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The Use of Dried Distillers Grains with Solubles in Feedlot Rations for Lambs

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Summary

Dried distillers grains with solubles (DDGS) are a valuable feed resource for ruminants due to their concentrations of both protein and energy. Average daily gain (ADG) of lambs appears to improve with inclusion rate of DDGS at 20% to 30% of dietary DM. Dry matter intake likewise appears to improve when DDGS is included at rates less than 30%, with intake declining as DDGS is included at rates ≥ 30%. Additionally, carcass characteristics of lambs have not been adversely affected by feeding DDGS. One of the negative connotations with feeding greater concentrations of DDGS is the risk of sulfur (S) induced polioencephalomalacia (PEM). Sulfur toxicity in lambs in research settings has not been a significant issue when the primary source of S is from DDGS, and inclusion rates of DDGS as high as 60% of dietary DM are possible with proper management. However, regardless of research outcomes, diets exceeding 0.4% dietary S increases the risk of PEM, and caution should be encouraged when high S diets are being fed. At present, the cost and availability of ethanol co-products are limiting their use in feedlot diets to the minimum amounts needed to meet protein requirements. However, when competitively priced DDGS can be utilized to meet both protein and energy requirements for ruminants. Continued research on DDGS will be important to understand changes in product quality especially as modifications to fermentation processes and oil extraction in the ethanol industry continue to alter co-product nutrient content.

Key Words: Dried Distillers Grain With Solubles, Feedlot, Lamb, Sulfur

Introduction

The ethanol industry in the United States of America produced 36.5 million metric tons of dried distillers grains with solubles (**DDGS**) on average over the past three years 2018-2020 (USDA-ERS Bioenergy Statistics, 2020). Only a handful of ethanol plants are located outside the midwestern states, increasing transportation costs of DDGS for western U.S. sheep industry. However, the distribution of ethanol production makes DDGS a potential feed resource for many Midwestern sheep operations. Competitively priced DDGS can be utilized to meet both protein and energy requirements for ruminants. The evolution of ethanol production has resulted in changes to the nutrient content of DDGS. These changes have resulted in reduction in fat content and increases in protein content of some, but not all, DDGS products making feed analysis critically important in diet formulation. Dried distillers grains with solubles have been utilized in lamb feedlot diets at rates as high as 60% DM basis (Schauer et al., 2008; Neville et al., 2010; Felix et al., 2012). Due to greater concentrations of phosphorus (**P**) and sulfur (**S**) in DDGS, proper care must be taken in diet formulation to ensure animal performance and prevent urinary calculi and polioencephalomalacia (**PEM**; NRC, 2007). The objective of this review will be to provide an overview of research on lamb performance and carcass characteristics, as well as to address some of the perceived barriers to increasing the use of DDGS in lamb feedlot rations.

Nutrient Profile Of Dried Distillers Grains With Solubles

The nutrient content of DDGS has changed with the evolution of the ethanol production process. Traditionally, crude protein (**CP**), fat, and P would increase by 3-fold when comparing corn to distillers grains (Klopfenstein et al., 2008). Understanding the nutrient content of the DDGS products is critical to ensure properly balanced rations as variation in nutrient content can occur based on ethanol production processes. One of the benefits to utilizing DDGS as a primary energy source is the low starch content. The removal of starch during the fermentation process leaves a higher fiber co-product that is safely fermented in the rumen, and potentially lessens the risk of acidosis when included at rates above 20% of dietary DM in feedlot diets (Klopfenstein et al., 2008).

With modifications to the fractionation process, and centrifugation of thin stillage, oil is now being removed resulting in a lower fat product than previously described (U.S. Grain Council). Furthermore, variation between ethanol plants and processing methods can impact fat content of DDGS with fat values ranging from 5.4% (U.S. Grain Council) to 12% (Lardy and Anderson, 2014). Previous research with lambs fed a low-fat DDGS resulted in similar performance to those fed either conventional DDGS or low-fat DDGS with added corn oil (Redding et al., 2014). Similar results from Van Emon et al. (2012) also observed lamb performance was not impacted by total dietary fat concentration (3.5 to 7.0%) in rations containing either 25% or 50% DDGS.

