Separation of Fiber from Distillers Dried Grains with Solubles (DDGS) Using Sieving and Elutriation

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ABSTRACT

A process was developed to separate fiber from distillers dried grains with solubles (DDGS) in a dry-grind corn process. Separation of fiber from DDGS would provide two valuable coproducts: 1) DDGS with reduced fiber, increased fat, and increased protein contents; and 2) fiber. The process, called elusieve process, used two separation methods, sieving and elutriation, to separate the fiber. Material carried by air to the top of the elutriation column was called the lighter fraction and material that settled to the bottom of the column was called the heavier fraction. We evaluated the compositions of fractions produced from sieving and elutriation. Two commercial samples of DDGS were obtained from two dry-grind corn plants. Sieving over four screens (869, 582, 447, and 234 μm openings) created five size categories. The two smallest size categories contained >40% (w/w) of the original DDGS and had reduced fiber and increased protein and fat contents relative to the original DDGS. Elutriation of the remaining three size categories increased protein and fat contents and reduced fiber contents in the heavier fractions. Elutriation at air velocities of 1.59–5.24 m/sec increased the protein content of the heavier fraction by 13–41% and increased the fat content of the heavier fraction by 4–127% compared with the bulk fractions of each size category. This process was effective in separating fiber from both DDGS samples evaluated. Elusieve process does not require changes in the existing dry-grind process and can be implemented at the end of the dry-grind process.

In a dry-grind corn plant, starch is fermented to ethanol. Remaining components in the corn (protein, fiber, fat, unconverted starch, and ash) form a coproduct known as distillers dried grains with solubles (DDGS). DDGS is defined as the product obtained after removal of ethyl alcohol by distillation from the yeast fermentation of a grain or a grain mixture by condensing and drying at least 75% of the resultant whole stillage (AAFCO 2002). Currently, dry-grind corn plants produce about 70% of fuel ethanol in the United States. Ethanol production in the United States is expected to increase in the future (RFA 2004); DDGS supply will increase proportionately. Supply and demand of DDGS will play an important role in the economics of ethanol production. In the current scenario of rapidly increasing DDGS supply, there is a need for enhancing the value of DDGS. Separation of fiber from DDGS could result in two products: 1) DDGS with reduced fiber, increased fat, and increased protein contents; and 2) fiber.

DDGS with reduced fiber content could be used in nonruminant animal diets. DDGS with increased protein and fat content will enhance nutritional value and could increase market value. DDGS with high fat (13%) and high protein (33%) is worth about $5–20/ton more from a nutrient content basis than DDGS with lower fat (11%) and lower protein (28%) (Belyea et al 2004). Fiber produced from the elusieve process would be an additional coproduct of the dry-grind plants. Corn fiber could be used to make valuable products such as corn fiber oil, corn fiber gum, bioethanol, and xylitol (Grohmann et al 1997; Moreau et al 1999; Anonymous 2002; Buchanan 2002).

Singh et al (2002) investigated air aspiration as a method to separate fiber from DDGS. They showed limited success for aspiration in recovering fiber from DDGS and in recovering phytosterol compounds. In the present study, we used a combination of two separation methods, sieving and elutriation, to separate fiber from DDGS. This process is referred to as the elusieve process. Elutriation is defined as the separation of particles by means of an upward flowing stream of fluid. Aspiration is defined as "the act or the result of removing, carrying along, or drawing by suction" (McGraw-Hill 1978). The term aspiration is commonly used in the cereal processing industry to refer to the separation of particles by means of a stream of air, regardless of the method used to generate the flow of fluid. In this study, a blower was used to produce an upward stream of air; hence, elutriation is used here instead of aspiration. Equipment such as aspirators and cyclones may be used for industrial applications of this process.

Sieving is used to separate particles based on the difference in size. Elutriation by air is used to separate the particles in DDGS based on combined effects of density, shape, and size characteristics. In the dry-milling process, fiber is separated from other components of corn based on its lower density. Fiber would be less dense than nonfiber components in DDGS. When air is passed through DDGS, fiber would be carried away. Some nonfiber also would get carried with the air because nonfiber particles that are more dense and have smaller size would experience the same force as fiber particles that are less dense and have larger sizes.

