Using Reduced Fat Distillers Grains with Solubles in Beef and Dairy Cattle Diets

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Take-Home Message

Concentration of ether extract in distillers grains with solubles (DGS) currently sold is lower due to oil removal by ethanol plants to capture greater value. This has led to two distinct DGS production streams; one known as reduced-fat DGS is derived from oil extraction after centrifugation of condensed distillers solubes prior to adding it back to DGS fraction, the other, known as low-fat DGS, is derived from fractioning corn grain before fermentation. Ether extract concentrations in reduced-fat DGS range between 7% and 9% and those of low-fat DGS range between 3% and 5%. Energy value of resulting DGS products is altered by removal of oil. In growing beef cattle diets where experimental diets were formulated by simple substitution of grain or full-fat DGS, feed conversion, gain and resulting estimation of dietary energy based on performance were increased by inclusion of co-products with greater ether extract content. Although this effect was not observed when evaluating impact of feeding low- or reduced-fat DGS diets to lactating dairy cattle as diets were formulated to be isocaloric, isonitrogenous and isolipidic, indirect calorimetry measurements confirmed that energy value of low- or reduced-fat DGS was lower than that of full-fat DGS. From an energetic standpoint, the impact of altering oil concentration on metabolizable energy value of DGS when fed in growing beef or lactating dairy cattle diets is similar and was estimated at 2.75 Mcal/cwt DM for every percentage unit change in ether extract. This value simply translates to the energy equivalents used in formulating beef or dairy cattle diets at: 2 Mcal NE_g/cwt DM or 2.5 Mcal NE_l/cwt DM for every percentage unit change in ether extract.

Introduction

Feeding distillers grains with solubles or corn syrup (condensed distiller solubles) to beef or dairy cattle became common practice since the mid 2000's. Considerable research and resulting education efforts resulted as dairy or beef producers continued to incorporate these co-products of the dry-milling process to transform corn or other grain starch into ethanol. Several excellent fact sheets (Erickson et al., 2008), reviews (Klopfenstein et al., 2008a), and book chapters (DiCostanzo and Wright, 2011; Klopfenstein et al., 2008b) were written on the subject. Along the way, producers and nutrition consultants learned to handle idiosyncrasies of formulating, procuring, storing, mixing and feeding distillers grains and solubles (DGS). Challenges with high-protein, high-sulfur, high-phosphorus diets were addressed both via research effort s and by ethanol plants by reducing excesses, particularly of sulfur contained in DGS. Broadly defined, the product that was researched and fed during that time frame was known as full-fat DGS, but the full-fat qualifier was not necessary as most DGS sources contained at least 10% fat. Spiehs et al. (2002) cited the average ether extract concentration at 10.9% in their review of 118 samples. Recently, we measured ether extract concentrations, among other nutrients, of DGS samples collected quarterly from 40 ethanol plants in the Upper Midwest (Paulus et al., 2013). Concentrations of ether extract varied from 5.5 to 9.3%, already indicating incorporation of de-oiling procedures in ethanol plants from whence these samples originated.

Presently, anecdotal information points to a dramatic down shift in ether extract concentration of DGS purchased from many Upper Midwest ethanol plants. Researchers at universities represented in this region quickly responded by conducting research aimed at re-discovering the energy value and potential upper inclusion limits for DGS produced under new technology aimed at capturing corn oil for biodiesel production. The following is a review based on a meta-analysis of the effects of feeding reduced- or low-fat DGS in diets of growing beef cattle and a review of the existing literature on the effects of feeding reduced- or low-fat DGS in the diets of lactating dairy cattle. The objective of this review is to provide the reader with an energy value for de-oiled DGS to use in formulating growing beef and lactating dairy cattle diets.

Low- vs Reduced Fat DGS and Their Origin

Recent changes in dry milling of corn for ethanol production to retain more of the valuable corn oil have led to generation of co-products with variable concentrations of oil. Typically, fractionation of corn before fermenting yields distillers grains with solubles (DGS) with the lowest ether extract concentrations; in the range of 3% to 5%. This product is known in the industry as low-oil or low-fat DGS. Alternatively, when oil is centrifuged from the thin stillage fraction, oil extraction is less than through corn fractionation, resulting in DGS containing from 7% to 9% ether extract. Because of the high cost to build or retrofit existing ethanol plants to accommodate corn fractioning, low-fat DGS is not as common in the market place as reduced-fat DGS; retrofitting existing plants to accommodate a centrifuge for thin stillage being less expensive. Indeed, most ethanol plants serving localities where cattle feedlots and dairies occur are marketing reduced-fat DGS today as wet (35% DM), modified wet (49% DM) or dry (92% DM) DGS. The market quickly transformed from full-fat DGS to reduced-fat DGS without notice (or price change to adjust for potentially lower energy value)—users were left to determine reduced-fat DGS energy value and/or to adjust dietary energy formulations to compensate for potentially lower energy value. This change occurred at a time when international sales of DDGS increased and corn grain prices were elevated; therefore, discovery of impact of reduction in ether extract concentrations of DGS on performance of beef and dairy cattle and determination of its energy value became a priority for universities and other research centers.

