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Nutrient Utilization in Polypay and Percentage White Dorper Lambs Fed a High-Roughage and a High-Concentrate Diet

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Summary

Nutrient utilization was compared in Polypay (PP), 1/2 White Dorper 1/2 Polypay (1/2 D), and 3/4 White Dorper 1/4 Polypay (3/4 D) lambs. Six lambs (35 kg; 5 months) of each genetic type were fed a high-roughage diet (HR) of 60-percent ground-grass hay and 40-percent concentrate in Phase 1 (14-day diet and digestion crate adjustment and 7-day fecal and urine collection). Lambs were offered a daily ration (2-percent BW) in equal amounts two times daily. Fecal aliquots (10 percent) were collected daily, dried, and composited by lamb. Composites were analyzed for dry matter (DM), nitrogen (N), neutral-detergent fiber (NDF), and acid-detergent fiber (ADF). Aliquots (1 percent) of daily-urine outputs were composited by lamb and analyzed for N. Digestibilities of DM, N, NDF, and ADF were similar across genetic types. Nitrogen-retention values (percent of N intake) were 9, 13, and 11 for PP, 1/2 D, and 3/4 D lambs, respectively. Percent of digested N retained was 12, 19, and 16 for PP, 1/2 D, and 3/4 D, respectively. Upon completion of Phase 1, lambs were adjusted to a 90-percent concentrate and 10-percent ground-grass hay diet (HC) in Phase 2. Aliquots of feces and urine were collected and analyzed as described for Phase 1. Digestibility of HC diet DM was higher in 1/2 D ($P = 0.03$) and 3/4 D ($P = 0.09$) lambs than in PP. Digestibility of N, NDF, and ADF was not affected by genetic type. Although N retention values were numerically highest in 1/2 D lambs, differences were not statistically significant. Overall utilization of the high-quality diets fed in this study tended to be highest in the 1/2 D lambs.

INTRODUCTION

Although there are more than 200 breeds of sheep in the world, not one is the most productive in every production environment. Even though Givens and Moss (1994) concluded that breed of sheep had a greater effect on nutrient utilization than either age or weight, there is still limited information on the effects of genetic makeup on digestibility and nutrient utilization in ruminants. Variable-digestive efficiencies and nitrogen-metabolism capacities have been noted for different species of cattle (Hungate et al., 1960; Howes et al., 1963; Hunter and Siebert, 1985) and different breeds of goats (Hart et al., 1993; Sahlu et al., 1993; Silanikove et al., 1993). If it is genetic makeup that causes animals to perform differently in the same environment, then these differences may be a result of variation in digestive-tract anatomy (Ragland, 1990), rumen-microbial population (Ranilla, 1997), or digesta-passage rates (Huston et al., 1986); all of which affect diet digestibility. The objective of this study was to determine the effect of three genetic types on nutrient utilization of two divergent diets fed to lambs.

MATERIALS AND METHODS

Animals and Diets

Research protocols were approved by the University of Kentucky Institutional Animal Care and Use Committee. A two-phase nutrient digestion/N retention trial (Fig. 1) was conducted with six wether lambs of each genetic type: Polypay (PP), 1/2 White Dorper 1/2 Polypay (1/2 D), and 3/4 White Dorper 1/4 Polypay (3/4 D). All lambs were born in the University of Kentucky sheep flock. Lambs averaged 35 kg (32 kg to 37 kg) and were 5 months of age at the start of the study. Animals were housed in individual pens for diet adjustment and digestion crates for collection of feces and urine. Lambs had ad libitum access to fresh water at all times.

Diets were high roughage (HR; Phase 1) and high concentrate (HC; Phase 2). The HR diet consisted of 60-percent ground-grass hay and 40-percent concentrate. The HC diet contained 90-percent concentrate and 10-percent ground-grass hay. Both diets were balanced to meet nutrient requirements (NRC, 1985) and were fed at 2-percent BW daily (as-fed), based on individual lamb weights at the start of each phase. Each lamb received equal amounts of its daily dietary allotment twice daily at 0800 hours and 1600 hours. Diet samples were taken at each feeding during the 7-day fecal- and urine-collection periods and composited to represent an average ingredient and chemical composition (Table 1).