Dried distillers grains with solubles have an average CP content of 30.8% (NASEM, 2016) with 63% of the CP being rumen undegradable protein (Castillo-Lopes et al., 2013). As a result of new technology which resulted in improved milling and fiber separation, high-CP DDGS with CP values between 44 to 50% (U.S. Grains Council) are now available. It is important to note that not all ethanol plants utilize this technology and the actual CP content of DDGS received at each producer operation should evaluated and actual values used to balance diets appropriately.

Mineral content of DDGS must also be considered when developing rations for feedlot lambs. Due to high P content (0.86 ± 0.11%; NASEM 2016) of DDGS additional calcium (Ca) is generally required to maintain a 2:1 Ca to P ratio in diets for prevention of urinary calculi (Schauer et al., 2005; NRC 2007). Sulfur present in DDGS should also be considered when balancing rations and will be discussed in a later section.

Other grain sources including sorghum and wheat have also been used in the ethanol production industry and may be available in the southern states and Canada, while corn is the predominant grain source used in the central United States. Wheat-DDGS contains more CP than conventional corn-DDGS (39.4% vs. 30.5%, respectively), similar ADF (15.8% vs. 13.3%), but less crude fat than conventional corn-DDGS (4.8 vs 12.1%; Curry, 2014). Cellulosic ethanol production is also producing by-products for use in livestock production, although little information on these products is currently available. Data from Lundy et al. (2015) reported that digestibility of by-products resulting from corn-fiber fermentation may be lower than those of traditional grain ethanol production in lambs.

Feed And Ration Management

One of the major management issues with feeding diets containing greater concentrations of DDGS to lambs is sorting that can occur in a textured or mixed diet. Some research has circumvented this issue by providing a finely ground diet which prevents sorting (Schauer et al., 2008; Crane et al., 2017). Totally ground rations decreased ruminal pH, below the 5.0 threshold representative of acute ruminal acidosis (Crane et al., 2017) although clinical acidosis was not observed; whereas ruminal pH decreased from 5.8 to 5.3 when lambs were provided rations including cracked corn, ground hay, and DDGS (Neville et al., 2011). In either case, the lower end of the pH reported in these studies would be indicative of either sub-acute or acute acidosis. While total mixed rations with cracked or rolled grain, DDGS, and roughage will require diligent bunk management to prevent sorting, both conventional and completely ground diets still have the potential to induce acidosis if managed inappropriately. Changes in feeding behavior could also explain the lack of visual signs of ruminal acidosis in some previous research. For example, in steers feeding behavior including number of meals and size of meals have been affected by concentrations of DDGS and corn particle size indicating potential adaptation by the animal to diet (Swanson et al., 2014) to help regulate ruminal pH. These principles have not been evaluated in lambs and further research would be needed to determine if use of fine-ground diets or traditional particle sizes and feeding method (self-feeders vs. daily feeding) are in fact altering lamb feeding behavior.

Inclusion of wet products such as silages or liquid binders may aide in decreasing sorting issues found in DDGS rations but eliminate the use of self-feeders. Including wet or modified distillers grains with solubles instead of DDGS is another option to improve ration consistency and reduce sorting in total mixed rations provided daily. The use of modified and wet distillers grains products has not been extensively researched in lamb finishing diets. Utilizing either wet or modified distiller products will increase cost associated with transport due to low DM content, and require additional inputs associated with handling and storage, especially in warmer climates.

Research in beef cattle has demonstrated feeding roughage at conventional rates is important even in diets containing distillers grains products to optimize performance (NASEM, 2016). This topic has not been as thoroughly evaluated in lamb finishing diets, however the general practices of beef and lamb finishing management are similar, a brief review of recent literature indicates that typical roughage levels in lamb finishing diets are 10% (Huls et al., 2006; Van Emon et al., 2012) but can range from 5 to 30%. These concentrations are greater than the 6% (Hales et al., 2013) and 7.5% (May et al., 2011) roughage shown to optimize gain in beef cattle fed diets containing wet distillers grains with solubles. However, more detailed research is needed to accurately relate beef cattle data to the actual results in lamb finishing. Further, data on the use of lower quality roughage sources with various grain processing methods when fed in combination with DDGS to finishing lambs are also warranted.

