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Composition of Fat in Distillers Grains

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Abstract
Distillers grains (DG) originating from the corn-based fuel ethanol industry are an excellent source of energy and non-rumen degradable protein, and are an effective ingredient for dairy cattle diets. However, in spite of competitive price when compared to other protein sources and their high availability in the market, DG are not always sought as a dietary ingredient by some nutritionists and dairy producers. In a recent survey conducted in South Dakota by South Dakota State University Dairy Extension, where 28% of all Grade A dairy producers replied (Unpublished. 2011), many confirmed they did not use DG in their dairy cattle diets.

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Composition of Fat in Distillers Grains

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Introduction

Distillers grains (DG) originating from the corn-based fuel ethanol industry are an excellent source of energy and non-rumen degradable protein, and are an effective ingredient for dairy cattle diets. However, in spite of competitive price when compared to other protein sources and their high availability in the market, DG are not always sought as a dietary ingredient by some nutritionists and dairy producers. In a recent survey conducted in South Dakota by South Dakota State University Dairy Extension, where 28% of all Grade A dairy producers replied (Unpublished. 2011), many confirmed they did not use DG in their dairy cattle diets.

Survey of attitudes

In another survey on the use of DG, sent to 10 nutritionists specializing in dairy cattle (0wens, F. 2009), their high fat content was the main reason why DG inclusion was restricted in dairy diets. Half of those surveyed (5 out of 10), agreed that the high concentrations of unsaturated fatty acids (FA) in DG reduced fat content in milk. Nine out of ten of the dairy consultants indicated that the level of DG inclusion in diets could be increased if a portion of the fat in DG was removed. In addition, these nutritionists agreed that the cost of DG as a feed ingredient should be reduced proportionally to the energy content reduction as a result of fat extraction. Estimations as to what degree the cost of DG should be reduced varied from 2% to 50%, with an average of 24%.

In another survey (Unpublished, 2011), individual South Dakota dairy producers were asked if they used DG in their diets, and to rank from 1 to 4 the degree of importance of fat content in DG (1 = no importance; 2 = low importance; 3 = average importance; and 4 = high importance). Results indicated an average importance of 3.3. This parallels another survey, published by the National Agricultural Statistics Service (NASS, 2007), which showed that variation in DG fat content was a concern to dairy producers. On a scale of 1 to 4 (similar to the aforementioned study), the average was slightly higher at 3.6. Thus, results obtained from all these surveys provide considerable evidence that the high fat content in DG, together with high concentrations of unsaturated fatty acids, can be a matter of worry for dairy consultants and producers alike.

Fat in distillers grains

Several publications have reported the nutrient composition of a large number of distillers dried grains with solubles (DDGS) samples, and have indicated fat content values between 10.9% and 12.6% on a dry basis (DM; Table 1). Coefficients of variation (CV) for published fat content values are typically not extremely high within a given study, with published values of approximately 6.6% (Belyea et al. 2004) and 7.8% (Spiehs et al. 2002). Results published by the New York State Dairy One Lab (4819 samples in 2011), however, showed an average fat content in DDGS of 12.6% (DM), but with a range of values from 9.4 to 15.7%, and a CV above 25%. These results indicate very high variability in DDGDS fat content.

The nutrient composition of corn DDGS, published in different books and nutrition guides, also show high variability. The NRC (2001) reports a fat content of 10%, on a dry basis, which is similar to nutrient composition tables of the Spanish Foundation for the Development of Animal Nutrition (FEDNA) at 10.9%. The nutrient composition of feedstuffs tables of the Institut National de la Recherche Agronomique (INRA, 2004), however, published a value of 4.4%. This wide range in published data suggests that the information in books about the fat content in DDGS cannot be completely trusted, so it is suggested to formulate diets based on actual chemical analyses of ingredients, rather than using tabular values.

One of the major causes of DDGS fat variation is the amount of condensed distillers solubles (CDS) added back to the non-fermented wet cake prior to drying (which then produces DDGS). The amount of fat in the condensed solubles is greater than in the wet cake, and can represent almost a 21.5% of the DM in the CDS (Schingoethe et al. 2010). Ganesan et al. (2005) evaluated the effect of the fat content in DDGS as the proportion of CDS inclusion increased. The fat level in DDGS increased from 8.8% up to 11.8% of the DM when the CDS increased from 10 to 25%. Noll et al. (2007) also documented an increase in DDGS fat content with an increase of CDS addition.

