Nutrient Analysis of Sorghum Dried Distillers Grains with Solubles from Ethanol Plants Located in the Western Plains Region[1]

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Summary

Samples of sorghum dried distillers grains with solubles (DDGS) were collected and analyzed to establish a nutrient database and evaluate the quality and consistency between and within samples taken from 5 ethanol plants in the Western Plains region. Four plants were located in Kansas and 1 in Texas. A total of 21 samples were collected, with 4 plants contributing 4 samples each and 1 plant contributing 5 samples from different manufacturing lots of DDGS. Each sample was analyzed for amino acids, DM, CP, crude fiber, crude fat, ash, NDF, ADF, Ca, P, trace minerals, GE, and starch. In addition, DE, ME, and NE were calculated from the nutrient analysis. Of the 5 plants, 3 produced pure sorghum DDGS samples while 2 produced mixed sorghum and corn DDGS samples, with sorghum representing 60 or 70% of the DDGS. For the pure sorghum DDGS, the overall sample average means for each nutrient on a DM basis were: DM (89.5%), CP (34.2%), crude fat (10.5%), ash (4.4%), NFE (40.3%), crude fiber (10.6%), ADF (26.4%), NDF (35.1%), starch (4.3%), calculated DE (1,560 kcal/lb), calculated ME (1,454 kcal/lb), calculated NE (919 kcal/lb), Ile (1.37%), Leu (3.84%), Lys (0.88%), Met (0.55%), Thr (1.04%), Trp (0.26%), Val (1.67%), Ca (0.01%), and P (0.72%). The mixed DDGS samples' means were generally similar to the pure sorghum DDGS nutrient analysis values. Results of these analyses can be used by nutritionists to better utilize sorghum DDGS in swine diets.

Key words: dried distillers grains with solubles, nutrient analysis, sorghum

Introduction

Dried distillers grains with solubles (DDGS) are usable by-products of ethanol production. Dried distillers grains with solubles are commonly added to swine diets to lower feed costs. However, concern about consistency and quality variation among ethanol plants presents challenges to swine nutritionists in using DDGS in diet formulation. Dried distillers grains with solubles also tend to have low lysine and tryptophan concentrations, limiting the inclusion rate. Quality depends upon crop selection, fermentation type, and drying temperature and duration (Spiehs et al, 2002[3]). While most of the information gathered to date has focused on corn DDGS, little information exists regarding sorghum DDGS from the Great Plains region. Therefore, the objective of this study was to determine the nutrient content of Great Plains sorghum DDGS.

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[3] Spiehs, M.J., M.H. Whitney, and G.C. Shurson. 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80:2639-2645.

Procedures

A total of 21 samples of sorghum DDGS were collected from 5 plants in the Western Plains Region (KS=4, TX=1) between May and June 2010. Four of the plants contributed 4 individual samples, while 1 plant contributed 5 individual samples. Of the 5 ethanol plants, 3 produced pure sorghum DDGS while 2 produced a DDGS mixture of either 60 or 70% sorghum with 40 or 30% corn. The 21 samples were then divided into subsamples for proximate and mineral composition analyses (Ward Laboratories, Kearney, NE), amino acid analysis (University of Missouri, Experiment Station Laboratory, Columbia, MO), and particle size analysis and bomb calorimeter (Kansas State University). Digestible, metabolizable, and net energy values on a DM basis were calculated using the following equations:

- DE kcal/kg = -174 + (0.848 × GE) + {2 × [100 - (CP + EE + Ash + NDF)]} - (16 × ADF); Ewan (1989[4])
- ME kcal/kg = (1 × DE) - (0.68 × CP); Noblet and Perez (1993[5])
- NE kcal/kg = (0.726 × ME) + (13.3 × EE) + (3.9 × starch) - (6.7 × CP) - (8.7 × ADF); Noblet et al. (1994[6])

Descriptive statistics (Microsoft Excel 2007; Microsoft Corp., Redmond, WA) were used to calculate the mean for each plant as well as the combined samples within each DDGS type. Also, descriptive statistics were used to calculate the standard deviation from samples within each plant, within all samples of each DDGS type, and across plants.

