Variation in Particle Size and Bulk Density of Distiller's Dried Grains with Solubles (DDGS) Produced by "New Generation" Ethanol Plants in Minnesota and South Dakota

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Background

Particle size and particle size uniformity of feed ingredients are important considerations of livestock and poultry nutritionists when selecting sources and determining the need for further processing when manufacturing complete feeds or feed supplements. Particle size affects:

Nutrient digestibility – as particle size is reduced, nutrient digestibility and feed conversion is improved. This is due to the increasing amount of surface area of an ingredient that is exposed and available for digestive enzymes to act upon.

Mixing efficiency – a more uniform particle size in a mixture of ingredients will reduce mixing time in order to achieve a uniformly distributed mix of ingredients in a complete feed.

Amount of ingredient segregation during transport and handling – particle and ingredient segregation (separation) occurs when particles of different sizes and bulk densities are blended together and transported or handled.

Pellet quality – is often defined as the hardness of the pellet and percentage of fines in the complete feed after pelleting. For corn-soybean meal based diets, a low mean particle size (400 microns) generally results in a higher quality pellet (less % fines).

Bulk density – is a measure describing the weight of an ingredient per unit volume. In general, bulk density can be increased by reducing particle size to increase the weight of a feed ingredient or complete feed per unit of volume.

Palatability and sorting of meal or mash diets – depending on the animal, a finely ground, powdery feed will reduce feed intake and cause bridging in feeders and storage bins. Extremely coarsely ground feeds can also reduce palatability.

Incidence of gastric ulcers – in swine, the incidence of gastric ulcers increases as the mean particle size of the diet is reduced.

Bulk density is an important factor to consider when determining the storage volume of transport vehicles, vessels, containers, totes, and bags. Bulk density affects transport and storage costs (low bulk density ingredients have higher cost per unit of weight). It also affects the amount of ingredient segregation that may occur during handling of complete feeds (high bulk density particles settle to the bottom of a load during transport, whereas low bulk density particles rise to the top of a load).

Methodology

In order, to obtain data on average particle size and bulk density of DDGS produced in "new generation" ethanol plants, we conducted a study during the summer of 2001 to obtain a representative sample of DDGS from 16 ethanol plants in Minnesota, South Dakota, and Missouri. A 10 lb sample of DDGS was obtained from each plant. From this 10 lb sample, a 200 gram subsample of DDGS from each plant was screened through five U.S. sieves and the weight of the DDGS not filtering through each screen was determined and recorded. The fine particles that filtered through all screens were collected in the pan and weighed. The U.S. sieve numbers and their corresponding size of screen openings (microns) were #10, #16, #18, #20, #30 representing 2000, 1180, 1000, 850, 600, respectively. The size of DDGS particles collected in the pan was < 600 microns. The weights of DDGS collected on each screen were then used to calculate the percentage of weight of each fraction of the total separated. In addition to determining the average particle size (geometric mean), we also calculated the variation (coefficient of variation – CV and standard deviation – SD) in particle size within and among ethanol plants. These results are shown in Table 1.

Bulk density (lbs/cubic foot) was determined by filling a one quart container and weighing the amount of DDGS to fill the container (results shown in Table 1). Samples were sent to Woodson-Tenent Laboratories for chemical analysis of moisture, crude protein, crude fat and crude fiber. These results are shown in Table 2. Samples were also visually evaluated for color and the presence of "syrup balls".

Results and Discussion

Table 1 shows a summary of the bulk density and particle size analysis results from this study. The average particle size among the 16 ethanol plants was 1282 microns (SD = 305, CV= 24%), and ranged from 612 microns in plant 6 to 2125 microns in plant 15. Thus there is considerable variation in average particle size of DDGS originating from these "new generation" ethanol plants. As a point of reference, the target mean particle size for meal or mash diets for swine and poultry is 600-800 microns. Only plants 6 and 7 were close to this target range. All other plants produced coarser DDGS particles suggesting that further grinding of DDGS may be warranted to reduce the mean particle size, improve particle size uniformity, an optimize nutrient digestibility of DDGS in a complete mixed feed. Plant 15 had the highest mean particle size (2125 microns). Ethanol plants that produced DDGS with high amounts of syrup balls tended to have a higher mean particle size. The distribution of particle size fractions are shown in Figures 1-16. There was similar distribution of particle size among all plants where the amount of DDGS particles collected on the 1180 micron screen tended to have the greatest proportion in all plants except plants 6 and 15. Plant 6 had the lowest average particle size and had a relatively high proportion of particles being collected on the 600 micron screen and in the pan. Plant 15 produced DDGS with the highest mean particle size, where the highest proportion of the particles were collected on the <2000 and 1180 screens.