Traditional roughage sources fed in combination with DDGS have included alfalfa hay (Neville et al., 2010), soybean hulls (Felix et al., 2012), or commercially manufactured pellets (Redding et al., 2014; Crane et al., 2018). Alternative roughage sources fed in combination with DDGS has also been evaluated. Cottonseed hulls have been used in lamb rations containing 40% DDGS (Whitney and Lupton, 2010). Other non-traditional roughages, including redberry juniper, have also been used as roughage sources in DDGS based feedlot rations (Whitney et al., 2014). However, Whitney and Lupton, (2010) and Whitney et al. (2014) both expressed the need for caution related to plant secondary compound concentrations e.g., condensed tannins or volatile oils present in cottonseed hulls and redberry juniper.

Animal Performance

Dried distillers grains with solubles are typically included in rations at rates sufficient to reach protein requirements for the class of animals. This is largely a function of two factors; cost and availability. Recently, DDGS have been less competitively priced compared to corn or other energy sources, providing an economic barrier to inclusion rates beyond those needed to meet protein requirements. Costs associated with transport for many western states sheep producers has also been a barrier to further use of DDGS within the sheep industry. Recent discussion relative to an apparent decrease in overall co-product availability may further limit use of DDGS in the sheep industry. However, research has demonstrated that DDGS can be utilized in lamb finishing rations at levels up to 60% of dietary DM without significant decreases in animal performance (Schauer et al., 2006; Neville et al., 2010) allowing for DDGS to be used as the primary source of energy in finishing rations if economical.

The impacts of DDGS inclusion rate on DMI in lambs has been evaluated. Intake data from nine unique research studies utilizing DDGS in lamb feedlot rations have been summarized (Table 1). Studies summarizes had to include corn-DDGS, a control or 0% DDGS treatment, and at least one additional inclusion rate of DDGS. While not analyzed statistically, average intakes appear to increase when DDGS is included at rates less than 30% of dietary DM, while DDGS inclusion at rates ≥30% of dietary DM appear to decrease DMI. This trend is consistent with previous reviews on DDGS in beef cattle (Klopfenstein et al., 2008). However, not all research follows this trend. Felix et al. (2012) reported no differences in DMI with increasing dietary DDGS inclusion. Schauer et al. (2008) found feeding greater concentrations of DDGS increased DMI from1.68kg to 1.91kg, for 0% DDGS and 60% DDGS, respectively, which is contrary to most research with sheep and beef cattle. Decreased DMI was attributed to increased crude protein of the diet in lambs fed DDGS (Van Emon et al., 2012). Additional research evaluating the impacts of inclusion rates less than 20% and greater than 40% are needed to further elucidate responses at lesser and greater levels of DDGS.

The impacts of DDGS inclusion on ADG and G:F have also been evaluated and are presented in Tables 2 and 3, respectively. These studies were summa-

Table 1. Impacts of dried distillers grains with solubles (DDGS) inclusion on dry matter intake (DMI; kg) of feedlot lambs.[1]

	DDGS, %				
	0	<20	20-30	30-40	>40
Lodge et al., 1997	1.24	-	-	1.27	-
Huls et al., 2006	1.59	-	1.65	-	-
Schauer et al., 2006	1.87	1.92	1.92	-	-
Schauer et al., 2008	1.68	-	1.78	1.83	1.91
McKeown et al., 2010	1.39	-	1.47	-	-
Neville et al., 2011	1.30	-	1.50	1.40	1.30
Felix et al., 2012	1.48	-	1.56	1.49	1.47
Whitney et al., 2014	1.47	-	-	1.28	-
Crane et al., 2017	1.80	1.75	1.55	-	-
Mean DMI[2], kg	1.53	1.83	1.63	1.45	1.56

[1] Data utilized from published research articles utilizing corn DDGS in lamb rations. Studies included used a 0% control and at least one DDGS treatment.
[2] Mathematical average.

