CHAPTER 24

DDGS in Sheep and Goat Diets

Introduction

WHILE LIMITED STUDIES HAVE BEEN CONDUCTED TO EVALUATE THE EFFECTS of feeding DDGS to sheep and goats compared with other species, DDGS is an economical and excellent feed ingredient in diets for sheep and goats. The high fiber and low starch content of DDGS provides diet formulation flexibility and allows it to safely partially replace a portion of the forage or grain in diets with reduced risk of rumen acidosis compared to feeding grain-based diets (Held, 2006a,b).

Gestating and Lactating Ewes

Ely et al. (1991) fed 20 crossbred ewes with twin lambs from 14 to 56 days post-partum on fescue-hay based diets to provide 75 to 85 percent of the NRC requirements for protein and energy, a forage to concentrate ratio of 2:1, and diets were supplemented with soybean meal or DDGS. Ewes fed the DDGS supplemented diets lost less weight during lactation, but produced less total milk than soybean meal supplemented ewes. Ewes fed at 75 percent of the recommended nutrient intake level lost more body weight, but milk production was not affected compared to feeding a diet at 85 percent of NRC requirements for energy and protein. Lambs from ewes fed the soybean meal supplemented diet, or the 85 percent of recommended nutrient intake level had improved average daily gain. Neither the soybean meal nor DDGS supplements affected daily milk dry matter, crude protein, ash or lactose content. However, ewes fed the DDGS supplemented diet produced 16.5 percent more milk fat per day. Lambs from ewes fed the soybean meal supplemented or the 85 percent level of recommended nutrient intake used milk nutrients more efficiently than lambs nursing ewes fed the DDGS supplemented diets or the 75 percent of the requirement diet. Ewes fed the soybean meal diet had greater dry matter and crude protein digestibility than ewes fed the DDGS diet.

More recently, when DDGS was used instead of soybean meal as a protein supplement in lactating ewe diets, no differences were observed in ewe body condition score and suckling lamb weight gain (Held, 2006a). A lactation study evaluating the use of DDGS to replace 2/3 of the corn (25 percent of the diet) resulted in a 12 percent improvement in reared lamb growth for ewes nursing triplets, but there were no effects for ewes nursing twin and single lambs (Held, 2006a). A possible reason for the comparative differences between soybean meal and DDGS supplementation in Ely et al. (1991) and Held (2006a) reports may be due to differences in dietary nutrient levels fed and the quality of the DDGS sources used.

Radunz et al. (2011) compared ewe and lamb performance of three winter-feeding gestation systems to crossbred ewes, haylage, limit-fed corn or limit-fed DDGS. At parturition, ewe body weight was heaviest for those fed DDGS, lowest for those fed haylage, and intermediate for those fed corn. Ewes fed corn and DDGS had greater body condition scores at parturition than those fed haylage, and at weaning, ewes fed DDGS had greater body condition scores than those fed corn or haylage rations. Body weight of lambs at birth tended to be heavier from ewes fed corn and DDGS compared to ewes fed haylage, but there was no effect of ewe gestation diet on lamb weaning weight. Body composition of lambs at birth, ewe milk production, as well as preweaning lamb growth rate and mortality were not affected by feeding program. Feeding DDGS reduced feed costs, but ewes had an increased incidence of ketosis prior to parturition. These researchers then evaluated feedlot performance, glucose tolerance and carcass compositions of lambs weaned from ewes fed the 3 winter-feeding programs (Radunz et al., 2011b). Their results showed that the type of mid- to late-gestation ewe diet fed affects maternal plasma insulin concentration. Lambs from ewes fed DDGS tended to have greater insulin response than those from ewes fed corn or haylage diets. This difference in insulin resistance was associated with alternations in fat deposition affecting primarily internal fat. However, these changes in carcass composition likely have small practical significance, but provide evidence that changes in maternal metabolism due to winterfeeding system may have long-term impacts on progeny growth and body composition.