Bulk density averaged 35.7 lbs/cubic foot (SD = 2.79, CV = 7.8%), but ranged from 30.8 to 39.3 lbs/cubic foot. However, the correlation between mean particle size and bulk density was surprisingly very low (r= 0.05) which may be due to the variable amounts of syrup balls among the samples collected.

Most samples had a “golden” color, but samples from plants 2, 8b, and 15 were considerably darker than the other samples collected.

Chemical analysis of DDGS from each ethanol plant for moisture, crude protein, crude fat, and crude fiber are shown in Table 2. Average moisture content of DDGS was 11.69% (SD = 0.91, CV = 7.8%). Average crude protein, crude fat, and crude fiber of DDGS was 26.63% (SD = 0.97, CV = 3.63%), 10.06% (SD = 0.70, CV = 7.00%), and 6.9% (SD = 0.78, CV = 11.27%), respectively. Crude fiber content of DDGS was the most variable among ethanol plants, followed by moisture, crude fat, and crude protein content. The correlation between bulk density and moisture was r = –0.68, which means that there appears to be a moderate negative relationship between bulk density of DDGS and moisture content. In other words, as the moisture content of DDGS decrease, the bulk density tends to increase. However, unlike the moderate correlation between bulk density and moisture content, the correlations between bulk density and crude protein, crude fat and crude fiber were negative and low (r = - 0.18, - 0.16, and – 0.20, respectively. This suggests that nutrient content (except moisture) has very little relationship with bulk density of DDGS.

Conclusion and Implications

Although the physical characteristics and chemical analysis of corn DDGS produced by “new generation” DDGS plants may be more consistent that DDGS produced from other sources in the ethanol industry, significant improvements are needed to provide a more consistent quality DDGS relative to particle size, bulk density, color, and nutrient composition among “new generation” ethanol plants. Ethanol plants that have implemented production procedures that improve consistency of DDGS have become preferred suppliers of DDGS for commercial feed manufacturers. The proposed implementation of standard operating procedures in the Minnesota Certified DDGS Quality Handbook will improve DDGS quality consistency among participating ethanol plants. A similar program has been implemented to produce a high quality, more consistent “Dakota Gold” DDGS.

Table 1. Mean and Variation of Particle Size Within Ethanol Plants and Bulk Density of DDGS.

	Particle Size Mean	Standard Deviation	Bulk Density	CV %	68% of the particles will fall between	
Plant 1	1398	2.32	36.3	0.17	603	3243
Plant 2	1322	2.00	39.2	0.15	661	2644
Plant 3	1425	1.62	36.8	0.11	880	2309
Plant 4	1370	1.84	36.3	0.13	745	2521
Plant 5	1255	1.68	33.5	0.13	747	2108
Plant 6	612	2.75	39.3	0.45	223	1683
Plant 7	974	2.15	36.1	0.22	453	2094
Plant 8a	1258	1.70	33.7	0.14	740	2139
Plant 8b	1142	1.84	30.8	0.16	621	2101
Plant 9	1337	1.78	31.8	0.13	751	2380
Plant 10	1488	1.62	38.2	0.11	919	2411
Plant 12	1235	1.75	31.4	0.14	706	2161
Plant 13	1198	1.87	35.9	0.16	641	2240
Plant 14	1229	2.09	39.2	0.17	588	2569
Plant 15	2125	1.56	37.6	0.07	1362	3315
Plant 16	1148	2.25	35.1	0.20	510	2583
Average	**1282.25**	**1.93**	**35.7**	**0.15**	**697**	**2406**

Figure 1. DDGS Particle Size Distribution in Plant 1.