Phase 1: Digestibility and Nitrogen Metabolism of a High-Roughage Diet

To begin the study, 18 wether lambs were removed from a flock that was consuming pasture plus a 90:10 concentrate:roughage supplement (1-percent BW daily). Lambs were assigned to individual pens, the HR diet (Table 1) replaced the 90:10 supplement, and was gradually increased to 2-percent BW during the 7-day diet-adjustment period (Figure 1). Lambs were then moved into individual digestion crates and allowed 7 days to adjust to the crates. During this time, lambs continued to receive the HR diet at 2-percent BW daily in equal amounts at 0800 hours and 1600 hours. Crates were modified to fit each lamb so feces and urine could be collected in separate buckets. In addition, a 10-cm^2 plastic screen with 2-mm openings was placed in each urine funnel to prevent fecal, wool, and/or hair contamination. Total feces were collected and weighed for each lamb at 1600 hours for 7 consecutive days (d 15 through d 21). A 10-percent aliquot (by weight) was taken from each day's collection, dried at 50° C in a forced-air oven for 24 hours, air-equilibrated, and composited for each lamb to provide a representative sample of the 7-day fecal output.

Urine was also collected daily for 7 days (d 15 through d 21; Figure 1). All urine collection buckets were acidified with 10 ml of 50-percent hydrochloric acid prior to the start of collection and after each daily collection. Total urine was weighed daily at 1600 hours. Urine output of each lamb was stirred to ensure homogeneity and a 1-percent aliquot (by weight) was taken daily, composited by lamb, and frozen until analyzed for N content.

Phase 2: Digestibility and Nitrogen Metabolism of a High-Concentrate Diet

All lambs returned to individual pens upon completion of Phase 1. The HR diet was gradually replaced with the

Figure 1. Timeline of events in a two-phase nutrient digestion/nitrogen retention trial with lambs fed a high-roughage (HR) and a high-concentrate (HC) diet.

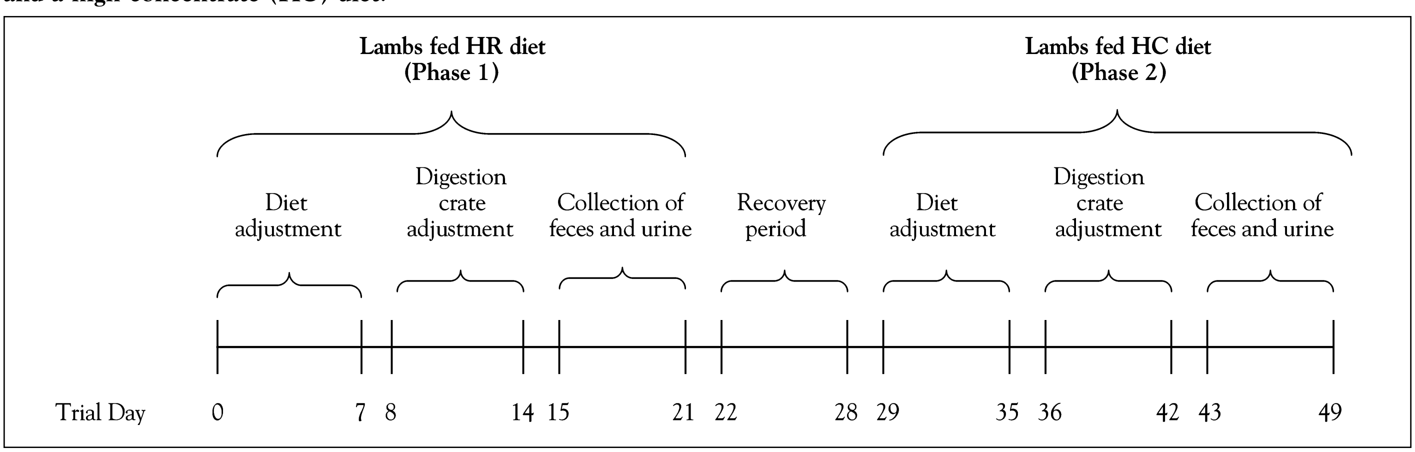

Table 1. Chemical composition of high-roughage (HR) and high-concentrate (HC) diets fed to lambs.

	Diet	
	HR	HC
Dry Matter (DM), %	93.5	92.2
	% of DM	
Organic Matter (OM)	92.4	94.5
Crude Protein (CP)	16.5	17.0
Neutral-Detergent Fiber (NDF)	52.4	22.7
Acid-Detergent Fiber (ADF)	23.5	5.1
Acid-Detergent Lignin (ADL)	2.8	0.3

HC diet over a 7-day adjustment period, as daily intake was maintained at 2-percent BW. Lambs were returned to their original digestion crate on day 36 and continued to consume the HC diet at 2-percent BW daily in equal amounts at 0800 hours and 1600 hours for 7 days. Feces and urine were collected daily at 1600 hours for 7 days (d 43 through d 49; Figure 1). Sampling procedures were the same as described for Phase 1.