Rams

Although feeding DDGS in diets for growing rams is increasing, only one study has been published to evaluate these effects on male reproductive traits (Van Emon et al., 2013). Suffolk × western white face ram lambs (40 kg in body weight) were fed 0, 15 or 30 percent DDGS diets as a partial substitute for corn for a 116 day feeding period until market weight. Increasing dietary DDGS levels resulted in a linear increase in dry matter intake and ADG, but there were no effects on final body weight, change in scrotal circumference, carcass characteristics, serum testosterone

concentrations and spermatozoa motility score. However, spermatozoa concentration linearly decreased with increasing DDGS content in the diets. Since this is the only published study that has evaluated reproductive performance of rams, more research is needed to confirm or refute the results from this study.

Growing-Finishing Lambs

Protein and amino acid utilization of DDGS has been evaluated in growing lambs and results from two studies indicate that it is an excellent protein source. Waller et al. (1980) conducted a lamb metabolism trial to evaluate the effects of feeding combinations of proteins that are slowly degraded in the rumen with urea. Combinations of urea and DDGS were used were used to replace urea as sources of supplemental protein and did not significantly affect dry matter or N digestibility of the diets. Archibeque et al. (2008) demonstrated that feeding DDGS improves amino acid nutrition of lambs consuming moderate quality forages.

Gutierrez et al. (2009) fed Suffolk lambs three dietary levels of DDGS (0, 15 or 30 percent, dry matter basis). Feed intake was similar among DDGS levels, but body weight gain was reduced when lambs were fed the 30 percent DDGS diet (0.221 kg/d) compared with feeding the 0 and 15 percent DDGS diets (0.284 and 0.285 kg/d, respectively), suggesting that a much lower DDGS feeding level (15 percent) be used for lambs compared to the feeding recommendations by Schauer et al. (2008).

McKeown et al. (2010) showed that DDGS from corn, wheat or triticale can replace a mixture of barley grain and canola meal at 20 percent of diet dry matter without adversely affecting dry matter intake, growth rate, or carcass characteristics of growing lambs, but wheat DDGS may reduce gain:feed and triticale DDGS may improve the fatty acid profile of carcass fat. Felix et al. (2012) fed diets containing 0, 20, 40 or 60 percent DDGS to growing lambs and concluded that DDGS can be fed to sheep at up to 60 percent of the diet dry matter without affecting dry matter intake, but higher dietary inclusion rates may decrease ADG. They also observed that feeding high inclusion rates of DDGS may affect marbling score and reduce hot carcass weight. Therefore, they recommended that feeding diets containing 20 percent DDGS of dry matter is optimal. In contrast, Van Emon et al. (2011) showed results that indicate that DDGS can be included in the diets of finishing lambs at levels up to 50 percent of dry matter intake without negatively affecting growth performance, carcass quality, and metabolite concentrations. Similarly, O'Hara et al. (2011) showed that replacing portions of canola meal and barley with 20 percent high or low oil corn DDGS in Canadian Arcott lamb finishing diets was effective in maintaining healthy rumen function, growth performance, and carcass characteristics.

Rambouillet wether lambs were ad libitum fed diets that contained DDGS to replace 0, 33, 66 or 100 percent of cottonseed meal during a 84-day feeding period (Whitney and Braden, 2010). Carcass characteristics were not affected by dietary treatment but the amount of fat in the loin muscle increased with increasing levels of DDGS in the diet. Meat from lambs fed the 100 percent DDGS diet had less cook loss and greater juiciness than meat from lambs fed the 0 percent DDGS diet. These results indicate that partial or complete substitution of DDGS for cottonseed meal in finishing lamb diets provide acceptable carcass characteristics and may enhance sensory traits of meat. In a subsequent study, Whitney et al. (2014) fed 40 percent DDGS diets and increasing amounts of ground juniper hay to Rambouillet lambs during a 91 day feeding trial and showed that reported that DDGS-based diets can reduce total feedlot costs compared to feeding sorghum grain and cottonseed meal-based diets.