Results and Discussion

All nutrient values are presented on a 100% DM basis (Tables 1, 2, 3 and 4).

For the pure sorghum samples, the average DM was 89.5% with a standard deviation of 0.96% (Table 1). The average CP was 34.2% with a standard deviation of 3.78 %. The CP in DDGS from Kansas ethanol plants was consistently between 31 and 33%, with CP from the Texas plant being considerably higher at 39.13%. This could be due to the lower percentage of solubles present in the Texas DDGS sample. This is also suggested because the Texas sample had a much lower particle size, again suggesting fewer solubles added back to the DDGS. In comparison, values from Feoli (2008[7]) showed the average value for DM sorghum DDGS was 88.30% and the DM value for CP at 34.14% (Feoli, 2008). The NRC (1998[8]) reported the CP (converted to DM at 89%) to be 10.34% for sorghum grain. The CP of DDGS is generally 3 times higher than the CP of the grain

[4] Ewan, R. C. 1989. Predicting the energy utilization of diets and feed ingredients in pigs. pp. 271-274 in Energy metabolism, European Association of Animal production Bulletin No. 43, Y. van der Honing and W. H. Close, eds. Pudoc Wageningen, Netherlands.

[5] Noblet, J., and J. M. Perez. 1993. Prediction of digestibility of nutrients and energy values of pig diets from chemical analysis. J. Anim. Sci. 71(12): 3389-3398.

[6] Noblet, J., H. Fortune, X. S. Shi, and S. Dubois. 1994. Prediction of net energy value of feeds for growing pigs. J. Anim. Sci. 72(2): 344-354.

[7] Feoli, C. Use of corn and sorghum-based distillers dried grains with solubles in diets for nursery and finishing pigs. Dissertation Abstract. Retrieved September 17, 2010 from K-State Electronic Theses, Dissertations, and Reports: 2004 – Present.

[8] NRC, 1998, Nutrient Requirements of Swine, 10th ed.. Natl. Acad. Press, Washington, D.C.

from which it originated, thus values for the DDGS sampled in this study are generally close to that correlation.

The average crude fat content of pure sorghum DDGS was 10.49% with a standard deviation of 1.10%. The mixed DDGS samples were slightly higher in crude fat, which might be a result of the corn blended with the sorghum before fermentation. According to Feoli (2008), the average value for crude fat in sorghum DDGS was 8.61%, lower than the reported values in the present study.

The average ADF was 26.43% (4.96) and the average NDF was 35.07% (5.34) for the pure sorghum DDGS samples. The mixed DDGS samples had average ADF and NDF values of 22.07% (2.28) and 36.73% (1.46), respectively. Because NDF is more digestible than ADF, the mixed samples might be considered to have slightly greater digestibility than the pure sorghum DDGS samples. Stein (2007[9]) reported the ADF and NDF of corn DDGS to be 13.48% and 44.94%, respectively. The average values for the sorghum grain (NRC, 1998) were lower for both ADF (9.33%) and NDF (20.22%) compared to the DDGS in the present study, which was expected, due to ADF and NDF being concentrated in DDGS compared to the grain from which it originated.

For amino acids, the average lysine content in the pure sorghum DDGS was 0.88%, while the mixed DDGS samples had a value of 0.87%. Feoli (2008) reported pure sorghum DDGS had 0.97% lysine, while Stein (2007[9]) reported corn DDGS had 0.88% lysine. For sorghum grain, the NRC (1998) published a lysine value of 0.25%.

The average tryptophan and threonine values for the pure sorghum DDGS were 0.26% and 1.04%, respectively. Tryptophan was higher than Feoli's (2008) value of 0.17%, and Stein's (2007) corn DDGS value of 0.24%. In DDGS, regardless of cereal grain source, tryptophan is considered limiting and generally restricts the amount of crystalline lysine that can be added to the diet.

Average methionine content was 0.55% for the pure sorghum DDGS and mixed DDGS samples. The samples' values were slightly lower than Feoli's (2008) sorghum DDGS value of 0.59% and Stein's (2007) corn DDGS value of 0.62%.