Fat composition

The fat in DDGS is mainly composed of unsaturated FA; this profile is reflected in six research trials summarized in Table 2. Linoleic (C18:2) and oleic (C18:1), are the most abundant FA, with an average of almost 50% (CV=14.2%) and 25% (CV=28.9%) of the total FA, respectively. The high CV observed could be the result of the analyses being performed by different labs, and also maybe because of variations in extraction methods and analyses. The average values for the most abundant FA are similar to those reported by Moreau et al. (2011). These authors found that the linoleic and oleic content of DDGS from three different ethanol plants were 53.7 and 25.6%, respectively; the CV, however, were substantially lower at 1.7% and 1.3% for linoleic and oleic, respectively. In addition, this trial determined the variations in the FA profile during the ethanol production process by analyzing corn grain, DDGS and seven intermediate products (Table 3). Although with some slight differences in the exact values between different fractions, the FA profile varied little during the production process, with the exception of the predominant FA, which generally remained constant.

Bauman and Griinari (1998) demonstrated that there are two conditions which can reduce milk fat. One of them is the presence of unsaturated FA in the rumen; the other is an altered rumen environment that would cause incomplete bio-hydrogenation. Under certain conditions, the pathways for rumen bio-hydrogenation are altered and through alternative routes, intermediaries are produced, some of which, like trans-10-cis-12 CLA, are potent inhibitors of milk fat synthesis in the mammary gland (Griinari et al. 2001). The concentration of the unsaturated FA in the rumen can be a key factor that contributes to changes in microbial population and an increase in the CLA isomer trans-10-cis-12 (Jenkins et al. 2009).

In addition to the degree of FA unsaturation, the rumen concentration of free FA (FFA) should also be considered. This fat fraction may have greater capacity to produce negative effects in rumen fermentation than other fractions, as for example, saturated FFA or triglycerides (TG; Jenkins et al. 1993). Chalupa et al. (1984) evaluated the production of volatile FA in vitro in terms of long chain FA (palmitic, stearic, and oleic) in the form of FFA or TG. The FA supplied as TG did not produce any significant changes in rumen fermentation. However, when the FA were supplied as FFA, there was an increased production of propionic acid, and a reduction in the production of acetic, butyric, and total VFA. The authors concluded that the FFA affected fermentation more than the TG, and that their anti-microbial activity increased with their degree of unsaturation.

The FFA content in corn and various co-products from seven ethanol plants are in Table 4. (Moreau et al. 2011). The FFA content in the oil extracted from corn grain was 2.28% (as-is basis). In DDGS, however, the average FFA content increased to 9.1% (as-is basis). In addition, DDG (distillers dried grains) and thin stillage, both fractions obtained after centrifugation, also contain high concentrations of FFA (7.4 and 9.4%, respectively). These results agree with those published by Noureddini et al. (2009; Table 5), with FFA values close to 7.5% for DDGS, whole stillage, and condensed solubles. These authors separated FFA into saturated (palmitic and stearic) and unsaturated (oleic, linoleic and linolenic) components. The unsaturated FFA represented between 75 and 80% of the total FFA, while the TG were 91% of the total fat content of the co-products (Table 5). Vegetable oils are, in general, low in FFA (typically ~ 0.5 – 1.5%). The TG are protected by protein membranes in whole seeds with very little lipolytic activity until germination (Quettier and Eastmond. 2009). The reason why it increases in DG is unknown at the moment, but possible reasons could be lipase activity in corn or yeasts, continuous pH changes, and the high temperatures used during evaporation and drying (Winkler-Moser, 2011).

In recent years there has been growing interest by many ethanol plants to extract a portion of the oil from DDGS or other process streams as a means of increasing plant profitability. Several technologies are available to recover the oil either before or after fermentation. One method consists of fractionating corn into three different fractions before fermentation: the endosperm (starch-rich), germ (oil rich), and bran (fiber rich). The bran is used as a high fiber feedstuff, mainly for ruminants. The germ, which has a high fat content, can be de-oiled (and the oil used for human foods) and the resultant co-product is called germ meal. This process allows for only the endosperm, with a high starch concentration, to be fermented into ethanol. The DG obtained by this process will have high protein content (35-55%), but lower concentrations of fat and fiber (Table 6); these DG are generally labeled high protein distillers grains or HPDDG.