Huls et al. (2006) conducted a study to determine the effects of replacing soybean meal and a portion of the corn with DDGS on growth performance, carcass characteristics and the incidence of acidosis, bloat or urinary calculi in wethers fed a high-grain finishing diet with soyhulls as the only source of dietary fiber. Diets were balanced to have similar CP (14.6 percent), ME (3.4 Mcal/kg), and calcium:phosphorus (2:1) and pelleted. Average daily gain, dry matter intake, gain:feed and carcass characteristics were not different between dietary treatments, and no symptoms of acidosis, bloat or urinary calculi were observed. These results suggest that DDGS is an acceptable substitute for soybean meal and a

portion of the corn in finishing lamb diets where soybean hulls are the only source of fiber.

Sewell et al. (2009) fed various crop residues (i.e. wheat straw, corn stover, switchgrass, corn fiber and wheat chaff) that were either thermochemically processed or not, in combination with DDGS and showed that nutrient digestibility of these crop residues was improved by thermochemically processing, and these processed crop residues can be fed in combination with DDGS to partially replace corn in ruminant diets.

McEachern et al. (2009) reported results which indicate that DDGS can replace all of the cottonseed meal in lamb finishing diets without negatively growth rate, feed conversion, wool characteristics, and can potentially reduce feed cost/kg of gain. Whitney and Lupton(2010) showed that cottonseed hulls are a good roughage source for lamb finishing diets containing 40 percent DDGS.

Bárcena-Gama et al. (2016) evaluated the effects of feeding diets with and without DDGS (0, 15, 30 or 45 percent) on dry matter intake and digestibility, NDF and ADF digestibility, growth rate and carcass composition of Criollo lambs (29 kg body weight). Feeding diets containing 15 percent DDGS dry matter intake and ADG compared to those fed the control diet with no DDGS, but feeding the 45 percent DDGS diet decreased dry matter digestibility. Furthermore, lambs fed the DDGS diets had greater carcass weight and yield with no difference in backfat thickness.

Similarly, Wrzosówka ram lambs (16 kg) were fed a meadow hay, straw and concentrate diet containing 45 percent DDGS, compared with a concentrate that contained barley, wheat, and soybean meal, for 60 days to evaluate effects on carcass and meat quality (Kawęcka et al., 2017). Dietary treatment had no effect on carcass quality, proportion of cuts, chemical and cholesterol content of meat. The intramuscular fat contained a greater proportion of linoleic acid and conjugated linoleic acid in lambs fed the DDGS diet. These results are consistent with other studies showing that feeding DDGS has beneficial effects on the sensory properties of lamb meat, especially taste.

As discussed in **Chapter 15** of this handbook, DDGS contains variable, but sometimes high concentrations of sulfur, and when added to ruminant diets, it can reduce dry matter intake, rumen pH, and cause polioencephalomalacia (PEM). Sulfur-induced PEM involves bacterial reduction of sufate to sulfide and protonation of S^{2-} to hydrogen sulfide gas. When hydrogen sulfide concentrations are elevated in the rumen, the risk of sulfur-induced PEM is increased. Felix et al. (2014) showed that sulfur derived from DDGS is more readily reduced than sulfur from Na_2SO_4 or H_2SO_4. Several recent studies have evaluated the effects of sulfur content in high DDGS diets on rumen characteristics, growth performance and potential mitigation strategies.

Schauer et al. (2008) fed 240 Rambouillet wether and ewe lambs (31.7 kg BW) diets containing alfalfa hay, soybean meal, barley, and a trace mineral supplement, and DDGS replaced barley and soybean meal at 0, 20, 40 and 60 percent of the diet on a dry matter basis. Sulfur concentrations of diets were 0.22, 0.32, 0.47 and 0.55 percent for the 0, 20, 40, and 60 percent DDGS diets, respectively. Thiamin was included at a level of 142 mg/hd/d (dry matter basis) in all rations for the prevention of polioencephalomalacia. Rations were mixed, ground and provided *ad libitum*. Lambs were harvested after the 111 d feeding trial and carcass data collected. Final weight, ADG, gain:feed, mortality, hot-carcass weight, leg score, carcass conformation score, fat depth, body wall thickness, ribeye area, quality and yield grade and boneless closely trimmed retail cuts were not affected by DDGS inclusion rate, and feed intake increased linearly as level of DDGS inclusion increased. These results suggest that feeding high dietary levels of DDGS results in acceptable lamb performance with no negative effects on carcass traits.