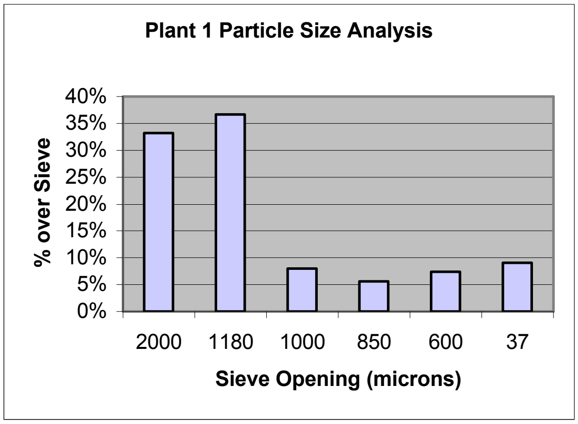

Figure 2. DDGS Particle Size Distribution in Plant 2.

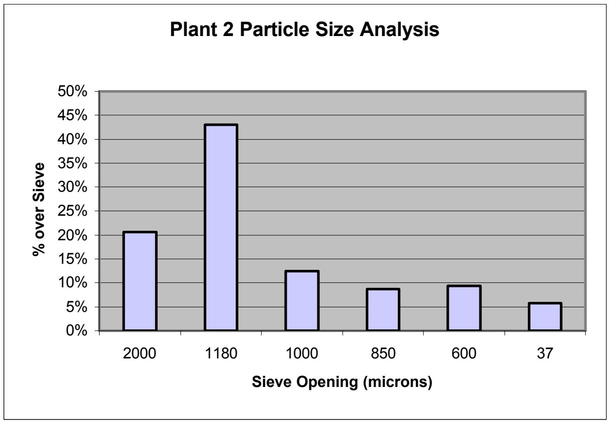

Figure 3. DDGS Particle Size Distribution in Plant 3.

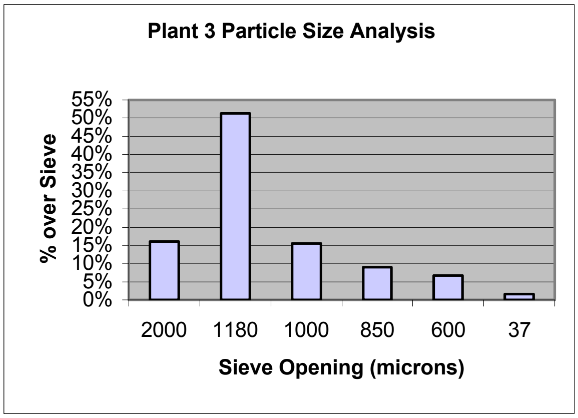

Figure 4. DDGS Particle Size Distribution in Plant 4.

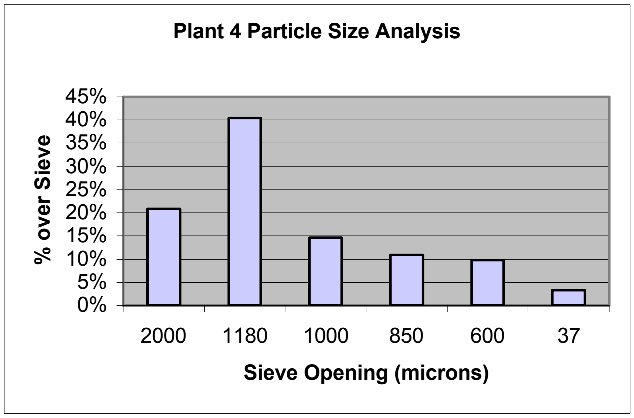

Figure 5. DDGS Particle Size Distribution in Plant 5.