Fiber in the original DDGS spans a wide range of sizes; hence, elutriation of DDGS would selectively remove fiber with a size that can be carried by the air at the operating velocity. At high air velocities, air would carry fiber of all sizes, but the carry over of nonfiber material would be high. Hence, it could be effective to first sieve the DDGS into various size categories and then elutriate the material in each size category at appropriate velocities to separate fiber from each size category. Objectives of this study were to 1) determine the composition and other nutritional characteristics of fractions produced after sieving and elutriation steps; and 2) assess the effect of velocity of air on composition and yield of lighter fractions.

MATERIALS AND METHODS

DDGS samples (20 kg) were obtained from two dry-grind corn plants in the United States. The dry-grind corn plants used only corn as their feedstock. DDGS-1 was produced from a flash-drying process. DDGS-2 was produced from a ring-drying process. In a flash dryer, the wet feed is dried by transporting it for a few seconds in a hot gas stream. Ring dryers contain a centrifugal

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classifier in the flash-drying loop that recirculates larger, wetter particles back for further drying.

Sieving

A vibratory screen (model LS188333, Sweco Vibro-Energy Separator, Los Angeles, CA) was used to sieve DDGS samples into size categories. The screens were 24T (869 μm), 34T (582 μm), 35M (447 μm), 60M (234 μm), and pan. The letters "M" and "T" refer to market-grade cloth and tensil bolt cloth. The size categories of material retained on these screens are referred to as 24T, 34T, 35M, 60M, and Pan, based on their respective screen labels. Material (1 kg) was sieved on each screen for 2 hr. The completion of sieving was ensured by measuring the weight change in the receiving container. The material passing through the sieve with a larger opening was collected and then fed to the next smaller sieve size. Only one sieve was used at a time.

Elutriation

An elutriation apparatus (Fig. 1) was developed for separating fiber from DDGS. It consisted of an elutriation column, an air blower for supplying air to the elutriation column, a surge box mechanism for controlling airflow, a vibratory feeder for feeding material into the column, and collection vessels for receiving the lighter and heavier fractions. Material elutriated by the air was called the lighter fraction. Material that settled to the bottom of the elutriation column was called the heavier fraction. The elutriation column was constructed using transparent perspex material to be able to visualize the separation process. The internal diameter of the column was 63 mm and the distance from the powder inlet to the air inlet nozzle was 360 mm. The distance of the lighter fraction collection vessel from the powder inlet was 1,100 mm. The lighter fraction collection vessel (300 × 300 × 300 mm) was constructed of transparent perspex material and had a hole 66 mm in diameter in the center of the bottom plate to insert the vessel onto the elutriation column. During operation, the open top was covered to 95% of its area using a wooden sheet. The velocity of airflow was measured by inserting a hotwire anemometer (model 8355, TSI Velocicalc, St. Paul, MN) into the powder inlet nozzle, with a set time constant of 10 sec. The anemometer was calibrated using a wind tunnel (model 8390, TSI). Air inlet diameter was 63 mm and powder inlet diameter was 19 mm.

The air was supplied using a blower (model 2C701, Dayton, Chicago, IL). Airflow was controlled by a sliding plate arrangement on top of a cubical wooden box that was used as a surge vessel for the air supply. The air flow through the elutriation column is in the turbulent regime for the range of flow rate used in this study. DDGS material was fed into the elutriation column by a vibratory feeder (model 3090, Powdertec sample mill, Germany) at a rate of 1.0 g/min.

Experimental Procedure

Elutriation of each size category was conducted at four different velocities. The velocity range was selected such that the yield of lighter fraction was a minimum of 15% and a maximum of 90%. Air velocities were 1.59–5.24 m/sec, depending on DDGS material characteristics and size category.

Analytical Tests

Chemical analyses were conducted at a commercial analytical laboratory. Protein was reported as 6.25 × total nitrogen. Samples were analyzed for crude protein (Method 990.03, AOAC 2003), crude fat (Method 920.39), ash (Method 942.05), crude fiber (Method 962.09), and acid detergent fiber (Method 973.18). Neutral detergent fiber (NDF) content was determined by the procedure outlined by Van Soest et al (1991). Crude fiber is the residue remaining after extraction by acid and alkaline hydrolysis; NDF is a measure of the cellulose, hemicellulose, and lignin contents; while acid detergent fiber (ADF) is a measure of cellulose, acid detergent insoluble nitrogen, acid insoluble ash, and lignin contents (Van Soest et al 1991). Sample moisture contents were determined using the two-stage convection oven method (Approved Method 44-18, AACC International 2000). Total digestible nutrients (TDN%) was calculated using digestive factors of 0.78, 1.90, 0.57, and 0.85 for protein, fat, fiber, and nitrogen free extract, respectively, and was calculated as (NRC 1982): TDN% = {(% crude protein × 0.78) + (% crude fat × 1.90) + (% crude fiber × 0.57) + (% nitrogen free extract × 0.85)}. Metabolizable energy (ME, Mcal/kg) was calculated as: ME = {0.96 – (0.00202 × % crude protein)} × TDN × 0.02/0.4536; net energy gain (NEg, Mcal/kg) was calculated as: NEg = {(0.00786 × % TDN) – 0.051}/0.4536.