Morrow et al. (2013) fed lambs diets containing 60 percent DDGS with and without 2 percent NaOH to adjust diet acidity and varying amounts of Na_2SO_4 to adjust diets to contain similar total sulfur content (0.60 percent). Lambs fed DDGS treated with 2 percent NaOH had improved dry matter intake, ADG, and final body weight, reduced NDF digestibility, but had no effect on gain:feed compared with lambs fed the untreated 60 percent DDGS diet. Increasing dietary sulfur by adding Na_2SO_4 tended to reduce dry matter intake but did not affect ADG, gain:feed, or final body weight. Rumen H_2S concentrations were not affected by dietary sulfur or NaOH treatment.

Crane et al. (2017) evaluated the effects of feeding 0, 15 or 30 percent DDGS diets, with or without 22 g/metric ton of lasalocid, to Suffolk × Rambouillet lambs (32 kg initial body weight) on growth performance and production of ruminal hydrogen sulfide gas. Increasing dietary DDGS inclusion rate increased ruminal H_2S concentration, linearly reduced dry matter intake and ruminal volatile fatty acid concentrations, but linearly increased gain:feed. The combination of adding lasalocid to diets containing DDGS improved growth performance with no effects on lamb morbidity or mortality.

Neville et al. (2010) conducted two studies to evaluate the effects of increasing dietary levels of thiamine supplementation (0, 50, 100, 150 mg/animal/day) to prevent potential development of polioencephalomalacia (PEM) in lambs fed a finishing diet containing 60 percent DDGS and 0.73 and 0.87 percent sulfur (dry matter basis; **Table 1**). No clinical cases of PEM were observed, and there were no effects on most carcass charateristics. Feeding the 60 percent DDGS diets had no effect on growth performance in the second study, but dry matter intake was affected quadratically by thiamine supplementation level in the first study. Despite feeding diets

Table 1. Effect of thiamine supplementation on growth performance and carcass characteristics of lambs fed 60 percent DDGS diets (adapted from Neville et al., 2010)

	Control	Low thiamine	Medium Thiamine	High Thiamine
Initial body weight, kg	32.6	32.6	32.5	32.6
Final body weight, kg	62.3	62.8	62.5	60.5
ADG, kg	0.268	0.274	0.272	0.253
ADFI, kg	1.77	1.78	1.98	1.74
Gain:Feed	0.15	0.15	0.14	0.15
Mortality %	1.67	0	0	0
Hot carcass weight, kg	31.4	32.1	31.7	30.9
Leg score[1]	11.3	11.5	11.6	11.1
Conformation score[1]	11.5	11.4	11.6	11.2
Fat depth, cm	0.79	0.86	0.76	0.84
Body wall thickness, cm	2.72	2.99	2.54	2.67
Ribeye area, cm^2	15.6	15.5	15.7	15.7
Flank streaking[2]	337	340	353	336
Quality grade[1]	11.3	11.3	11.5	11.2
Yield grade	3.5	3.8	3.4	3.7
Boneless closely trimmed retail cuts %	44.7	44.3	45.0	46.8

[1]Leg score, conformation score, and quality grade: 1 = cull to 15 = high prime

[2] Flank streaking: 100 to 199 = practically devoid; 200 to 299 = traces; 300 to 399 = slight; 400 to 499 = small; 500 to 599 = modest

containing high sulfur and DDGS content, supplementing thiamine to prevent PEM was unnecessary in this study.