For pure sorghum DDGS, arginine (1.17%), histidine (0.67%), and phenylalanine (1.48%) average values were lower than Feoli's (2008) reference values (1.35%, 0.85%, and 1.90%, respectively) for the sorghum DDGS sand Stein's (2007) corn DDGS references values (1.30%, 0.81%, and 1.51%, respectively). Amino acids are essential components of pigs' growth and performance. Due to their importance, nutritionists should be aware of the variability within the ingredients and ethanol plants when determining a diet source.

Phosphorus is important because of its cost as well as its role in land base requirements for manure application. Both corn and sorghum DDGS contain relatively high concentrations of P, which are highly available to the pig, resulting in a lower requirement level

[9] Stein, H. 2007. Dried distillers grains with solubles (DDGS) in diets fed to swine. In: Swine Focus-#001. pp. 1-8.

of dietary inorganic phosphorus. The average phosphorus content of the pure sorghum DDGS was 0.72%, while the content of the mixed DDGS samples was 0.74%.

The average ash concentration in the pure sorghum DDGS samples was 4.42%, with the Kansas region ethanol plants (5.02% and 4.93%) being higher than the Texas ethanol plant (3.32%) in this study. The composite means and standard deviations for Ca, K, Mg, S, Na, Zn, Mn, Cu, and Fe were all profiled to determine the amounts present in each sample.

The gross energy (GE) for the pure sorghum DDGS samples was 2,142 kcal/lb with a standard deviation of 42.7, while the GE for the mixed DDGS samples was 2,187 kcal/lb with a standard deviation of 28.2. The GE values for the mixed DDGS samples were higher than those of the pure DDGS samples, which was expected because corn has a higher energy content than sorghum grain. In comparison, Feoli (2008) reported a GE value of 2,232 kcal/lb for the sorghum DDGS while Stein (2007) reported 2,465 kcal/lb for the corn DDGS. The digestible energy (DE), metabolizable energy (ME), and the net energy (NE) for the pure sorghum DDGS samples were 1,560 kcal/lb (54.6), 1,454 kcal/lb (62.9), and 919 kcal/lb (79.3), respectively. While the NRC (1998) sorghum grain values were DE at 1,723 kcal/lb, ME at 1,702 kcal/lb, and NE at 1,149 kcal/lb. The difference in energy content between sorghum grain and sorghum DDGS is wider than we would have expected. Research has shown that corn and corn DDGS have similar energy values. The DE, ME, and NE for the mixed DDGS samples were 1,629 kcal/lb (17.1), 1,528 kcal/lb (19.5), and 1,005 kcal/lb (32.2) respectively (Table 4). The mixed samples contained a higher amount of energy than the pure sorghum samples as expected, but still lower than the sorghum grain (NRC, 1998). Also, the energy value standard deviations of the pure DDGS samples were approximately double those of the mixed DDGS samples, meaning there was a larger variation in energy content within samples for the pure DDGS compared to the mixed DDGS samples.

Particle size of the pure sorghum DDGS samples varied from 447 to 843 microns, with an average of 670 microns. There was considerable range in average particle size between plants, which may have been influenced by the amount of solubles added back to the mash during drying. The average of the mixed DDGS samples was 632 microns. Particle size and DM are generally considered the two biggest contributors to the flow ability of both corn and sorghum DDGS, in which a higher DM and lower particle negatively affect flow ability.

The nutrient and calculated energy values established from this study of pure sorghum DDGS and sorghum-corn DDGS mixtures can now be used by swine nutritionists to more accurately formulate diets. Routine analysis of sorghum DDGS is essential to update nutrient specifications, as variability among geographic regions, crop-growing conditions, and plant manufacturing processes will influence DDGS composition.