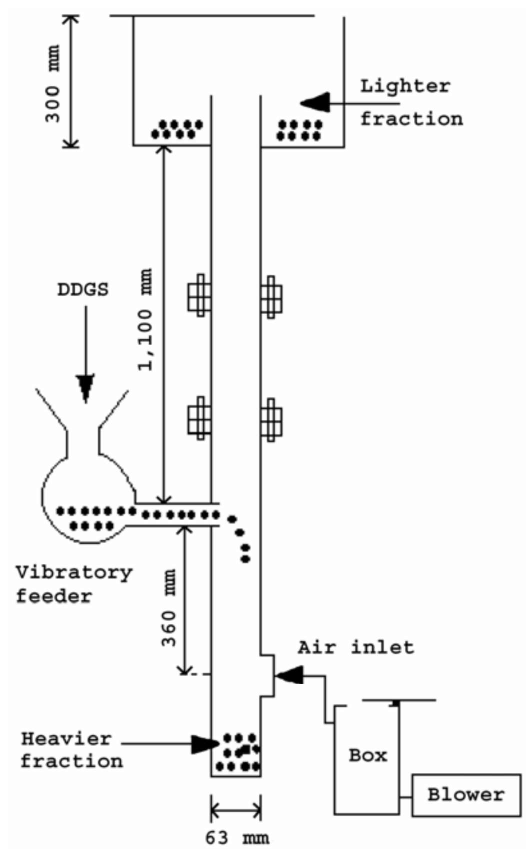

Fig. 1. Schematic of elutriation apparatus.

TABLE I
Weight Percent of Material Retained on Each Screen

Mesh Category	Opening (μm)	Referred to as	DDGS-1 (%w/w) Retained on Screen	DDGS-2 (%w/w) Retained on Screen
24T	869	24T	27.0	12.7
34T	582	34T	19.4	16.9
35M	447	35M	13.3	13.3
60M	234	60M	20.1	30.1
Pan	0	Pan	20.2	27.0

NDF Separation Factor

NDF separation factor for elutriation is defined as the ratio of the NDF%/Non-NDF% of the lighter fraction to the NDF%/Non-NDF% of the heavier fraction. It is calculated as: $[\text{NDF\%}/(100 - \text{NDF\%})]_{\text{Lighter fraction}}/[\text{NDF\%}/(100 - \text{NDF\%})]_{\text{Heavier fraction}}$. NDF separation factor indicates the selectivity of air in carrying fiber rather than nonfiber at the operating air velocity.

A high NDF separation factor indicates that the selectivity of air in carrying fiber is high. NDF separation factor is analogous to solvent selectivity in liquid extraction and relative volatility in ditillation (Treybal 1980).

Statistical Analyses

The repeatability of the elutriation experiments was verified. Elutriation of DDGS-1 24T size category was done five times at an air velocity of 2.47 m/sec and powder feeding rate of 1 g/min. Mean yield of lighter fraction obtained was 16.7% with a coefficient of variation of ±2.5%.

Elutriation of DDGS-2 35M size category was done five times at air velocity of 1.59 m/sec and powder feeding rate of 1 g/min. Mean yield of lighter fraction obtained was 16.8% with a coefficient of variation of ±9.9%. All composition values are reported as the mean of two determinations taken from the same material lot.

RESULTS AND DISCUSSION

Sieving

The two smallest size categories, 60M (234 – 447 μm) and Pan (<234 μm), which were produced by sieving of the original DDGS samples, comprised 40% of the mass of the original DDGS for DDGS-1 and 57% of the mass of the original DDGS for DDGS-2 (Table I). Size categories 60M and Pan contained lower fiber and higher protein contents with respect to the original DDGS samples (Tables II and III).

