "aspirated DDGS" and the remaining DDGS sample (without the aspirated DDGS) was called "residual DDGS." Mass balance was used to determine the amount of aspirated DDGS that could be recovered. All three of the samples (original DDGS, aspirated DDGS, and residual DDGS) were dried in a forced–air convection oven to determine their moisture contents (AACC, 2000).

All aspiration experiments were repeated once for the original, aspirated, and residual DDGS yields (for each dry–grind plant). The original, aspirated, and residual DDGS samples from both replicates were analyzed via HPLC at least twice. Results presented are the means and standard deviations of the multiple analyses. Dried samples (original DDGS, aspirated DDGS, and residual DDGS) were ground to 20 mesh in a Wiley mill and were extracted with hexane using an accelerated solvent extractor (Dionex ASE200, Dionex Corporation, Sunnyvale, Cal.). Ground samples (2 to 4 g) were placed in 11–mL sample extraction cells. The extraction conditions in the cells were as follows: pressure of 6895 kPa (1000 psi), temperature of 100°C, heat time of 5 min, start time of 10 min, 3 static cycles, 100% flush volume, and purge time of 60 sec, with a total volume of 22 mL.

For HPLC analysis, a part of the sample was removed from the extracted solvent, as previously outlined by Moreau et al. (1996). The lipid classes in samples were separated and quantified by a modified version of an HPLC technique developed by Moreau et al. (1996). The ternary gradient HPLC system used was a Hewlett Packard Model 1050 modular system (Hewlett Packard, Avondale, Pa.). Two detectors were connected in series. The first was a Hewlett Packard Model 1050 fixed wavelength UV–visible detector set at 295 nm. The second was an Alltech–Varex Mark III evaporative light–scattering detector (Alltech Associates, Deerfield, Ill.) operated at a temperature of 40°C, with nitrogen as a nebulizing gas at a flow rate of 1.60 L (STP)/min. The column was a Chromsep Cartridge LiChrosorb DiOL, 5 μm, 3 × 100 mm (Chrompack, Raritan, N.J.). The mobile phase gradient of hexane/2–propanol/acetic acid was the same as used by Moreau et al. (1996), and the flow rate was constant at 0.5 mL/min. The rest of the solvent sample was dried under nitrogen and heat using an N–EVAP analytical evaporator (Organomation Associates Inc., Berlin, Mass.).

Nitrogen content of all three of the samples from each plant (original DDGS, aspirated DDGS, and residual DDGS) was determined by thermal conductivity (Leco, 1994); a conversion factor of 6.25 was used to estimate the protein content. Neutral detergent fiber and acid detergent fiber content for the samples were estimated by the procedure outlined by Van Soest et al. (1991). Ash content of the samples was measured as the residue of sample placed in a muffle furnace at 550°C for 24 hours (AOAC, 2000).

Results and Discussion

Depending on the plant (fuel ethanol or beverage alcohol), the aspirated DDGS fraction recovered varied from 25.8% to 37.2% (table 1). On average, the amount of aspirated DDGS fraction recovered from fuel ethanol plants (33.1%) was comparable to the amount of aspirated DDGS recovered from the beverage alcohol plants (32.1%). Depending on the plant (fuel ethanol or beverage alcohol), the FPE extracted from the aspirated DDGS ranged from 26.5% to 34.8% of the total FPE present in the original DDGS fraction (table 2). The amount of St recovered ranged from 12.3% to 25.0%, while the amount of St:E recovered ranged from 28.6% to 39.5%. Total phytosterol recovery (FPE, St, and St:E) from the aspirated DDGS, depending on the plant, varied from 28.2% to 37.4% of the total present in the original DDGS fraction (table 2).

These results suggest that approximately 60% to 70% of the total phytosterols were retained in the residual DDGS fraction of the original DDGS and are not available in the aspirated DDGS fraction. Visually, the aspirated DDGS fraction appeared to be mainly pericarp fiber. Our previous research on the analysis and extraction of corn fiber indicated that most of these phytosterol compounds are concentrated in the aleurone layer of the fiber fraction (Singh et al., 2001a). Recovery of aleurone with pericarp fiber is a function of the milling/processing parameters (Singh et al., 1999, 2000, 2001b).

There were slight differences in the feedstock between the fuel ethanol and beverage alcohol plants (table 1), and on average, only slight differences were observed in the amount of individual and total phytosterols recovered from the aspirated DDGS from a fuel ethanol and a beverage alcohol plant (table 2). However, comparison of phytosterol recoveries among plant types (fuel ethanol or beverage alcohol) showed some significant differences. With certain plants (fuel ethanol plant 2 and beverage alcohol plant 3), it was easy to recover the aspirated DDGS from the original DDGS fraction and clean fiber fractions were obtained, while with other plants, small black particles (probably burned protein

Table 1. Dry–grind plants, their locations, feedstock, and yield of recovered, aspirated, and residual DDGS.