Table 1. Proximate analysis of sorghum dried distillers grains with solubles (DDGS) from ethanol plants located in the Western Plains region (DM basis)

		Nutrient, %								
Sample Origin	No of samples	DM	CP	Fat	Ash	NFE	Crude Fiber	ADF	NDF	Starch
Pure Samples										
1	4	88.64 (0.75)[6]	31.23 (0.84)	10.55 (0.26)	5.02 (0.16)	43.93 (0.84)	9.28 (0.57)	22.45 (1.29)	30.43 (0.78)	4.58 (0.44)
2	4	89.35 (0.35)	32.28 (0.66)	11.73 (0.21)	4.93 (0.07)	40.95 (0.75)	10.10 (0.22)	23.90 (1.49)	33.18 (1.44)	4.75 (0.61)
3	4	90.49 (0.60)	39.13 (1.43)	9.20 (0.24)	3.32 (0.28)	36.00 (0.42)	12.35 (0.93)	32.95 (0.31)	41.60 (3.41)	3.58 (0.49)
Average	12	89.49 (0.96)	34.21 (3.78)	10.49 (1.10)	4.42 (0.83)	40.29 (3.47)	10.58 (1.48)	26.43 (4.96)	35.07 (5.34)	4.30 (0.72)
SD among plants	3	0.93	4.29	1.26	0.96	4.00	1.59	5.69	5.82	0.63
Mixed Samples										
1[1]	5	90.26 (0.27)	32.00 (1.08)	11.10 (0.26)	3.64 (0.07)	41.62 (1.62)	11.64 (0.66)	20.38 (1.32)	36.38 (1.66)	3.42 (0.38)
2[2]	4	90.29 (0.38)	33.55 (1.20)	11.60 (0.34)	4.58 (0.15)	39.40 (1.29)	10.88 (0.46)	24.18 (0.90)	37.18 (1.25)	3.55 (0.17)
Average	9	90.27 (0.30)	32.69 (1.34)	11.3 (0.4)	4.06 (0.51)	40.63 (1.82)	11.30 (0.68)	22.07 (2.28)	36.73 (1.46)	3.48 (0.29)
SD among plants	2	0.03	1.10	0.35	0.67	1.57	0.54	2.68	0.56	0.09
Feoli, 2008[3] sorghum DDGS		88.30	34.14	8.61	4.08	45.07	8.10	---	---	---
Stein, 2007[4] corn DDGS		89.00[7]	30.90	10.11		---	---	13.48	44.94	8.20
NRC, 1998[5] sorghum grain		89.00	10.34	3.26		---	---	9.33	20.22	---

[1] Mixed sample contained 60% sorghum and 40% corn.
[2] Mixed sample contained 70% sorghum and 30% corn.
[3] Feoli, C. Use of corn and sorghum-based distillers dried grains with solubles in diets for nursery and finishing pigs. Dissertation Abstract. Retrieved September 17, 2010, from K-State Electronic Theses, Dissertations, and Reports: 2004 – Present.
[4] Stein, H. 2007. Dried distillers grains with solubles (DDGS) in diets fed to swine. In: Swine Focus-#001. Pp. 1-8.
[5] NRC, 1998. Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington, D.C.
[6] () Values in parenthesis represent the standard deviation of the mean.
[7] Assumed DM for nutrient calculations.

Table 2. Essential amino acid concentrations for sorghum dried distillers grains with solubles (DDGS) from ethanol plants located in the Western Plains region (DM basis)