For DDGS-1, the original material contained 33.6% protein and 32.5% NDF; the 60M size category contained 37.5% protein and 29.3% NDF. The Pan size category contained 42.2% protein and 19.0% NDF (Table II). For DDGS-2, the original material contained 32.9% protein and 33.6% NDF; the 60M size category contained 33.6% protein and 29.7% NDF. The Pan size category contained 40.1% protein and 27.9% NDF (Table III). These two size categories (60M and Pan) of DDGS-1 and DDGS-2 were not subjected to elutriation due to low fiber and high protein contents.

Elutriation and Fiber Separation

To determine yields of lighter fraction at each velocity and compositions of lighter and heavier fractions, the three largest size

TABLE II
Composition (db) of Original Material and Size Categories for DDGS-1 After Sieving[a]

Size Category	Nominal Particle Size (μm)	Crude Protein%	Crude Fat%	TDN%	Ash%	NDF%	Crude Fiber%	ADF%	NEg (Mcal/kg)	ME (Mcal/kg)
Original material	All	33.6	12.5	90.7	3.95	32.5	11.5	18.7	1.46	3.57
24T	> 869	29.3	12.5	89.5	3.95	33.4	11.5	15.2	1.46	3.57
34T	582 to 869	26.9	11.3	88.8	4.15	37.8	9.25	15.3	1.43	3.55
35M	447 to 582	31.2	10.9	89.8	4.14	33.6	10.1	17.1	1.46	3.55
60M	234 to 447	37.5	11.3	89.7	4.33	29.3	7.75	19.6	1.46	3.51
Pan	< 234	42.2	12.9	90.9	4.57	19.0	6.12	14.3	1.48	3.51

[a] TDN, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid detergent fiber; NEg, net energy gain; ME, metabolizable energy.

TABLE III
Composition (db) of Original Material and Size Categories for DDGS-2 After Sieving[a]

Size Category	Nominal Particle Size (μm)	Crude Protein%	Crude Fat%	TDN%	Ash%	NDF%	Crude Fiber%	ADF%	NEg (Mcal/kg)	ME (Mcal/kg)
Original material	All	32.9	13.2	91.0	4.53	33.6	8.90	13.9	1.48	3.59
24T	> 869	21.2	13.1	90.3	4.09	39.0	12.60	15.5	1.46	3.66
34T	582 to 869	24.1	11.9	90.0	3.30	40.1	10.70	15.9	1.46	3.64
35M	447 to 582	27.5	12.7	90.3	4.32	34.5	8.60	13.4	1.46	3.62
60M	234 to 447	33.6	12.5	89.3	4.80	29.7	8.55	11.5	1.46	3.51
Pan	< 234	40.1	13.3	90.9	4.70	27.9	4.35	10.8	1.48	3.53

[a] TDN, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid detergent fiber; NEg, net energy gain; ME, metabolizable energy.

TABLE IV
Composition (db) of Fractions from Elutriation of DDGS-1 Demonstrating Separation of Fiber[a]

Size Category	Velocity (m/sec)	Yield% (L)	Crude Protein% (H)	Crude Fat% (H)	NDF% (L)	NDF% (H)
24T (size > 869 μm)	0*	· · ·	29.3*	12.5*	· · ·	33.4*
	2.47	17.20	33.0	13.0	62.8	31.4
	3.35	27.80	35.6	14.2	53.3	32.6
	4.45	43.30	41.2	15.5	46.8	24.2
	5.24	61.68	35.5	16.4	42.3	27.6
34T (582 μm < size < 869 μm)	0*	· · ·	26.9*	11.3*	· · ·	37.8*
	2.22	23.13	32.0	12.6	62.7	34.5
	2.55	33.40	33.1	13.8	58.7	32.4
	2.85	52.82	34.9	16.2	48.1	31.6
	3.86	82.30	35.5	16.3	41.3	26.2
35M (447 μm < size < 582 μm)	0*	· · ·	31.2*	10.9*	· · ·	33.6*
	1.84	19.30	35.4	13.1	56.0	27.6
	2.03	31.80	36.2	13.3	51.4	28.3
	2.22	47.10	36.5	14.1	44.3	26.9
	2.60	75.98	37.1	15.4	39.3	25.8

[a] *, Values at 0 m/sec denote initial bulk material; NDF, neutral detergent fiber; H, heavier fraction; L, lighter fraction.