Energy Value of Reduced- or Low-fat DGS in Growing Beef Cattle Diets

A dataset derived from 15 manuscripts containing 85 means for treatments comparing a corn- or barley-based control diet with diets containing various concentrations of low-, reduced- or full-fat DGS in growing and finishing beef cattle experiments was subjected to a meta-analysis to determine impact of lowering ether extract in DGS on performance and energy value. Table 1 lists average ether extract concentrations of DGS products evaluated, and corresponding performance response. In all instances, DGS substituted grain or grain and protein supplement source at a given percentage of diet DM without regard to impact on caloric, lipid, protein or dry matter concentrations of dietary treatments.

Performance traits and concentrations of dietary ingredients were entered into a master file where DGS characteristics, and those of any other feeds listed in the original manuscript, were entered to determine feed-to-gain (FTG) from gain-to-feed (GTF) reported, or vice versa, check final body weight (BW), and to check diet concentrations of dry matter (DM), crude protein (CP), degradable intake protein (DIP), ether extract (EE), neutral detergent fiber (NDF), sulfur (S), and total digestible nutrients (TDN). Subsequently, average metabolic body weight ($kg^{0.75}$), dry matter intake (DMI) and average daily gain (ADG) were run through iterative procedures to estimate energy content (observed Metabolizable, ME, net energy for maintenance , NE_m, and gain, NE_g) using NRC equations (NRC, 2000). Therefore, the final dataset contained information regarding type and concentration of grain, roughage, co-product, and supplement used. Other information such as use of Rumensin and Tylan, breed, and sex were also included in the dataset.

Table 1. Characteristics of data analyzed.

Item	N	Average	SD	Minimum	Maximum
		Condensed distillers solubles diets			
Formulated ME, Mcal/lb DM	8	1.13	0.16	1.00	1.39
Ether extract, % DM	8	5.59	2.73	2.45	8.88
In BW, lb	8	562	62	527	663
DMI, lb/d	8	15.85	2.80	11.50	19.40
ADG, lb	8	2.58	0.72	1.72	3.53
FTG, lb/lb	8	6.31	0.78	5.49	7.58
Iterated ME, Mcal/lb DM	8	1.21	0.13	1.06	1.43
		Corn or barley-based diets			
Formulated ME, Mcal/lb DM	20	1.34	0.12	0.90	1.43
Ether extract, % DM	20	3.62	0.88	1.54	5.43
In BW, lb	20	795	151	530	1052
DMI, lb/d	20	21.84	3.99	12.50	27.60
ADG, lb	20	2.98	0.90	1.27	4.43
FTG, lb/lb	20	7.65	1.46	5.27	10.00
Iterated ME, Mcal/lb DM	20	1.24	0.12	1.02	1.47
		Distillers grains with solubles-based diets			
Formulated ME, Mcal/lb DM	57	1.43	0.10	1.11	1.57
Ether extract, % DM	57	5.41	1.27	2.33	9.31
In BW, lb	57	800	116	637	1118
DMI, lb/d	57	22.58	3.67	10.90	27.90
ADG, lb	57	3.46	0.86	0.77	4.56
FTG, lb/lb	57	6.92	1.75	4.55	14.09
Iterated ME, Mcal/lb DM	57	1.32	0.14	1.05	1.75

Using a mixed model approach with multiple regression procedures, attempts were made to rely on continuous variable evaluation of the impacts of independent variables on performance variables (DMI, ADG, FTG, analyzed as GTF, final BW, observed ME) to prevent reducing error term degrees of freedom. Although corn and barley grain were the only grains represented, corn grain was fed in various forms from whole, dry rolled, high-moisture-stored, and steam-flaked. Barley grain was only fed in one experiment as dry-rolled barley. Roughage sources included grass hay and silage, legume hay and silage and stover (either straw or corn stalks).