Plant Type and Location		Feedstock	Original DDGS (%)[a]	Aspirated DDGS (%)[a]	Residual DDGS (%)[a]
Fuel Ethanol					
Plant 1	U.S.	Corn (100%)	100	29.7	67.3
Plant 2	U.S.	Corn (100%)	100	36.0	62.0
Plant 3	U.S.	Corn (70%), Wheat flour (30%)	100	33.7	65.2
			Mean:	33.1	64.8
Beverage Alcohol					
Plant 1	U.S.	Corn (80%), Rye (10%), Malted barley (10%)	100	25.8	72.9
Plant 2	U.S.	Corn (80%), Rye (10%), Malted barley (10%)	100	33.2	65.6
Plant 3	Canada	Corn (90%), Malted barley (10%)	100	37.2	61.3
			Mean:	32.1	66.6

[a] All yields reported on dry basis.

Table 2. Yield of phytosterols in original, aspirated and residual DDGS from different dry–grind processes[a].

Plant Type	Sample fraction (DDGS)	FPE[b] (mg/100g sample)	% FPE recovered of the total in DDGS	St[c] (mg/100g sample)	% St recovered of the total in DDGS	St:E[d] (mg/100g sample)	% St:E recovered of the total in DDGS	Total phyto. (mg/100g sample)	% Total phyto. recovered of the total in DDGS
Fuel Ethanol									
Plant 1	Original[e]	46.78 ±0.57[f]		67.98 ±2.01		178.22 ±7.60		292.97	
	Aspirated	41.77 ±2.43	26.5	64.58 ±2.48	28.2	172.53 ±17.68	28.7	278.88	28.2
	Residual	46.46 ±0.80	66.8	64.74 ±0.72	64.1	174.80 ±1.52	66.0	286.00	65.7
Plant 2	Original	47.35 ±0.19		71.41 ±1.67		183.92 ±29.30		302.68	
	Aspirated	45.69 ±0.32	34.8	69.23 ±1.86	34.9	178.33 ±2.12	34.9	293.25	34.9
	Residual	52.29 ±1.61	68.5	76.12 ±4.78	66.1	175.07 ±19.55	59.0	303.48	62.2
Plant 3	Original	43.16 ±0.55		69.51 ±1.31		230.27 ±7.11		342.95	
	Aspirated	40.13 ±2.28	31.3	64.65 ±4.05	31.3	210.11 ±10.65	30.7	314.89	30.9
	Residual	42.52 ±1.97	64.2	74.44 ±6.85	69.8	212.66 ±26.93	60.2	329.62	62.7
Beverage Alcohol									
Plant 1	Original	35.35 ±0.72		44.52 ±1.30		156.63 ±8.26		236.50	
	Aspirated	38.76 ±0.69	28.3	47.57 ±0.56	27.6	173.52 ±7.61	28.6	259.85	28.4
	Residual	35.37 ±0.81	73.0	44.49 ±1.05	72.9	145.25 ±7.47	67.6	225.11	69.4
Plant 2	Original	55.29 ±0.69		75.53 ±2.26		163.16 ±6.06		293.98	
	Aspirated	50.61 ±4.94	30.4	75.48 ±2.22	33.2	168.04 ±1.34	34.2	294.13	33.2
	Residual	50.34 ±3.14	59.7	77.41 ±1.94	67.2	158.50 ±8.83	63.7	286.25	63.9
Plant 3	Original	46.46 ±0.84		69.85 ±4.64		129.81 ±8.08		246.12	
	Aspirated	43.27 ±1.50	34.6	66.51 ±4.88	35.4	137.84 ±1.66	39.5	247.61	37.4
	Residual	46.71 ±0.42	61.6	62.60 ±0.82	54.9	122.68 ±1.48	57.9	231.99	57.7

[a] All yields are averages of two values.
[b] FPE = ferulate phytosterol esters.
[c] St = free phytosterols.
[d] St:E = phytosterol fatty acyl esters.
[e] DDGS = distillers dried grains with solubles.
[f] Averages ± standard deviation.

particles) were also recovered in the aspirated DDGS fraction. These two plants also gave the highest aspirated DDGS recovery, approximately 36% to 37%, compared to other plants (25% to 33 % recovery) (table 1). The individual and total phytosterol recoveries (34% to 37%) for these two plants also were high, compared to individual and total phytosterol recoveries (26% to 33%) from other plants (table 2).

These differences in phytosterol recoveries and quality of fiber recovered were probably due to differences in the milling parameters among plants. In almost all of the dry–grind ethanol plants, corn is ground in a hammer mill before it is mixed with water and processed for ethanol production. In the dry–grind ethanol industry, there are two schools of thought regarding the size reduction of corn kernels and its relationship to the amount of ethanol produced. In some plants, corn kernels are reduced to fine flour, and in other plants corn kernels are ground to larger particle sizes. Although the exact milling parameters from any of these plants currently are not known, differences probably exist in milling/processing conditions among plants that would lead to different amounts of aleurone in the pericarp fiber and, therefore, in the recovered aspirated DDGS fraction. The present study suggests that by changing the milling/processing conditions, the characteristics of the pericarp fiber in the DDGS can be changed such that more high–valued phytosterols can be recovered.