categories, 24T (>869 μm), 34T (583–869 μm), and 35M (447–583 μm) were each subjected to air elutriation at different velocities. High NDF in the lighter fractions in conjunction with high protein and fat content in the heavier fractions signify effective separation of fiber from the bulk of each size category subjected to elutriation. For both DDGS samples, elutriation using air was effective in separating fiber from the bulk material of each size category (Table IV for DDGS-1 and Table V for DDGS-2). For example, for the bulk material in the 35M size category of DDGS-1 and air velocity of 2.03 m/sec, NDF increased from 33.6 to 51.4% in the lighter fraction, protein increased from 31.2 to 36.2% in the heavier fraction, and fat increased from 10.9 to 13.3% in the heavier fraction (Table IV). For the bulk material in the 34T size category of DDGS-2 and air velocity of 2.55 m/sec, NDF increased from 40.1 to 54.6% in the lighter fraction, protein increased from 24.1 to 32.7% in the heavier fraction, and fat increased from 11.9 to 18.8% in the heavier fraction (Table V).

The relative values of NDF, protein, and fat contents in the fractions at each air velocity signify the separation of fiber, at all air velocities: NDF% (lighter fraction) > NDF% (bulk) > NDF% (heavier fraction); protein% (heavier fraction) > protein% (bulk) > protein% (lighter fraction) and fat% (heavier fraction) > fat% (bulk)

TABLE V
Composition (db) of Fractions from Elutriation of DDGS-2 Demonstrating Separation of Fiber[a]

Size Category	Velocity (m/sec)	Yield% (L)	Crude Protein% (H)	Crude Fat% (H)	NDF% (L)	NDF% (H)
24T (size > 869 μm)	0*	· · ·	21.2*	13.1*	· · ·	39.0*
	2.55	21.20	25.6	17.1	66.2	32.2
	3.35	45.82	26.7	20.1	50.0	37.2
	4.45	68.52	25.5	24.7	45.2	37.7
	4.80	89.44	24.9	24.7	45.3	33.4
34T (582 μm < size < 869 μm)	0*	· · ·	24.1*	11.9*	· · ·	40.1*
	2.09	21.22	29.6	13.8	67.1	35.2
	2.55	41.93	32.7	18.8	54.6	32.7
	2.85	58.45	31.4	18.6	50.9	29.3
	3.60	88.21	29.9	27.0	43.8	25.7
35M (447 μm < size < 582 μm)	0*	· · ·	27.5*	12.7*	· · ·	34.5*
	1.59	18.22	32.1	13.4	61.2	28.5
	2.03	40.10	33.7	15.1	55.8	32.7
	2.22	46.30	33.6	15.3	52.4	29.7
	2.72	88.40	32.8	18.1	41.9	26.7

[a] *, Values at 0 m/sec denote initial bulk material; NDF, neutral detergent fiber; H, heavier fraction; L, lighter fraction.

TABLE VI
Other Characteristics (db) of Fractions from Elutriation of DDGS-1[a]

Size Category	Velocity (m/sec)	Crude Protein% (L)	Crude Fat% (L)	Crude Fiber%		ADF%		TDN%	
				H	L	H	L	H	L
24T	2.47	13.0	5.28	5.95	14.8	16.8	16.5	91.4	82.5
	3.35	19.3	7.05	7.70	12.8	18.0	19.4	91.9	84.4
	4.45	23.2	14.90	7.00	11.5	22.5	20.6	92.6	92.5
	5.24	26.1	10.20	4.55	9.6	18.0	15.6	95.1	88.1
34T	2.22	12.2	5.66	8.70	13.4	18.2	18.4	90.0	83.0
	2.55	15.5	6.45	10.60	15.6	18.8	18.3	90.5	83.1
	2.85	21.7	7.93	9.15	11.6	17.2	18.0	92.8	85.1
	3.86	26.2	10.30	11.50	9.6	20.9	18.8	81.8	87.7
35M	1.84	16.5	8.46	7.10	13.7	18.9	17.3	90.4	85.6
	2.03	23.0	8.30	8.40	10.8	18.3	18.7	90.0	85.5
	2.22	25.3	9.19	6.80	11.1	17.7	19.0	91.5	86.2
	2.60	28.8	10.40	6.50	9.7	14.6	17.9	92.6	87.6

[a] ADF, acid detergent fiber; TDN, total digestible nutrients; H, heavier fraction; L, lighter fraction.