Final models for effects of independent variables included whether co-product was fed or not (variables included DGS, CDS or neither), which proved to be significant on performance with P-values ranging from 0.004 (GTF) to 0.09 (DMI; Table 2). In the present analysis, feeding

CDS to growing cattle resulted in greater feed conversion efficiency due to greater ADG (P = 0.02) at similar DMI (P = 0.93). This resulted in greater (P < 0.04) observed dietary ME concentration for cattle fed CDS. No differences (P > 0.24) were detected in ADG or GTF for cattle fed DGS or control diets. Therefore, observed ME concentration derived from iterating ADG and DMI for cattle fed DGS or a Control diet did not differ (P = 0.50). When examining this information the reader is reminded that average ether extract concentration of DGS in this dataset was 7.25%, and this is the DGS impact modeled in the preceding discussion.

With the exception of impact on DMI, ether extract content, or a measure thereof, proved to be a significant effect on performance with P-values ranging from 0.005 (observed ME) to 0.12 (ADG; Table 2). In all instances, modeled effects of ether extract on ADG, GTF or observed ME were positive indicating that as ether extract concentration of co-product increases, performance response improves. In contrast, ether extract, expressed as percentage of that in co-product or as co-product ether extract intake, had no impact on DMI. This observation demonstrated that changing concentration of ether extract in co-product, as a result of capturing greater value from the dry milling process, had no impact on DMI. The reader is reminded that although some experiments included in this meta-analysis contained information on diets were DGS was fed at up to 65%, insufficient numbers of these observations may have prevented observing effect of full-fat DGS inclusion on DMI observed previously (Reinhardt et al., 2007).

Table 2. P-values from mixed regression models.

	Dependent variable				
Effect of independent variable	GTF	Iterated ME	ADG	DMI	Out BW
Co-product	0.0039	0.0182	0.0527	0.0874	0.0631
Grain type	NS	<.0001	0.0005	NS	NS
Roughage	0.0219	NS	0.0007	0.0002	0.1104
Ether extract measure	0.0506	0.005	0.1222	NS	NS
Formulated ME	<.0001	<.0001	<.0001	0.0037	<.0001
DM content	<.0001	0.0285	0.0008	0.0217	0.0387
ln BW	0.0012	NS	NS	0.0003	<.0001

Estimates of metabolizable energy (ME) derived from iterations of performance responses reflected impact of ether extract concentrations. Effect of co-product ether extract was significant (P = 0.05) and reflected an impact of 0.06 Mcal observed ME/1% change in co-product ether extract content. At an average 7.25% ether extract concentration for DGS modeled in this analysis (3.12 Mcal ME/kg DM or 1.41 Mcal ME/lb DM), the expected ME concentration of full-fat DGS(12% ether extract) would be 3.42 Mcal ME/kg DM (1.55 Mcal ME/lb DM). Similarly, low-fat DGS resulting from fractionation of corn prior to fermentation containing 3.5% ether extract would have an expected ME concentration of 2.89 Mcal/kg DM (1.31 Mcal ME/lb DM). Equivalent NE_g concentrations for DGS containing 12%, 7.25% or 3.5% ether extract, corresponding to average concentrations for full-, reduced- and low-fat DGS, would be 75.25, 66.08 or 58.73 Mcal NE_g/cwt, respectively. These values represent a 2 Mcal NE_g/cwt change for each percentage unit change in ether extract concentration of DGS. Although the unit change in Mcal NE_g for each percentage unit change in ether extract content of DGS is almost twice as that proposed by Pritchard et al. (2012). Data modeled here for effects of ether extract content on DGS NE_g content and those presented by Pritchard et al. (2012) for full-fat DGS containing 12.2% ether extract (75.25 vs 78.07 Mcal/cwt) and for DGS with no solubles containing 8.9% ether extract (69.19 vs 71.54 Mcal/cwt) agree.

Energy Value of Reduced- or Low-fat DGS in Lactating Dairy Cattle Diets

As for beef cattle diets, a number of studies have been conducted where reduced-fat or low-fat DGS are fed in lieu of full-fat DGS or corn grain in lactating cow diets. In contrast to growing beef studies, in all lactating dairy cow studies energy, protein, and ether extract concentrations were balanced for inclusion of co-product. Thus, lactating dairy cow studies were represented by isocaloric, isonitrogenous, and isolipidic diets. Some of the studies relied on modifying lipid or protein sources by using corn germ or oilseed meals to adjust for ether extract or protein concentrations of DGS.