Table 2. Impacts of dried distillers grains with solubles (DDGS) inclusion on average daily gain (ADG; kg) of feedlot lambs.[1]

	DDGS, %				
	0	<20	20-30	30-40	>40
Lodge et al., 1997	0.28	-	-	0.31	-
Huls et al., 2006	0.29	-	0.29	-	-
Schauer et al., 2005	0.31	0.34	-	-	-
Schauer et al., 2006	0.20	0.24	0.27	-	-
Schauer et al., 2008	0.26	-	0.28	0.28	0.28
McKeown et al., 2010	0.38	-	0.40	-	-
Felix et al., 2012	0.32	-	0.36	0.31	0.30
Whitney et al., 2014	0.20	-	-	0.23	-
Crane et al., 2017	0.29	0.29	0.29	-	-
Mean ADG[2], kg	0.28	0.29	0.32	0.28	0.29

1 Data utilized from published research articles utilizing corn DDGS in lamb rations. Studies included used a 0% control and at least one DDGS treatment.
2 Mathematical average.

Table 3. Impacts of dried distillers grains with solubles (DDGS) inclusion on feed efficiency (G:F; kg of gain: kg of feed) of feedlot lambs.[1]

	DDGS, %				
	0	<20	20-30	30-40	>40
Lodge et al., 1997	0.23	-	-	0.22	-
Huls et al., 2006	0.18	-	0.18	-	-
Schauer et al., 2006	0.11	0.12	0.14	-	-
Schauer et al., 2008	0.16	-	0.16	0.15	0.15
McKeown et al., 2010	0.27	-	0.28	-	-
Felix et al., 2012	0.22	-	0.23	0.21	0.21
Whitney et al., 2014	0.17	-	-	0.18	-
Crane et al., 2017	0.16	0.17	0.19	-	-
Mean G:F[2]	0.19	0.15	0.20	0.19	0.18

1 Data utilized from published research articles utilizing corn DDGS in lamb rations. Studies included used a 0% control and at least one DDGS treatment.
2 Mathematical average.

rized in the same format as DMI, however only 9 and 8 research reports provided ADG and G:F, respectively. While not statistically analyzed, ADG appears to increase when DDGS is included at rates between 20 and 30% of dietary DM. Average daily gain values presented here again correspond well to improved gains found in beef cattle consuming 20 to 30% DDGS (Klopfenstein et al., 2008). Feed efficiency appears to also improve when DDGS inclusion rates are between 20 and 30%, however reported results for G:F when DDGS is included at rates less than 20% and over 40% are very limited and require additional research in feedlot lamb.

There are studies that have reported improved, or at a minimum, no negative impacts of feeding greater concentrations of DDGS on feedlot lamb performance. Van Emon et al. (2012) determined that feeding lambs 50% DDGS did not cause negative effects on feedlot performance. Contrary to the data presented by Schauer et al. (2008) and Van Emon et al. (2012), lambs fed DDGS at greater than 20% had lower ADG and G:F (Felix et al., 2012). The ADG observed by Schauer et al. (2008) were 0.26 to 0.28kg/d while those presented by Felix et al. (2012) were consistently above 0.3kg/d. It is possible that factors related to roughage source played a role in the differences observed between research as these studies utilized a variety of roughages including hay and soybean hulls, or that the response was driven by CP content of the diets. When considering the CP content of the diets, Schauer et al. (2008) evaluated diets in excess of 20% while those of Felix et al. (2012) fell between 14.5 and 20.6%.

Future research evaluating when inclusion rate of DDGS optimizes the combination of ADG, DMI, and G:F in lambs is still warranted. The summary data presented in this manuscript appears to indicate that optimal inclusion level will be between 20% and 30% DDGS (DM basis). Further research on this topic, as well as more detailed research on the impacts of protein content of the ration, roughage source, and lamb breed type will aid in future industry recommendations.