TABLE VI (continued)
Other Characteristics (db) of Fractions from Elutriation of DDGS-1[a]

Size Category	Ash%		NEg (Mcal/kg)		ME (Mcal/kg)	
	H	L	H	L	H	L
24T	3.87	3.53	1.48	1.32	3.62	3.40
	3.98	3.62	1.48	1.34	3.59	3.44
	4.56	3.83	1.50	1.50	3.59	3.73
	3.93	3.69	1.54	1.41	3.73	3.53
34T	4.23	3.85	1.46	1.32	3.55	3.42
	4.31	3.78	1.46	1.32	3.57	3.42
	4.88	4.04	1.50	1.37	3.64	3.44
	4.80	4.19	1.32	1.41	3.22	3.53
35M	4.66	3.89	1.46	1.37	3.55	3.51
	4.74	4.17	1.46	1.37	3.53	3.44
	4.55	4.13	1.48	1.39	3.57	3.46
	4.90	4.30	1.50	1.41	3.62	3.48

[a] NEg, net energy gain; ME, metabolizable energy; H, heavier fraction; L, lighter fraction.

TABLE VII
Other Characteristics (db) of Fractions from Elutriation of DDGS-2[a]

Size Category	Velocity (m/sec)	Crude Protein% (L)	Crude Fat% (L)	Crude Fiber%		ADF%		TDN%	
				H	L	H	L	H	L
24T	2.55	10.7	4.8	12.6	16.5	13.9	17.5	93.9	81.4
	3.35	18.5	7.1	14.5	12.1	18.2	16.2	96.2	84.3
	4.45	20.7	8.0	12.5	13.4	17.5	16.3	101.0	85.7
	4.80	21.8	11.9	7.35	8.9	16.5	15.6	103.0	89.9
34T	2.09	11.5	5.4	9.20	15.9	14.4	18.3	90.7	81.9
	2.55	17.5	7.3	7.90	12.6	14.8	18.7	95.9	84.5
	2.85	20.5	8.4	7.35	14.1	13.7	16.6	95.8	84.9
	3.60	24.8	10.9	9.40	11.6	17.3	16.5	104.0	87.7
35M	1.59	12.3	6.0	6.70	12.7	11.8	17.1	91.2	84.0
	2.03	18.6	8.3	6.55	12.0	12.4	15.0	92.8	85.5
	2.22	20.8	9.0	6.00	10.5	15.4	15.7	92.9	86.6
	2.72	26.5	11.4	4.90	8.3	16.7	15.4	96.4	89.3

[a] ADF, acid detergent fiber; TDN, total digestible nutrients; H, heavier fraction; L, lighter fraction.

TABLE VII (continued)
Other Characteristics (db) of Fractions from Elutriation of DDGS-2[a]

Size Category	Ash%		NEg (Mcal/kg)		ME (Mcal/kg)	
	H	L	H	L	H	L
24T	4.46	3.89	1.52	1.30	3.77	3.37
	4.67	4.07	1.57	1.34	3.86	3.44
	4.98	4.03	1.65	1.37	4.08	3.48
	4.43	4.29	1.68	1.46	4.17	3.64
34T	4.89	4.07	1.48	1.30	3.62	3.40
	5.16	3.98	1.57	1.34	3.79	3.44
	5.17	4.20	1.54	1.37	3.79	3.44
	5.32	4.46	1.70	1.41	4.14	3.53
35M	4.47	3.34	1.48	1.34	3.62	3.46
	4.62	4.21	1.50	1.37	3.66	3.48
	4.89	3.99	1.50	1.39	3.66	3.53
	4.61	4.01	1.57	1.43	3.81	3.57

[a] NEg, net energy gain; ME, metabolizable energy; H, heavier fraction; L, lighter fraction.

> fat% (lighter fraction) (Tables IV–VII). Higher NDF content in the lighter fraction and higher protein and fat contents in the heavier fraction indicates that the combination of sieving and elutriation was effective in separating fiber from DDGS produced by two different drying methods (flash drying and ring drying). There were corresponding increases in protein and fat contents in the heavier fractions from DDGS-1 and DDGS-2.