Laboratory Analyses

All diet and fecal samples were ground in a Wiley mill to pass through a 1-mm screen and stored in sealed plastic bags at room temperature until chemically analyzed. Dry matter and ash contents were determined by AOAC (1999) procedures. Organic matter (OM) was calculated as 100 minus ash content. Neutral-detergent fiber (NDF) (Robertson and Van Soest, 1981) and acid-detergent fiber (ADF) (Goering and Van Soest, 1970) analyses followed the procedures modified for use in an Ankom 200 Fiber Analyzer (Ankom Co., Fairport, N.Y.). Heat-stable alpha-amylase was added for the neutral-detergent fiber analyses of all feed and fecal samples to degrade starch, which could inhibit filtration. Feed, feces, and urine samples were analyzed for N using the automated Kjeldahl method described in AOAC (1999).

Experimental Design and Statistical Analysis

Each phase was conducted as a generalized, randomized, complete-block design with a one-way treatment structure (genetic type). Three, environmentally controlled rooms were used to house lambs while in digestion crates. Two lambs of each genetic type were randomly assigned to each room. Rooms (3) constituted experimental blocks.

The statistical model included the effects of room and diet, which were considered fixed effects. Differences among genetic types were compared using the PDIFF option (all possible t-tests) of PROC GLM of SAS (Windows version 5.1.2600, SAS Inst., Inc., Cary, N.C.). Initial age and weight were included in preliminary analyses, but were found to be nonsignificant and were omitted from the final model. Significant differences were determined at 0.1, 0.05, and 0.01 levels of probability.

RESULTS AND DISCUSSION

Phase 1: Digestibility and Nitrogen Metabolism of a High-Roughage Diet

Genetic type did not alter digestibility of the HR diet DM, NDF, or ADF (Table 2). Other studies (Givens and Moss, 1994; Ranilla et al., 1997; Lopez et al., 2001) have reported similar digestibility percentages when lambs consumed diets of similar ingredient and chemical composition. These results agree with Ragland's (1990) conclusion that there is no breed advantage associated with fiber digestibility in lambs.

All lambs consumed a constant amount of daily N at approximately 17 g (Table 3). Daily fecal-excretion rates (5.5 g to 5.8 g) were similar for PP, 1/2 D, and 3/4 D lambs, as were N digestibilities (66.3 percent, 67.4 percent, and 67.8 percent for PP, 1/2 D, and 3/4 D, respectively). Daily urinary N excretion rates ranged from 9.3, (1/2 D) to 10.2 g (PP). Therefore, the 1/2 D lambs retained numerically more N (2.3 g/d), while PP lambs retained the least (1.3 g/d). Expression of N retention, either as a percentage of daily nitrogen intake (DNI) or nitrogen digested (ND), revealed numerically highest values for the 1/2 D lambs. A combination of limited number of lambs per genetic type (n=6) and the inherent variation associated with N retention measures (Glenn et al., 1977) could have prevented these differences from being statistically significant.

Phase 2: Digestibility and Nitrogen Metabolism of a High-Concentrate Diet

Digestibility of the HC diet DM (Table 4) was higher (*$P < 0.1$*) in 1/2 D lambs than PP and 3/4 D lambs, contradicting the conclusions of Notter et al. (1984) that DM digestibility did not differ due to genetic type of sheep. However, NDF and ADF digestion remained unaffected by genetic type, which agrees with other studies with lambs consuming a diet of similar chemical composition (Swanson et al., 2004; Atkinson et al., 2006; Haddad and Obeidat, 2006).

As in Phase 1, daily N consumption was approximately 17 g (Table 5). The amount of N excreted in the feces was similar among genetic types and was comparable to fecal N excretion by lambs consuming a similar diet (Swan-

Table 2. Dry matter, neutral-detergent fiber, and acid-detergent fiber digestibility (%) of a high-roughage diet consumed by Polypay (PP), 1/2 White Dorper 1/2 Polypay (1/2 D), and 3/4 White Dorper 1/4 Polypay (3/4 D) lambs.

	Genetic type			
Item	PP	1/2 D	3/4 D	SEM
DM	67.9	68.9	69.3	1.6
NDF	69.6	70.4	70.6	2.1
ADF	63.8	65.8	64.8	2.1

Table 3. Daily nitrogen utilization by Polypay (PP), 1/2 White Dorper 1/2 Polypay (1/2 D), and 3/4 White Dorper 1/4 Polypay (3/4 D) lambs fed a high-roughage diet.