		Amino acid, %[7]									
Sample origin	No. of samples	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val
Pure DDGS Samples											
1	4	1.15 (0.05)	0.62 (0.03)	1.28 (0.08)	3.31 (0.21)	0.88 (0.04)	0.47 (0.03)	1.30 (0.08)	0.98 (0.06)	0.25 (0.01)	1.56 (0.09)
2	4	1.18 (0.04)	0.67 (0.02)	1.32 (0.02)	3.61 (0.08)	0.93 (0.03)	0.62 (0.21)	1.41 (0.03)	1.02 (0.03)	0.25 (0.01)	1.63 (0.03)
3	4	1.18 (0.08)	0.73 (0.06)	1.52 (0.14)	4.60 (0.44)	0.83 (0.06)	0.57 (0.04)	1.74 (0.16)	1.14 (0.09)	0.28 (0.02)	1.83 (0.16)
Average	12	1.17 (0.06)	0.67 (0.06)	1.37 (0.14)	3.84 (0.63)	0.88 (0.06)	0.55 (0.13)	1.48 (0.22)	1.04 (0.09)	0.26 (0.02)	1.67 (0.15)
SD among plants	3	0.02	0.05	0.13	0.67	0.05	0.08	0.23	0.08	0.01	0.14
Mixed DDGS Samples											
1[1]	5	1.23 (0.03)	0.74 (0.02)	1.25 (0.03)	3.69 (0.10)	0.89 (0.01)	0.55 (0.01)	1.44 (0.03)	1.04 (0.02)	0.25 (0.01)	1.56 (0.03)
2[2]	4	1.20 (0.04)	0.72 (0.03)	1.37 (0.07)	3.91 (0.25)	0.85 (0.02)	0.77 (0.17)	1.50 (0.09)	1.05 (0.05)	0.24 (0.01)	1.69 (0.09)
Average	9	1.22 (0.04)	0.73 (0.03)	1.30 (0.08)	3.79 (0.20)	0.87 (0.03)	0.55 (0.16)	1.47 (0.07)	1.05 (0.04)	0.24 (0.01)	1.62 (0.09)
SD among plants	2	0.02	0.02	0.08	0.16	0.03	0.16	0.04	0.01	0.002	0.09
Feoli, 2008[3] sorghum DDGS		1.35	0.85	1.58	4.56	0.97	0.59	1.90	1.18	0.17	1.91
Stein, 2007[4,5] corn DDGS		1.30	0.81	1.13	3.56	0.88	0.62	1.51	1.20	0.24	1.52
NRC, 1998[6] sorghum grain		0.43	0.26	0.42	1.38	0.25	0.19	0.56	0.35	0.11	0.52

[1] Mixed sample contained 60% sorghum and 40% corn.
[2] Mixed sample contained 70% sorghum and 30% corn.
[3] Feoli, C. Use of corn and sorghum-based distillers dried grains with solubles in diets for nursery and finishing pigs. *Dissertation Abstract*. Retrieved September 17, 2010 from K-State Electronic Theses, Dissertations, and Reports: 2004 – Present.
[4] Stein, H. Dried distillers grains with solubles (DDGS) in diets fed to swine. 2007. In: Swine Focus-#001. pp. 1-8.
[5] Assumed DM of 89.0% for nutrient calculations.
[6] NRC, 1998 Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington, D.C.
[7] () Values in parenthesis represent the standard deviation of the mean.

Table 3. Mineral composition of dried distillers grains with solubles (DDGS) from ethanol plants located in the Western Plains region (DM basis)

		Mineral[4]									
Sample origin	No. of samples	Ca, %	P, %	K, %	Mg, %	S, %	Na, %	Zn, ppm	Mn, ppm	Cu, ppm	Fe, ppm
Pure Samples											
1	4	0.11	0.84	1.15	0.39	0.77	0.14	37.95	44.25	7.83	119.25
		(0.01)	(0.02)	(0.04)	(0.01)	(0.02)	(0.01)	(1.24)	(0.96)	(0.25)	(11.87)
2	4	0.07	0.87	1.17	0.42	0.54	0.12	45.58	42.75	6.53	117.00
		(0.01)	(0.02)	(0.01)	(0.01)	(0.05)	(0.01)	(0.79)	(1.89)	(0.19)	(10.23)
3	4	0.07	0.45	0.54	0.23	0.42	0.18	42.55	35.75	7.00	136.50
		(0.01)	(0.04)	(0.03)	(0.03)	(0.09)	(0.05)	(9.20)	(12.87)	(0.42)	(18.70)
Average	12	0.08	0.72	0.95	0.35	0.57	0.15	42.03	40.92	7.12	124.25
		(0.02)	(0.20)	(0.31)	(0.09)	(0.16)	(0.04)	(5.86)	(7.83)	(0.62)	(15.66)
SD among plants	3	0.02	0.24	0.36	0.10	0.18	0.03	3.84	4.54	0.66	10.67
Mixed Samples											
1[1]	5	0.05	0.68	0.81	0.28	0.57	0.04	41.00	21.60	4.82	92.60
		(0.03)	(0.02)	(0.01)	(0.01)	(0.04)	(0.01)	(0.78)	(1.52)	(0.52)	(6.91)
2[2]	4	0.06	0.82	1.07	0.37	0.47	0.11	57.88	43.50	7.05	12.25
		(0.01)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)	(1.58)	(2.52)	(0.44)	(14.86)
Average	9	0.06	0.74	0.93	0.32	0.53	0.07	48.50	31.33	5.81	106.22
		(0.02)	(0.07)	(0.14)	(0.05)	(0.06)	(0.04)	(8.96)	(11.69)	(1.26)	(19.18)
SD among plants	2	0.01	0.09	0.18	0.07	0.07	0.05	11.93	15.49	1.58	21.67
NRC, 1998[3] sorghum grain		0.03	0.33	0.39	0.17	0.09	0.01	16.85	17.05	5.68	51.14