In recent years there has been increased interest in extracting the oil from different fractions after the fermentation process, but before drying. Different commercial processes have been developed to extract the oil from thin stillage, semi-concentrated stillage and even condensed solubles. The majority of the methods are based on physical separation techniques, using different separation columns or centrifuges, and they are capable of extracting between 30% and 70% of the oil contained in the co-product (Rosentrater et al. 2011). Another possibility is the chemical extraction with solvents of the oil in DG. Some examples of commercial DDGS obtained through these post-fermentation processes appear in Table 7. When part of the oil is removed, the rest of the nutrients increase proportionately. The final fat content is variable, depending on the method used by each company, and it ranges between 2.5 and 7.5% (DM); these DG are, in general, called low fat DG. Due to their greater FFA content, the oil obtained after fermentation is presently used as animal feed or a substrate for biodiesel production.

The high concentration of unsaturated FA in DG, together with high FFA content, can sometimes lead to milk fat depression in dairy cattle fed diets that include high levels of coproducts. In a meta-analysis of 24 experiments, Kalscheur (2005) found that use of DG caused milk fat depression only when diets had less than 50% forage or less than 22% NDF from forage. Thus, new ethanol co-products which have lower fat content will have less capacity to modify the rumen environment and reduce milk fat concentration and yield.

Table 1. Typical DDGS composition (% dry matter basis)				
	Spiehs et al. (2002)	Belyea et al. (2004)	UMN (2009)	Dairy One Lab (2011)
Number of Samples	118	235	49	*
DM, as-fed basis	88.9	NA	89.22	88.1
CP, %	30.2	31.3	30.8	31.17
ADF, %	16.2	17.2	13.7	16.8
NDF, %	42.1	NA	NA	33.9
Ash, %	5.8	4.6	5.69	5.87
EE, %	10.9	11.9	11.2	12.57

DM = dry matter; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; EE = ether extract; * Number of sample ranged by nutrient, from 4,819 to 6,702.

Table 2. Fatty acid composition in DDGS g/100 g of total fatty acids)							
FA	Ranathunga et al. (2010)	Anderson et al. (2006)	Nyoka (2010)	Tang et al. (2011)	Martinez Amezcua et al. (2007)	Owens T. M. (2009)	Mean
C12:0	NA	0.78	NA	0.02	0.04	0.01	0.21
C14:0	0.42	2.45	3.95	0.07	0.09	0.38	1.23
C16:0	14.7	15.5	16.9	16.7	12.8	12.5	14.9
C16:1	0.13	NA	2.46	0.16	0.18	0.11	0.61
C18:0	1.99	2.38	2.82	2.62	2.03	1.68	2.25
C18:1	26.9	17	21.4	23.1	23.2	38.2	25.0
C18:2	50.7	52.5	40.2	53.7	56.3	40.3	49.0
C18:3	1.6	4.79	1.44	0.45	1.48	1.05	1.80
C20:0	0.39	1.45	0.55	1.99	0.39	0.26	0.84
C20:1	0.22	NA	3.46	0.29	0.27	0.14	0.88
C20:2	0.03	NA	0.13	NA	0.05	0.03	0.06

FA = fatty acid; NA = not determined

Table 3. Fatty acid composition of 9 fractions during the ethanol fermentation process manufacturing (% dry weight basis)					
	Palmitic (C16:0)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)	Linolenic (C18:3)
Ground corn	13.3 ± 1.0	1.8 ± 4.0	27.2 ± 1.6	56.5 ± 0.9	1.3 ± 0.8
Cooked slurry	16.2 ± 5.4	2.0 ± 4.1	25.9 ± 2.7	54.3 ± 3.1	1.4 ± 5.0
Liquefied mass	16.4 ± 3.6	1.9 ± 9.3	25.9 ± 1.3	54.4 ± 3.1	1.3 ± 7.9
Fermented mass	15.9 ± 4.0	2.2 ± 5.8	25.9 ± 1.3	54.8 ± 2.2	1.3 ± 3.5
Whole stillage	15.8 ± 4.0	2.2 ± 5.4	26.0 ± 2.0	54.6 ± 2.0	1.3 ± 1.6
Thin stillage	15.3 ± 6.2	2.3 ± 6.5	27.1 ± 1.1	54.2 ± 1.9	1.1 ± 3.3
Distillers soluble	15.8 ± 6.5	2.3 ± 4.5	26.7 ± 2.1	54.0 ± 1.4	1.2 ± 4.7
Distillers grains	16.5 ± 2.8	2.2 ± 3.7	25.3 ± 2.2	54.7 ± 1.5	1.4 ± 1.2
DDGS	16.2 ± 3.4	2.3 ± 2.7	25.6 ± 1.3	54.5 ± 1.7	1.4 ± 1.8
Average ± CV ; Adapted from Moreau et al. 2011.					