	Genetic type			
Item[1]	PP	1/2 D	3/4 D	SEM
DNI, g	17.2	17.2	17.1	
DFN, g	5.8	5.6	5.5	0.5
ND, %	66.3	67.4	67.8	2.3
DUN, g	10.2	9.3	9.6	3.1
DNR, g	1.3	2.3	2.0	3.3
DNR, % of DNI	7.6	13.4	11.7	19.1
DNR, % of ND	11.4	19.8	17.2	27.5

[1] DNI=Daily nitrogen intake, DFN=Daily fecal nitrogen, ND=Nitrogen digestibility, DUN=Daily urinary nitrogen, DNR=Daily nitrogen retained.

Table 4. Dry matter, neutral-detergent fiber, and acid-detergent fiber digestibility (%) of a high-concentrate diet consumed by Polypay (PP), 1/2 White Dorper 1/2 Polypay (1/2 D), and 3/4 White Dorper 1/4 Polypay (3/4 D) lambs.

	Genetic type			
Item	PP	1/2 D	3/4 D	SEM
DM	83.1[a]	84.8[b]	83.6[a]	1.2
NDF	72.8	76.5	72.4	5.0
ADF	50.2	57.2	46.9	11.3

[1] Means within a row with different superscripts differ ($P < 0.1$).

Table 5. Daily nitrogen utilization by Polypay (PP), 1/2 White Dorper 1/2 Polypay (1/2 D), and 3/4 White Dorper 1/4 Polypay (3/4 D) lambs fed a high-concentrate diet.

	Genetic type			
Item[2]	PP	1/2 D	3/4 D	SEM
DNI, g	17.1	17.4	17.4	
DFN, g	3.9	3.5	3.8	0.3
ND, %	77.2[a]	79.9[b]	78.2[a, b]	1.8
DUN, g	7.2	6.8	7.8	3.6
DNR, g	6.0	7.1	5.8	3.7
DNR, % of DNI	35.1	40.8	33.3	20.8
DNR, % of ND	45.5	51.1	42.6	26.5

[1] Means within a row with different superscripts differ ($P < 0.05$).
[2] DNI=Daily nitrogen intake, DFN=Daily fecal nitrogen, ND=Nitrogen digestibility, DUN=Daily urinary nitrogen, DNR=Daily nitrogen retained.

son et al., 2004). Digestibility of N provided in the HC diet was higher ($P < 0.05$) in the 1/2 D lambs than the PP, yet similar to the 3/4 D lambs. These differences imply that 1/2 D lambs may be more efficient in retaining dietary N. This is substantiated by the numerically lower urinary N excretion values (g/d) and larger amounts of N retained (g/d) in the 1/2 D lambs compared with the PP and 3/4 D lambs. Nitrogen-retention values for lambs consuming the HC diet, as a percentage of DNI, ranged from 33.3 percent (3/4 D) to 40.8 percent (1/2 D) and, as a percentage of ND, from 42.6 percent (3/4 D) to 51.1 percent (1/2 D). Although numerical differences were apparent for N-retention variables, the only statistically significant differences were found for ND. Experimental variability may have prevented finding more significant differences in both phases of this experiment.

Comparison of Phases 1 and 2

Statistical comparisons of Phases 1 and 2 were not possible because they were conducted consecutively with the same lambs rather than simultaneously with different lambs. Potter and Dehority (1973) found only 5 days were required to stabilize digestion coefficients, when lambs were abruptly switched from a 100-percent orchard-grass-hay diet to one containing 40-percent cracked corn and 60-percent hay. If so, the 7-day adjustment period before Phase 1 and between Phases 1 and 2 should have been adequate to provide confidence in the digestion coefficients calculated from both phases. Overall, DM digestibilities were greater with the HC than with the HR diet (80^+ percent vs. 60^+ percent; Tables 2 and 4). In fact, all digestibility values were higher when the HC diet was fed because it contained lower levels of NDF, ADF, and ADL (Table 1). When comparing the NDF and ADF digestibilities in Table 2 with those of the HC diet in Table 4, larger numerical differences were found among genetic types when the HC diet was fed. A relatively large numerical difference that does not show statistical significance is probably a result of the smaller amounts of NDF and ADF provided in the HC diet (Table 1). Small variations in laboratory analyses could have magnified digestibility differences with the HC diet.

Similar to Phase 1 (HR), lambs fed the HC diet in Phase 2 consumed approximately 17 g of N/d (Table 5). However, HC lambs excreted only 66 percent as much fecal N, resulting in higher N digestion coefficients (70^+ percent vs. 60^+ percent). Overall, daily urinary N loss was less when lambs consumed the HC diet (Table 5) than when the HR diet (Table 3) was consumed. Consequently, N retention values (g/d, percent of intake, and percent of digested) were greater when the HC diet was consumed. Although genetic type differences for N retention were statistically nonsignificant in both phases, from a practical standpoint, 1/2 D lambs may be able to utilize dietary N from a HC diet more efficiently than PP or 3/4 D lambs.