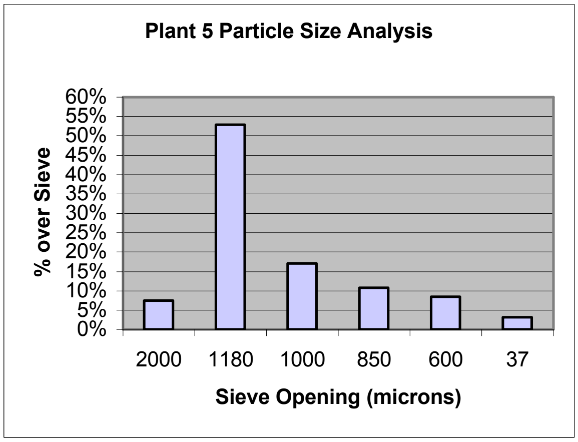

Figure 6. DDGS Particle Size Distribution in Plant 6.

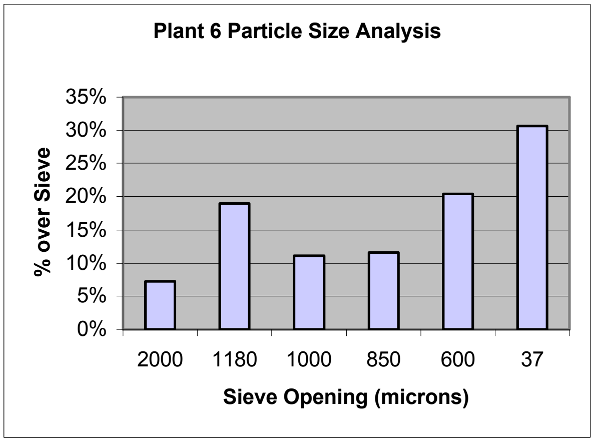

Figure 7. DDGS Particle Size Distribution in Plant 7.

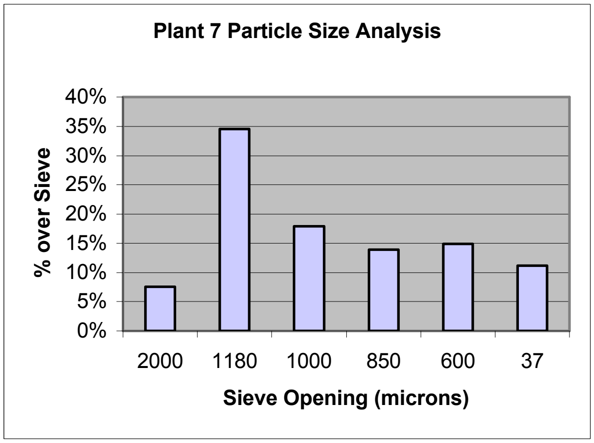

Figure 8. DDGS Particle Size Distribution in Plant 8a.

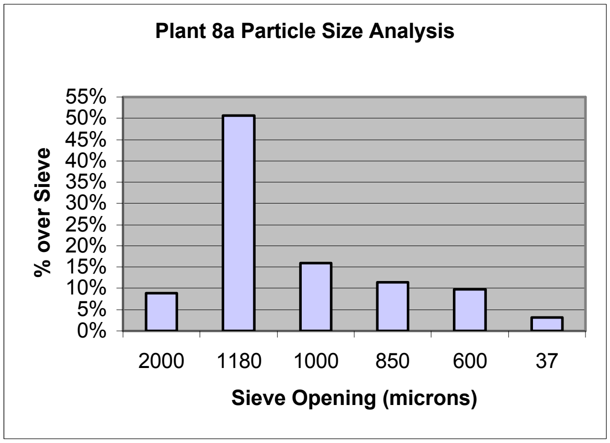

Figure 9. DDGS Particle Size Distribution in Plant 8b.

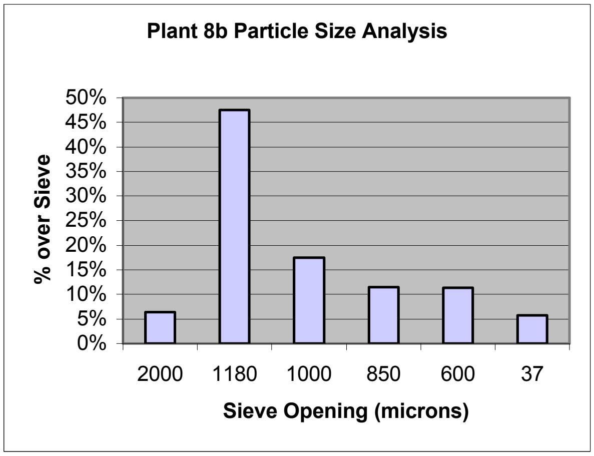

Figure 10. DDGS Particle Size Distribution in Plant 9.