Meat Quality

Currently, the U.S. lamb industry pays almost exclusively on carcass weight basis; therefore, we have summarized the impacts of DDGS inclusion on carcass weight (Table 4). These data were summarized in the same format as previously described for DMI, ADG, and G:F in this manuscript. As with other summaries provided in this manuscript very few studies have reported carcass data with DDGS inclusion less than 20% and greater than 40% thus more data and research are needed to draw conclusive inferences about the impacts of DDGS on hot carcass weight at these inclusion rates.

Previous research feeding DDGS to finishing lambs has demonstrated that when DDGS were provided between 0 and 20% (DM basis) no differences in carcass characteristics were found (Schauer et al., 2005). While other research has demonstrated that loineye area was greater in lambs fed 30% DDGS (16.8 cm^2) compared to lambs not feed DDGS (16.1cm^2; Schauer et al., 2006). Schauer et al. (2008) found that lambs fed DDGS had increased flank streaking in lambs compared to lambs not receiving DDGS. However, Schauer et al. (2008) reported no additional benefit to flank streaking when concentrations of DDGS was increased from 20 to 40 or 60% inclusion rates. Research feeding lambs diets containing 60% DDGS has

Table 4. Impacts of dried distillers grains with solubles (DDGS) inclusion on hot carcass weight (HCW, kg) of feedlot lambs.[1]

	DDGS, %				
	0	<20	20-30	30-40	>40
Huls et al., 2006	33.3	-	33.3	-	-
Schauer et al., 2005	29.5	29.0	29.5	-	-
Schauer et al., 2006	31.3	31.8	31.8	-	-
Schauer et al., 2008	30.0	-	32.0	31.0	31.0
McKeown et al., 2010	25.3	-	25.4	-	-
Felix et al., 2012	29.9	-	32.5	29.1	28.7
Crane et al., 2017	31.0	31.7	31.1	-	-
Mean HCW[2]*, kg*	30.0	30.8	30.8	30.1	29.9

[1] Data utilized from published research articles utilizing corn DDGS in lamb rations. Studies included used a 0% control and at least one DDGS treatment.
[2] Mathematical average.

also demonstrated improvements in flank streaking with added S (Neville et al., 2010). Previous work reported that carcasses from lambs receiving 0.43% S, in the form of elemental S, graded better than carcasses from lambs fed either 0.13 or 1.3% S (Smith et al., 1964). Replacing barley and canola meal in in the diet with 20% corn-DDGS did not impact fatty acid content of subcutaneous fat (McKeown et al., 2009). However, when DDGS was included as 45% of the diet meat fatty acids concentrations including C12:0, C18:3 n-3, and PUFAn-3 were decreased while C18:2 n-6, CLA c9-t11 and CLA t9-tll were increased when compared to lambs feed 0% DDGS (Kawecka et. al., 2018). Until there is a long-term commodity-based grid marketing structure in the lamb industry feeding DDGS at greater levels should be more a concern of economics related to feed cost than that of marketing value of carcasses.

Managing Excess Sulfur

The concerns over the incidence of sulfur toxicity in ruminants while feeding DDGS has received great attention over the past few decades as high dietary S can induce PEM in ruminants. Symptoms of PEM include: impaired coordination, blindness, and seizures which can be followed by death (NRC, 2005). As a result, DDGS has been associated with onset of PEM as the S content of DDGS is typically 0.3 to 1.7% S (Buckner et al., 2011; Kim et al., 2012; Drewnoski et al., 2014). In comparison, the maximum tolerable level of S is 0.3% and 0.5% DM basis for high-concentrate and high-roughage diets, respectively (NRC, 2005), and are still the guidelines used today in beef cattle (NASEM, 2016). It is important to note that PEM is more appropriately a sign of toxicity rather than an issue related to maximum tolerable level and further delineation of S concentrations representing toxicity are needed. Outside of the issues with PEM, high dietary S may impact dietary copper and selenium absorption in small ruminants (NRC, 2007). Much of the research conducted with lambs fed high DDGS diets has focused on either S metabolism, adaptation to S, or management practices to offset potential negative consequences of increased S intakes (Neville et al., 2011; Felix et al., 2012; Felix et at., 2014).