More differences may have been found in this study if lambs had possessed larger genetic variation or differences in production type had been greater. Hart et al. (1993) found differences in digestive capacities, digesta-passage rates, and ruminal-fermentation rates using breeds of goats that were different production types (fiber, dairy, and dual purpose). Both the PP and White Dorper breeds can be traced back to the Dorset breed of sheep (Polled Dorset in the PP and British Dorset Horn in the White Dorper; SID, 2002). Therefore, the genetics from each parent breed used in this study cannot be considered unique. Furthermore, the model for this study was intended to represent the physiological state and nutritional status of growing lambs in a production setting, rather than "maintenance models" that have been able to show larger differences in digestibility among and between breeds (Howes et al., 1963; Hunter and Siebert, 1985; Ragland, 1990). Additionally, Hart et al. (1993), Sahlu et al. (1993), and Silanikove et al. (1993) reported differences in digestive efficiency and nutrient utilization among breeds of goats, but only when low digestibility diets were fed. Even though digestibility of the HR diet was lower than the HC for all components across genetic types, both diets in the present study were considered high quality. The HR diet contained 16.5 percent CP and highly digestible hay (vegetative stage). The HC diet contained 17.0 percent CP, but lower amounts of fiber. Both of these CP levels exceed the requirements for growing wether lambs (NRC, 1985), so the small differences noted among genetic types could have been, in part, due to the high quality of both diets. Evidence in support of this conclusion can be found in the genetic-type differences reported by Hunter and Siebert (1985), Huston et al. (1986), Givens and Moss (1994), Ranilla et al. (1997), and Ranilla et al. (1998). However, from a practical standpoint, growing lambs are typically fed high-quality diets. Differences in nutrient digestibility in the rumen, and through the entire gastrointestinal tract, of lambs of different genetic makeups, may be so subtle that they are not detected by gross measures, such as digestion coefficients.

CONCLUSION

When the HR diet was consumed, the 1/2 D lambs had a tendency to retain a larger portion of dietary N than either PP or 3/4 D, with the PP lambs retaining the least amount. When the HC diet was consumed, the 1/2 D lambs had significantly higher digestibility values for DM and N leading to larger numerical differences in N retention. Based on efficiency of N utilization, 3/4 D lambs may be able to use HR diets more efficiently than PP, but the reverse may be true when HC diets are consumed.

Theoretically, the improved DM and N digestibility of the 1/2 D compared with the PP and 3/4 D lambs could translate into increased weight gain. Furthermore, it can be concluded that genetic type does influence utilization of dietary nutrients in sheep. The magnitude of this effect is dependent on the quality of the diet fed and the variation in genetic type.

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PRNP Genotype and Sale Price

Associations of prion protein genotype with sale price in a flock of purebred Polled Dorsets[1]

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Summary

The objectives of this study were to determine prion protein (PRNP) genotype frequencies in a flock of Polled Dorsets and to estimate the association of PRNP genotype with the value placed on PRNP genotype by buyers of elite breeding stock. The association between selling price and genotype was determined for 161 sheep. Sale price and 90-d BW were analyzed with a mixed model that included PRNP genotype, year-season of birth, and litter size (90-d BW only) as fixed effects; animal, litter, and error as random effects; and 90-d BW as a covariate (sale price only). The frequencies of R/R (homozygous scrapie resistant), Q/R, and Q/Q (homozygous scrapie susceptible) genotypes were 25 percent, 49 percent, and 26 percent, respectively. The effect of genotype on sale price was highly significant, and buyers of elite breeding stock paid $799 more for R/R individuals than Q/Q individuals. The allele substitution effect for the R allele was $397. Sale prices for Q/Q sheep were significantly associated with 90-d BW and increased approximately $34 for a one kg increase in BW. The effect was not as strong ($22 per kg) and not significant for R/R sheep. Buyers of elite breeding stock are placing a strong emphasis on PRNP genotype relative to performance characteristics, indicating that sheep breeders are engaged in national scrapie-eradication efforts.

Key Words: Dorset, Genotype, Prion Protein, Scrapie

INTRODUCTION

Parry (1979) demonstrated that susceptibility to scrapie could be reduced by genetic selection. Scrapie susceptibility has been linked to polymorphisms in the prion protein (PRNP) gene (Bossers et al., 1996). Variation at codon 171 of the PRNP gene is the major determinant of scrapie susceptibility and the polymorphism resulting in arginine (R) confers scrapie resistance (NIAA, 2004).