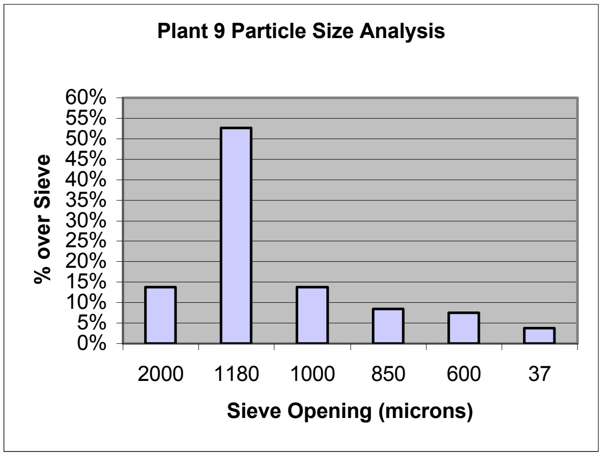

Figure 11. DDGS Particle Size Distribution in Plant 10.

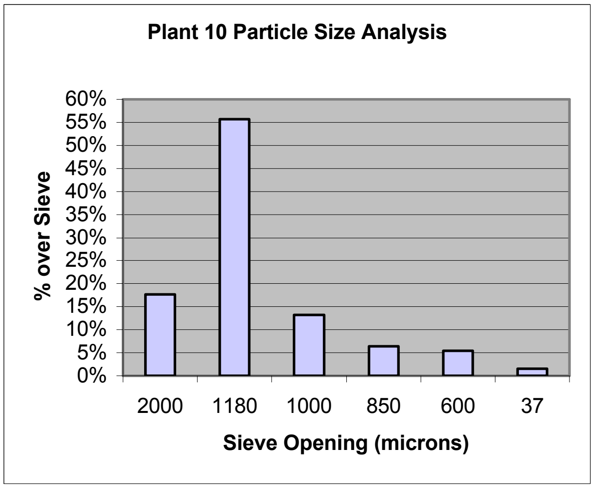

Figure 12. DDGS Particle Size Distribution in Plant 12.

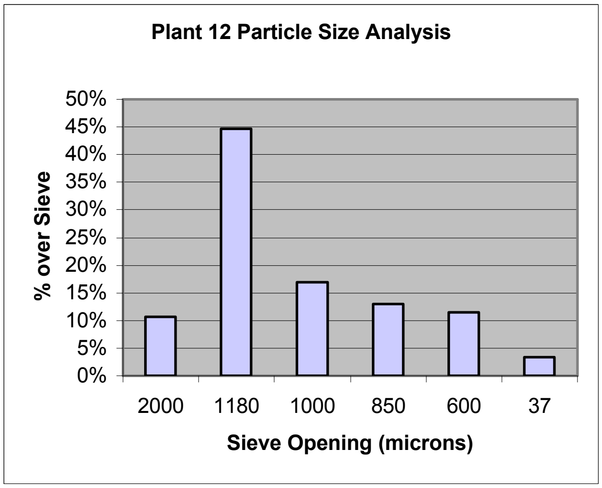

Figure 13. DDGS Particle Size Distribution in Plant 13.

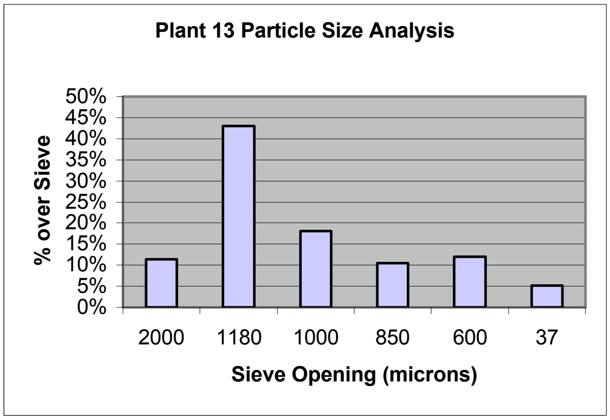

Figure 14. DDGS Particle Size Distribution in Plant 14.