Elutriation and Effect of Air Velocity on Fiber Separation

An increase in air velocity increased the mass of lighter fraction and reduced the mass of heavier fraction. Correspondingly, protein and fat were higher in the heavier fraction and NDF was lower in the lighter fraction because higher air velocities carried the denser nonfiber components into the lighter fraction (Tables IV and V). In general, an increase in air velocity reduced the NDF separation factors obtained by elutriating the size categories, which signifies reduced selectivity of the air in carrying fiber because of the ability of air to carry the denser nonfiber components at higher velocities (Fig. 2).

In general, protein contents of heavier fractions exhibited an increasing trend with increasing air velocity except for some size categories of both DDGS-1 and DDGS-2. Protein contents of heavier fractions tended to become constant or reduce at high air velocities (Tables IV and V). The fat contents of heavier fractions for all size categories showed an increasing trend as air velocity was increased (Tables IV and V).

In a dry-grind corn plant, the economic optimum air velocities for each size category will be governed by the dependence of fiber value on fiber purity and the dependence of the value of remaining DDGS on protein and fat contents. At low air velocities, fiber separated from the bulk material would have high NDF% (high purity of fiber), but the remaining DDGS would have lower protein and fat contents. At high air velocities, fiber separated from the bulk material would have low NDF% (low fiber purity), but the remaining DDGS would have higher protein and fat contents.

Decrease in size of particles fed to the elutriation column was expected to decrease the air velocity needed to produce a specific yield of lighter fraction as the force needed to carry smaller particles would be lower, density and shape would remain constant. Results from Tables IV and V confirm this. As the size of bulk material fed to the elutriation column decreased, operating air velocity needed to produce the same yield of lighter fraction decreased. For the size category >869 μm of DDGS-1, the yield of lighter fraction at air velocity of 2.47 m/sec was 17.2% (Table IV). For the size category 447–582 μm of DDGS-1, the air velocity needed to produce a similar yield (19.3%) was 1.84 m/sec (Table IV), which was lower than the operating air velocity for 24T size category.

Elutriation and Other Characteristics of Fractions

Crude fiber in the lighter fractions decreased as air velocity increased, exhibiting a trend similar to that of NDF, while ADF values did not follow any specific trend (Tables VI and VII). TDN in the heavier fractions increased with increasing air velocity, exhibiting a trend similar to those of protein and fat contents in the heavier fractions, while there was no specific trend observed in the ash content, NEg (net energy gain), and ME (metabolizable energy) values for heavier as well as lighter fractions.

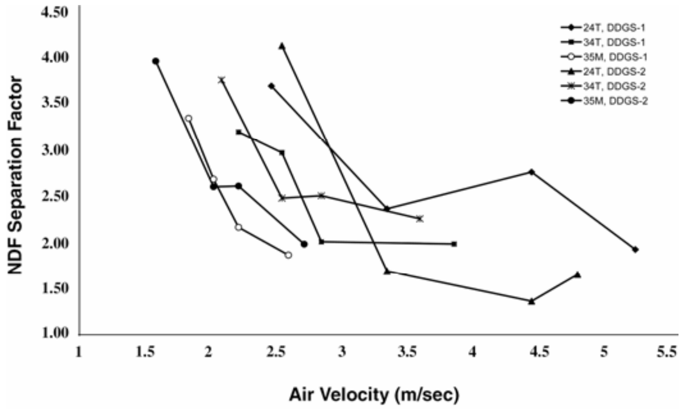

Fig. 2. Neutral detergent fiber (NDF) separation factors at different elutriation air velocities for elutriation of 24T, 34T, and 35M size categories of distillers dried grains with solubles (DDGS-1 and DDGS-2).

CONCLUSIONS

The elusieve process was effective in separating fiber from DDGS. Sieving alone produced two size categories that contained reduced fiber and increased contents of protein and fat. Elutriation of screened fractions resulted in increased contents of protein and fat and reduced fiber in the heavier fractions. Higher protein and fat content will increase market value of these DDGS fractions and decreased fiber content would increase the inclusion levels of DDGS in nonruminant diets. Fiber produced from the process is an additional coproduct and will further increase revenues because of its potential use in ruminant diets, production of corn fiber gum, corn fiber oil, phytosterols, xylitol, and bioethanol.

Thus, the elusieve process and its products would benefit dry-grind corn processors, especially important in the current scenario of rapidly increasing ethanol production. This separation process does not call for changes in the existing dry-grind corn process and facilitates easy implementation in existing plants. An economic feasibility study of elusieve process is underway.

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