Producers might be hesitant to select intensely for scrapie resistance if an unfavorable relationship between performance and PRNP genotype was evident. Several studies have investigated the relationship between PRNP genotype and lamb growth (Brandsma et al., 2004; Alexander et al., 2005; Vitezica et al., 2006), reproduction (Alexander et al., 2005; Vitezica et al., 2006; Casellas et al., 2007), carcass, and other traits (Isler et al., 2006; Sawalha et al., 2007). Most have found minimal evidence that selection to increase the frequency of R will directly compromise important performance traits, but there are exceptions related to litter size (Alexander et al. 2005; Casellas et al., 2007).

There is minimal evidence that selection for PRNP genotype will compromise sheep performance, but it is not clear how much emphasis producers are placing on scrapie resistance in sheep-selection programs. The percentage of scrapie-infected sheep detected by the Regulatory Scrapie Slaughter Surveillance has been steadily declining (APHIS, 2007) and selection for scrapie resistance is likely one factor contributing to that trend. The frequency of R/R was higher in lambs than in ewes in four out of five breeds evaluated (Alexander et al., 2005), and the frequency of the R allele in a French composite breed increased from 2001 to 2003 (Vitezica et al., 2006). However, the frequency of the scrapie-resistant haplotype (ARR) did not increase from 1999 to 2004 in a population of Scottish Blackface (Sawalha et al., 2007). The effect of PRNP genotype on the habits of breeding-stock purchasers would indicate how much emphasis is placed on scrapie resistance, but has not been described.

The objectives of this study were to determine PRNP-genotype frequency in an elite flock of Polled Dorsets and to estimate the association of PRNP genotype with the value placed on PRNP genotype by buyers of elite breeding stock.

MATERIALS AND METHODS

Sheep

All procedures were conducted under approval of the Institutional Animal Care and Use Committee at The Pennsylvania State University (IACUC #22956). A single blood sample was collected by jugular venipuncture into EDTA-coated Vacutainer tubes. Samples were submitted for genotyping to an APHIS-approved commercial laboratory (GeneCheck, Inc., Fort Collins, Colo.). Only genotype at codon 171 was considered, and no distinction was made between the Q, K and H alleles, which are collectively referred to as Q in the present study.

A total of 363 purebred Polled Dorsets from The Pennsylvania State University were genotyped, and 189 were sold in a Penn State production sale. Genotyped sheep sold for an average of $1,280, whereas 39 non-genotyped sheep sold for an average of $1,034. The distribution of sale price was skewed (Figure 1), so the natural log was used to transform sale price into a normally distributed variable. Body weights recorded between 75 d and 105 d were standardized to 90-d BW by FlockMaster for Windows (ABM Computer Systems, Springfield, Mo.). Data from 28 genotyped sheep that did not have 90-d BW were removed, leaving data from 161 sheep for analysis (144 ewes and 17 rams). Twenty-two rams sired the 161 sheep, with the number of offspring ranging from one to 41 per ram. The pedigree file included 419 animals.

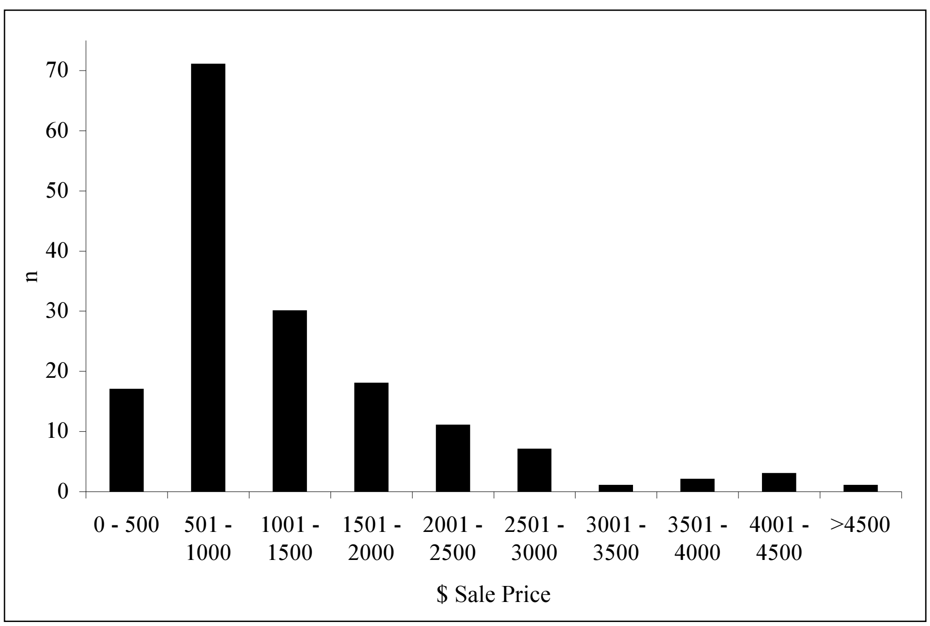
Statistical Analysis

The following animal model was used to analyze sale price in ASREML (Gilmour et al., 2006):