[1] Mixed sample contained 60%sorghum and 40% corn.
[2] Mixed sample contained 70% sorghum and 30% corn.
[3] NRC, 1998 Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington, D.C.
[4] () Values in parenthesis represent the standard deviation of the mean.

Table 4. Proximate analysis of sorghum dried distillers grains with solubles (DDGS) from ethanol plants located in the Western Plains region (DM basis)

		Energy, kcal/lb[9]				Particle size[9]	
Sample Origin	No of samples	GE	DE[1]	ME[2]	NE[3]	Mean,	Std deviation
Pure Samples							
1	4	2,123 (34.6)	1,579 (29.7)	1,483 (27.7)	965 (20.4)	843 (111.6)	1.78 (0.01)
2	4	2,161 (18.3)	1,597 (24.9)	1,497 (26.6)	974 (27.1)	721 (23.6)	1.73 (0.03)
3	4	2,142 (64.6)	1,504 (54.9)	1,384 (53.6)	817 (36.9)	447 (65.9)	2.06 (0.05)
Average	12	2,142 (42.7)	1,560 (54.6)	1,454 (62.9)	919 (79.3)	670 (186.0)	1.86 (0.16)
SD among plants	3	19.2	49.0	61.8	87.7	202.7	0.18
Mixed Samples							
1[4]	5	2,174 (24.0)	1,632 (15.6)	1,533 (17.3)	1,022 (31.0)	662 (44.0)	1.82 (0.03)
2[5]	4	2,204 (26.2)	1,626 (20.8)	1,523 (23.2)	984 (20.7)	594 (91.9)	1.78 (0.07)
Average	9	2,187 (28.2)	1,629 (17.1)	1,528 (19.5)	1,005 (32.2)	632 (73.8)	1.80 (0.05)
SD among plants	2	21.1	4.0	7.4	26.7	48.5	0.03
Feoli, 2008[6] sorghum DDGS		2,232	1,572	---	---	---	---
Stein, 2007[7] corn DDGS		2,465	1,878	1,768	---	---	---
NRC, 1998[8] sorghum grain		---	1,723	1,702	1,149	---	---

[1] DE = -174 + (0.848 × GE) + {2 × [100 - (CP + EE + Ash + NDF)]} - (16 × ADF).
[2] ME = (1 × DE) - (0.68 × CP).
[3] NE = (0.726 × ME) + (13.3 × EE) + (3.9 × starch) - (6.7 × CP) - (8.7 × ADF).
[4] Mixed sample contained 60% sorghum and 40% corn.
[5] Mixed sample contained 70% sorghum and 30% corn.
[6] Feoli, C. Use of corn and sorghum-based distillers dried grains with solubles in diets for nursery and finishing pigs. *Dissertation Abstract*. Retrieved September 17, 2010 from K-State Electronic Theses, Dissertations, and Reports: 2004 – Present.
[7] Stein, H. 2007. Dried distiller's grains with solubles (DDGS) in diets fed to swine. In: Swine Focus-#001. pp. 1-8.
[8] NRC, 1998 Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington, D.C.
[9] () Values in parenthesis represent the standard deviation of the mean from all individual samples.