The relative incidence rate of PEM in ruminants is relatively low, and multiple researchers (Schauer et al., 2008; Neville et al., 2010; Felix et al., 2012) did not observe PEM with diets in containing 60% DDGS, even though the diets provided by these researchers were in excess (0.35 to 0.87% S) of the maximum tolerable level of S (0.3% S; NRC, 2005). Other researchers had high incidence of PEM in lambs fed high S (0.72% S) and low-fiber diets not containing DDGS (Krasicka et al., 1999). Ruminal pH may be a major contributing factor related to onset of PEM (Felix and Loerch, 2011) due to the increased availability of free hydrogen ions needed for form hydrogen sulfide (Gould et al., 1997; Gould 1998; Kung et al., 2000). Ruminal pH increased and ruminal hydrogen sulfide gas concentrations decreased with increasing roughage (rNDF) in steer diets containing 32% DDGS (0.44-0.47% S; Morine et al., 2014). Research in beef cattle has further demonstrated that risk of PEM is decreased as roughage NDF increases (Nichols et al., 2013). Sulfuric acid contained within DDGS has also been suggested to decrease ruminal pH (Felix and Loerch, 2011). The interactions of roughage, grain, S concentrations, and other management decisions need to be evaluated further as they relate to the onset of acidosis and PEM.

Providing high sulfate water in conjunction with feeding DDGS can further increase risk of PEM. High sulfate water (600 mg sulfate/L) may lead to sulfur toxicity in ruminants fed high concentrate diets (NRC, 2005 and 2007). To date, feeding DDGS in combination with low sulfate water (31 and 141 mg sulfate/L, Neville et al., 2011; Schauer et al., 2008, respectively) did not result in any cases of PEM in lambs. However, feeding DDGS and providing high sulfate water would not be advisable as the occurrence of PEM would be expected to increase. In areas with high sulfate water other sources of protein with lower S content would be advisable.

One of the main practices utilized when feeding greater inclusion rates of DDGS within the feedlot industry is to include thiamin in the diet. However, the subsequent review of literature demonstrates that providing thiamin does not guarantee prevention of PEM when feeding high S diets to ruminants. Visual signs of PEM in lambs fed high S diets (0.63% S) were prevented by supplementing 243 mg thiamin/kg dietary DM (Olkowski et al., 1992). However, these same authors reported that microscopic lesions in brain tissue were not completely prevented (Olkowski et al., 1992). Lambs fed 60% DDGS (0.55% S; DM basis) receiving 142 $mg \cdot hd^{-1} \cdot d^{-1}$ of supplemental thiamin had no incidence of PEM (Schauer et al., 2008). Other work did not determine any benefits to supplementing thiamin at either 50, 100, or 150 $mg \cdot hd^{-1} \cdot d^{-1}$ compared to unsupplemented lambs fed 60% DDGS (0.74 to 0.87% S; DM basis; Neville et al., 2010).

Additional research establishing more defined concentrations of S detailing both maximum tolerable level and toxicity in sheep is warranted. When considering the relatively tight range between requirements 0.15% S (approximated from g/d S and estimated intake; NRC, 2007) and maximum tolerable level 0.30% S (NRC, 2005); and the apparent ability of lambs to perform within expectations at levels of S well above the maximum tolerable level understanding S requirements and metabolism in lambs is critically important. Further evaluation of the impacts of ration particle size, S concentration, and ruminal pH; quantification of ruminal available S, determination of S reducing bacterial populations, and the impacts of roughage concentrations are all needed as they relate to the incorporation of DDGS in lamb rations.

Applications

In conclusion, DDGS are a versatile feed well suited for use in rations for lambs. Feeding DDGS at rates up to 60% of dietary DM are possible, however, inclusion rates of 20-30% of the ration (DM basis) may be more appropriate. Carcass quality of lambs fed DDGS fall well within acceptable limits. Proper feed management and ration balancing are needed to address potential for mineral imbalances including phosphorus and sulfur. Additional research evaluating how ration particle size impacts intake, performance, and health would provide additional insight into feeding DDGS to lambs.

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