$$y_{ijkm} = YS_i + b_1{*}BW_{90} + G_j + a_k + l_m + e_{ijkm},$$

where y = the natural log of sale price; YS = fixed effect of year-season of birth i with three birth year groups (≤2003, 2004, and 2005) and two seasons corresponding to spring and fall; b_1 = a regression coefficient for 90-d BW; G = fixed effect of genotype j; a = the random effect of animal k; l = the random effect of litter m; and e = random error. Additionally, 90-d BW was nested within genotype to test for interactions of genotype with BW ($P = 0.009$). Sex ($P = 0.78$), classes corresponding to birth and rearing litter size ($P = 0.098$), and an interaction between genotype and year ($P = 0.56$) were not significant. An analysis of 90-d BW was also conducted to determine the association between 90-d BW and genotype. The model was the same as for sale price,

Figure 1. Distribution of sale price for 161 Polled Dorsets.



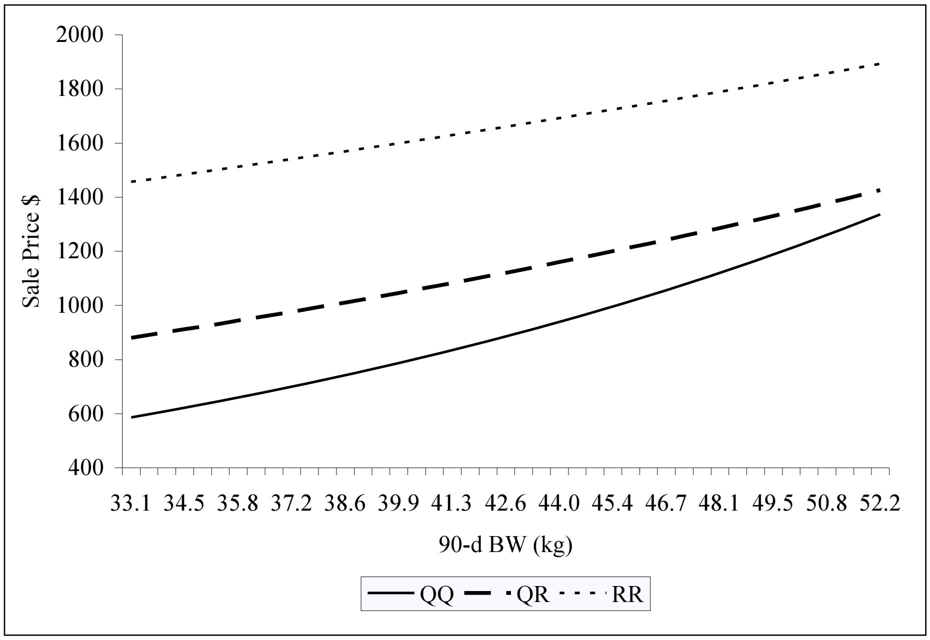
except that 90-d BW was removed as a covariate and the fixed effect for birth and rearing litter size was significant (*P < 0.001*) and included in the model.

The effect of genotype was quantified by generating predicted sale-price means, which are equivalent to least-squares means in ASREML, for genotype and by calculating the substitution effect of the R allele. The R allele substitution effect was:

$$a + (q-p)d,$$

where a = the deviation of the R/R genotype from the homozygote mean; d = the deviation of the Q/R from the homozygote mean; q = the frequency of the R allele; and p = the frequency of the Q allele (Falconer and Mackay, 1996). Sale-price-predicted means from the minimum 90-d BW that was observed in the range of all genotypes (33.1 kg) to the maximum observed in the range of all genotypes (52.2 kg) were plotted to demonstrate the interaction of genotype and 90-d BW.

Figure 2. Trend in sale price for genotype by 90 day body weight (90-d BW).