Removal of the aspirated DDGS from the original DDGS resulted in increased oil content of the residual DDGS from all the three ethanol plants; the increase varied from 0.2 to 1.9 percentage points (table 3). Two of the three beverage alcohol plants also had higher oil content in the residual DDGS. Increases in oil content should result in higher useful energy content in the residual DDGS, compared to the conventional DDGS. Because oil contains 2.25 times more energy than carbohydrate (NRC, 1982), increased oil content improves nutritional value. The protein content of residual DDGS was about 0.4 to 1.4 percentage points higher than the conventional DDGS. Increased energy and protein content means that the residual DDGS (DDGS after the removal of aspirated fraction) has higher market value than conventional DDGS. The NDF content of residual DDGS was lower than for the original DDGS in most samples; however, ADF content was either reduced very little or was greater in the residual DDGS than in the original DDGS (table 3). Reduction in NDF but not in ADF content of residual DDGS suggests that hemicellulose is being affected and not lignocellulose. Nevertheless, the reduction in fiber content of the residual DDGS is not large enough to make it a practical feedstuff for non–ruminants because the fiber levels are significantly above levels typically found in non–ruminant diets.

Although the reduction in the NDF values in the residual DDGS was not very significant, this study suggests that, by changing the characteristics of the fiber by milling and processing changes at the front end of the dry–grind process and with optimization of the aspiration parameters at the back end, a significant amount of fiber can be removed from the original DDGS. Optimization of fiber removal from the original DDGS may significantly reduce the amount of NDF in the residual DDGS.

No trend was observed in the ash content of the residual DDGS (table 3). Removal of the aspirated DDGS fraction from the original DDGS increased the ash content for three

Table 3. Proximate composition of original, aspirated, and residual DDGS from different dry–grind processes[a].

Plant Type	Sample Fraction (DDGS)	Oil (%)	Protein (%)	NDF[b] (%)	ADF[c] (%)	Ash (%)
Fuel Ethanol						
Plant 1	Original	11.21	28.01	40.06	15.33	3.72
	Aspirated	10.95	25.68	42.53	13.83	3.95
	Residual	11.41	28.76	37.78	13.79	4.09
Plant 2	Original	15.10	29.92	40.49	16.35	4.24
	Aspirated	12.21	28.91	42.22	13.08	3.86
	Residual	17.02	31.36	37.69	14.96	3.99
Plant 3	Original	7.89	28.42	37.51	17.12	4.61
	Aspirated	7.74	27.61	39.34	17.56	4.51
	Residual	8.08	29.25	36.56	17.87	4.87
Beverage Alcohol						
Plant 1	Original	8.88	29.37	48.74	18.25	4.59
	Aspirated	9.15	26.53	51.79	17.91	4.43
	Residual	8.86	30.48	48.64	18.11	4.42
Plant 2	Original	12.64	30.03	48.43	18.71	3.74
	Aspirated	12.25	27.11	45.73	16.16	3.85
	Residual	12.87	30.41	45.81	20.32	3.91
Plant 3	Original	11.02	29.71	42.06	13.92	4.04
	Aspirated	10.05	28.05	45.86	13.70	3.79
	Residual	10.84	30.80	41.85	14.28	3.94

[a] All values are averages of two observations.
[b] Neutral detergent fiber.
[c] Acid detergent fiber.

plants by 0.2 to 0.4 percentage points and decreased the ash content for the remaining three plants by 0.1 to 0.3 percentage points.

CONCLUSIONS

Aspiration of DDGS created two fractions. The fraction that was removed by aspiration was slightly enriched in fiber, which appeared to be mainly pericarp fiber. The residual fraction had slightly higher oil and protein content compared to the original DDGS sample. Differences due to aspiration were observed among plants in the enrichment of fiber in the aspirated DDGS fraction and in the enrichment of oil and protein in the residual DDGS fraction. These differences could be due to some unique characteristics of fiber produced via different milling/processing conditions of the dry–grind plants. This study shows limited success for aspiration in recovering fiber from DDGS and in recovering phytosterol compounds. Aspirating DDGS samples produced by the dry–grind ethanol process did not yield an aspirated fraction that was significantly enriched in phytosterols.

Aspiration of DDGS resulted in enrichment of oil and protein content and reduction of the neutral detergent fiber in the residual DDGS fraction (original DDGS after the removal of the aspirated fraction). Higher oil and protein content in the residual DDGS can increase its market value as a ruminant feedstuff.

This study suggests that milling parameters in a dry–grind ethanol plant can potentially be manipulated such that the characteristics of the fiber produced in the original DDGS would allow fiber to aspirated better, and to recover higher amounts of phytosterols from the aspirated fiber fraction. A more detailed study of the dry–grind milling procedures and optimization of the fiber–recovery procedure is needed so that a maximum amount of fiber in the aspirated DDGS fraction can be recovered from the original DDGS, leaving the residual DDGS (feed product) high in oil and protein content and low in fiber content. This would benefit dry–grind ethanol producers by improving coproduct diversity and quality.

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