A recent review of DGS studies (Schingoethe et al., 2009), including some reduced- or low-fat DGS sources, led to the determination that diets of lactating dairy cows could contain as much as 20% DGS. This conclusion resulted from observations that milk yield did not decrease until after cows were fed 30% DGS, but DMI decreased starting at 20% inclusion. Earlier, Birkelo et al. (2004) had established, by indirect calorimetry in lactating dairy cows, that the ME content, at 1X maintenance, of wet DGS containing 8.5% ether extract was 3.61 Mcal/kg DM (1.64 Mcal/lb DM). Equivalent energy content expressed as NE_l at 3X maintenance was 2.21 Mcal/kg DM or 100 Mcal/cwt DM. In that study, milk fat concentration tended ($P < 0.10$) to be greater while DMI and milk protein concentration decreased was lower ($P < 0.05$) with DGS.

Comparisons of full-fat and oil-extracted DGS were conducted by Christen et al. (2010) and Mjoun et al. (2010b). In the study by the former, milk fat concentration increased and that of protein tended to increase when a low-fat, high-protein DGS substituted full-fat DGS. No other impacts were observed on BW, DMI milk yield or concentration or yield of milk constituents. In the study by the latter, no effects of substituting full-fat DGS with low-fat DGS were apparent.

When the lipid fraction was derived from corn germ (Abdelqader et al., 2009) in diets of lactating dairy cows; a high-protein, low-fat DGS contributed protein and NDF in amounts equal to full-fat DGS treatment, there were not any notable differences in DMI, BW, milk yield or concentration or yield of milk constituents. In spite of balanced concentrations of protein, concentration of urea in milk was lower in cows fed the corn germ-low-fat DGS diet. There seemed to be no reasonable explanation for this effect.

In a total of three studies, researchers evaluated titrated concentrations of reduced-fat or low-fat DGS in lactating dairy cow diets. In spite of differences in ether extract content of DGS between studies, DMI, milk yield or BW was not affected by increasing concentrations of DGS (Castillo-Lopez et al., 2014; Mjoun et al., 2010a). Indeed, fat- or energy-corrected milk yield increased linearly in response to feeding greater concentrations of low-fat DGS (Mjoun et al., 2010a). In that study, concentration and yield of fat and concentration of lactose increased linearly with increasing low-fat DGS inclusion.

In a recent study involving indirect calorimetric measurements in lactating dairy cows, researchers at University of Nebraska demonstrated that the ME content of reduced-fat DGS (5.3% ether extract) DGS was 3.41 Mcal/kg DM (1.55 Mcal/lb DM; Foth, 2014). Equivalent energy content expressed as NE_l at 3X maintenance was 2.03 Mcal/kg DM or 92 Mcal/cwt DM.

Within a study, as nutrient concentrations were balanced across diets, no differences were expected in milk yield or BW and, in all studies, this was the case. Therefore, when full-fat DGS was substituted with reduced- or low-fat DGS, or other constituents of DGS, differences in energy content of DGS due to concentration of ether extract would have been eliminated. A few, inconclusive effects were observed on milk constituent concentration and yield were observed.

Results from the two studies with lactating dairy cows conducted using indirect calorimetry indicate that when comparing two sources of DGS with differing ether extract concentrations, energy content may differ as it was observed for studies with growing beef cattle. In the study by Birkelo et al. (2004), ether extract and NE_l concentration were 8.5% and 100 Mcal/cwt DM while in the study by Foth (2014) ether extract and NE_l concentrations were 5.3% and 92 Mcal/cwt DM. Thus, a relationship of 2.5 Mcal NE_l/cwt DM for every percentage unit change in ether extract is represented by these two measurements.

Interestingly, the relationship between ether extract concentration and NE_g in growing beef cattle diets or NE_l in lactating dairy cattle diets is similar as the efficiency of use ME for NE_l is greater than that for NE_g. Indeed, when expressing these values as Mcal of ME/lb DM for beef or dairy cattle diets, the relationship between ME and ether extract content is the same: approximately 2.75 Mcal ME/cwt DM for every 1% difference in ether extract content of DGS. As nutritionists continue to utilize oil-extracted DGS in beef or dairy cattle diets, corrections of 2 Mcal NE_g/cwt DM or 2.5 Mcal NE_l/cwt DM for every percentage unit change in ether extract relative to the original energy value they were placing on full-fat DGS are necessary to balance diets accordingly.

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Notes