Meat Goats

Very few studies have been published to evaluate the use of DDGS in meat goat diets, but the many positive results reported from feeding high dietary inclusion rates of DDGS to sheep and beef cattle studies should be also applicable to responses expected when feeding DDGS to meat goats. Gurung et al. (2009) fed a 51.6 percent concentrate mix containing 0, 10.3, 20.6 and 31 percent DDGS (dry matter basis) and 48.4 percent Bremuda grass hay diets to 29 kg Kiko × Spanish intact male kids for 57 days to evaluate effects on growth performance and carcass characteristics (**Table 2**). Initial and final body weight, dry matter intake, ADG and gain:feed were not different among dietary treatments. In addition, plasma urea nitrogen, carcass dressing percentage, rib eye area and body wall fat were not affected by DDGS inclusion rate in the concentrate, but serum cholesterol concentrations increased linearly with increasing dietary DDGS level. These results suggest that up to 31 percent DDGS can be added to meat goat diets without affecting dry matter intake, growth rate, feed conversion and carcass quality.

In a more recent study, castrated male kiko goats were fed diets containing 50 percent Bermuda grass hay and a 50 percent concentrate mix containing 0, 10, 20 or 30 percent reduced-oil DDGS for 84 days to determine the effects on subcutaneous adipose tissues in meat goats (Camareno et al., 2016). Feeding the reduced-oil DDGS diets did not affect total fatty acid content of carcass adipose tissues, but feeding the 30 percent DDGS diet increased the unsaturated fatty acid content in subcutaneous fat.

Dairy Goats

As for DDGS studies in meat goats, only one study has been published to evaluate feeding high amounts (59 percent) of DDGS to dairy goats. Williams et al. (2017) fed late lactation Alpine dairy goats diets containing ground eastern gamagrass (*Tripsacum dactyloides* L.) hay supplemented with 59 percent DDGS to replace corn and soybean meal. There were no differences in dry matter intake, plasma glucose and non-esterified fatty acids, and milk composition between does fed DDGS compared with those fed corn and soybean meal concentrates, but plasma urea nitrogen increased for goats fed the DDGS diet. These authors concluded that DDGS can replace corn and

Table 2. Growth performance and carcass characteristics of Kiko × Spanish male goat kids fed increasing amounts of DDGS (adapted from Gurung et al., 2009)

	0% DDGS	10.3% DDGS	20.6% DDGS	31.0% DDGS
Initial body weight, kg	28	30	28	30
Final body weight, kg	39	40	36	38
ADG, g	141	134	115	117
Total dry matter intake, g/day	1,017	1,138	1,106	1,003
Concentrate intake, g/day	519	591	575	520
Hay intake, g/day	499	547	531	483
Gain:Feed	0.12	0.12	0.11	0.12
Carcass dressing percentage %	44.6	45.1	44.7	42.2
Rib eye area, cm^2	9.75	10.25	9.50	9.00
Body wall fat, cm	0.94	1.09	0.91	0.97

soybean meal at 59 percent of the diets during a short (14 day) feedings period with no adverse effects on dry matter intake and milk composition during late lactation.

Conclusions

DDGS can be an excellent protein and energy supplement for ewes, rams, and growing-finishing lambs to replace a portion of the corn and soybean meal in the diet. The higher fiber content of DDGS compared to corn and soybean meal may be effective in preventing acidosis in growing-finishing lambs fed high grain diets. Sulfur content should be monitored and managed, especially when feeding high levels of DDGS with moderate to high sulfur levels to avoid polioencephalomalacia. However, several studies have suggested that relatively high sulfur diets can be fed without causing PEM, and thiamine supplmentation may not be necessary. Results from a few studies suggest that differences in performance may be using inaccurate nutritional information of the specific DDGS source being fed when formulating. Conservatively, adding DDGS at a level of 20 percent of growing-finishing lamb diets and 25 percent of lactating ewe diets will provide good performance results, although several studies have shown that DDGS diet inclusion rates of up to 60 percent can provide acceptable growth performance. Limited studies on feeding DDGS diets to meat goats suggest that up to 31 percent DDGS can be added to meat goat diets without affecting dry matter intake, growth rate, feed conversion and carcass quality, and DDGS can replace corn and soybean meal at 59 percent of the diets during a short (14 day) feedings period with no adverse effects on dry matter intake and milk composition during late lactation for lactating dairy goats.

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