Table 4. Free fatty acid content in corn and corn co-products (% fresh weight basis)					
	Corn	DDG	DDGS	TS	CDS
Plants (N)	1	5	7	2	1
Average	2.28	7.41	9.13	9.36	10.1
SD	0.02	0.78	1.49	0.63	NA
DDG = distillers dried grains; DDGS = distillers dried grains with solubles; TS = thin stillage; CDS = corn distillers solubles; NA = not available. Adapted from Moreau et al. (2011).					

Table 5. Fat composition from different corn co-products (% fresh weight basis).						
	SFFA	UFFA	TFFA	G1	G2	G3
DG	1.8±0.2	5.6±0.4	7.4	0.7±0.2	0.6±0.2	91.1±0.3
WS	1.7±0.1	5.9 ±0.3	7.6	0.6±0.1	0.6±0.3	91.3±0.2
CDS	1.5±0.3	5.9±-0.4	7.4	0.5±0.2	0.4±0.4	91.1±0.5
Average ± SD. FFA = saturated free fatty acids; UFFA = unsaturated free fatty acids; TFFA = total free fatty acids; G1 = monoglycerides; G2 = diglycerides; G3 = triglycerides; WS = whole stillage; CDS = corn distillers solubles. Adapted from Noureddini et al. (2009).						

Table 6. Nutrient composition of high protein distillers grains (HPDDG) (% dry basis)				
	POET	Solaris	MorTechnology	Renessen
Brand Name	Dakota Gold HPDDG	Glutenol		
DM, as-fed	91.7	90	94.09	NA
CP	43.5	47.75	53.39	NA
ADF	10.9	6.7	27.3	35-50
NDF	26.1	34.1	34	7.0-11.0
Ash	2.5	4.65	NA	15-25
EE	3.8	3.55	3.48	NA
Ca	0.02	0.07	0.16	<4
P	0.91	0.67	0.32	NA

DM = dry matter; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; EE = ether extract; Ca = calcium; P = phosphorus; NA = not available; POET = compilation of values from Depenbusch et al. 2008; Robinson et al. 2008; Widmer et al. 2008; Tedeschi et al. 2009; Abdelqader et al. 2009; Mjoun et al. 2010b; Christen et al 2010; Kelzer et al. 2010. SOLARIS = compilation of values from: Lohrmann 2006; MOR TECH.= Applegate et al. 2009; RENESSEN = Stern. 2007.

Table 7. Nutrient composition of low fat distillers grains (LFDDG) (% dry basis)						
	Solaris	Verasun	Dakota Ethanol	FWS	POET 6%	POET 8%
DM, as-fed	90.0	87.2	88.1	NA	90.2	90.36
CP	30.0	34.7	30.1	35-37	31.2	31.34
ADF	NA	25.3	NA	NA	10.5	10.04
NDF	NA	31.6	29.0	21	27.6	29.29
Ash	2.50	5.26	4.66	3.8	5.71	5.70
EE	2.50	3.85	7.55	6.50	6.16	8.17
Ca	NA	0.10	0.03	NA	0.07	0.08
P	NA	0.83	0.92	NA	1.09	1.07

DM = dry matter; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; EE = ether extract; Ca = calcium; P = phosphorus; NA = not available; POET = compilation of values from Lhrormann. 2006; VERASUN= compilation of values from Jacela. 2011, Mjoun et al. 2010 a,c: DAKOTA ETHANOL= Personal communication (unpublished); FWS=FWS (2011); POET= Personal communications (unpublished).

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