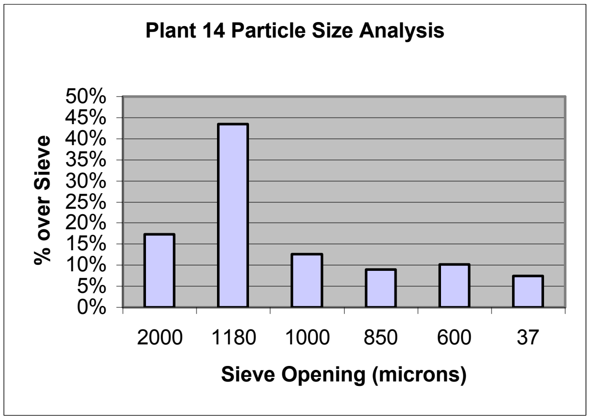

Figure 15. DDGS Particle Size Distribution in Plant 15.

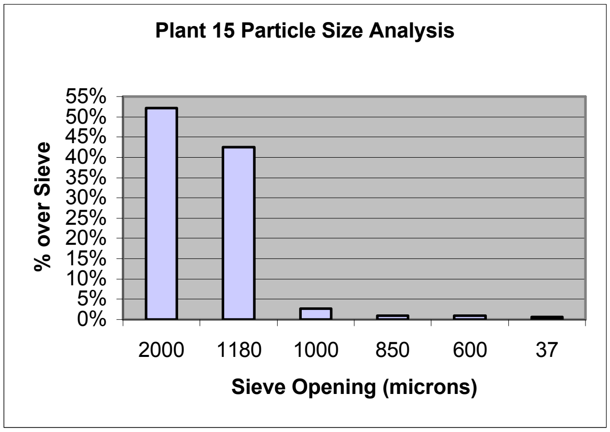

Figure 16. DDGS Particle Size Distribution in Plant 16.

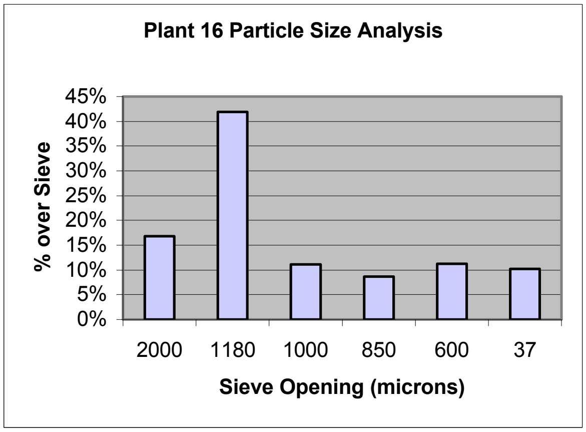

Table 2. Proximate Analysis of DDGS from "New Generation" Ethanol Plants in Minnesota, South Dakota, and Missouri.

Plant ID	Moisture, %	Crude Protein, %	Crude fat, %	Crude fiber, %
1	10.83	24.54	9.59	6.40
2	11.20	26.61	9.51	6.80
3	9.67	25.95	9.43	7.30
4	11.55	26.33	10.53	6.70
5	11.48	26.41	10.43	7.60
6	10.91	26.17	9.60	6.80
7	12.18	28.42	9.20	7.30
8a	11.83	27.36	9.27	6.80
8b	12.36	26.09	9.66	6.10
9	13.27	26.59	11.13	6.70
10	11.07	26.57	10.82	6.00
12	13.57	28.15	10.84	7.30
13	12.30	28.15	9.50	7.50
14	11.43	26.91	9.97	6.20
15	11.72	25.99	11.55	5.80
16	11.65	25.85	9.87	9.10
Avg.	11.69	26.63	10.06	6.90
Std. Dev. Among Plants	0.91	0.97	0.70	0.78
CV Among Plants	7.80	3.63	7.00	11.27