RESULTS AND DISCUSSION

PRNP Genotype Frequency

Genotype frequencies, predicted-sale-price means, and predicted 90-d BW for PRNP genotype are reported in Table 1. The frequency of the R allele was 49 percent. Selection for PRNP genotype was not practiced prior to sampling and, subsequently, the genotype frequencies appeared to be in Hardy-Weinberg equilibrium. The frequency of the Q allele has been reported to be greater than 50 percent in many populations, which indicates that a large proportion of U.S. and worldwide sheep populations are at risk of contracting scrapie if exposed to scrapie-infected animals. Alexander et al. (2005) reported Q allele frequencies ranging from 45 percent to 74 percent for Columbia, Suffolk, Rambouillet, Hampshire and Targee rams. Reported frequencies of ARR haplotypes in various populations were also less than 50 percent in several studies (Isler et al., 2006; Vitezica et al., 2006; Casellas et al., 2007; Sawalha et al., 2007). Predicted means for 90-d BW were highest for the R/R genotype (41.88 kg), which was not significantly different from predicted means for Q/Q (*P = 0.13*) or Q/R (*P = 0.11*). This supports observations from several studies (Brandsma et al., 2004; Alexander et al., 2005; Vitezica et al., 2006) that selection for R/R genotypes will not compromise growth performance.

Association of PRNP Genotype and Sale Price

Genotype at the PRNP locus had a highly significant effect (*P<0.001*) on sale price (Table 1). Predicted means for R/R and Q/R were $799 (*P<0.001*) and $267 (P = 0.002) higher, respectively, than predicted means for Q/Q. The top-selling individual ($7,500) was heterozygous. The top-selling Q/Q individual ($2,750) was the tenth-highest price of those with genotype information available, indicating that qualities other than PRNP genotype were still valued by purchasers. The random-animal effect was responsible for 22 percent ± 23 of the total variance in sale price, whereas litter effects accounted for 34 percent ± 18 of the total variance. Estimates for additive and dominance effects based on the numbers in Table 1 are $400 and -$133, respectively. The corresponding allele-substitution effect for the R allele was $397.

Table 1. Genotype frequencies and predicted means for sale price and 90 day body weight (90-d BW).

Genotype	Frequency (%)	Sale Price[1] ($)	90-d BW (kg)
Q/Q	26	770 ± 76	40.29 ± 1.14
Q/R	49	1,037 ± 90	40.29 ± 0.98
R/R	25	1,569 ± 159	41.88 ± 1.15

[1] Predicted means different (*P < 0.01*)

BW and genotype interactions

The effect of 90-d BW on sale price predicted means are demonstrated in Figure 2. The regression on BW was significant when genotype was Q/Q (*P = 0.008*), or Q/R (*P = 0.028*), but not when genotype was R/R (*P = 0.41*). Predicted-sale-price means for PRNP genotype at 90-d BW of 33.7 kg and 46.2 kg are reported in Table 2. Predicted sale price was $431 more for Q/Q sheep with a 90-d BW of 46.2 kg versus a 90-d BW of 33.7 kg. The predicted means for R/R sheep when 90-d BW was in the 10th percentile (33.7 kg) was $436 more than predicted means for Q/Q sheep with 90-d BW in the 90th percentile (46.2 kg),

Table 2. Predicted sale price means when 90 day body weight is 33.7 kg and 46.2 kg.

Genotype	33.7 kg	46.2 kg
Q/Q	$600 ± 81^{a,x}	$1,031 ± 153^{a,y}
Q/R	$892 ± 97^{b,x}	$1,224 ± 143^{a,y}
R/R	$1,467 ± 235^{c}	$1,743 ± 229^{b}

^{a,b,c} Column values with different superscripts are significantly different (P < 0.05).
^{x,y} Row values with different superscripts are significantly different (*P < 0.05*)

which approached significance (*P = 0.09*). It appeared that buyers were willing to pay a premium for R/R sheep and that the sheep's performance had a relatively small impact on sale price when genotype was R/R. However, performance had a large impact on sale price for Q/Q sheep.

Implications

The results of this and other studies indicate that the scrapie-susceptibility allele is still at a high frequency, but that producers are selecting for scrapie resistance. Buyers of elite, purebred Polled Dorset stock were willing to invest in reducing scrapie susceptibility, as evidenced by sale prices for R/R sheep that were more than double those for Q/Q sheep, and a substitution effect for the R allele of $397.

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The Yellowing Propensity of Rambouillet Wool

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Summary

The yellowing propensity of Rambouillet wool was evaluated. One hundred greasy side samples of Rambouillet ewes were collected in the spring of 2007, and 142 greasy side samples were collected from Rambouillet rams during the October 2006 Ram test. The propensity to develop yellow discoloration was determined on each of the greasy wool samples. After scouring, average-fiber diameters were obtained. Absorbance measurements of supernatant liquids clearly indicated there was a wide range in yellowing propensity for both the rams and the ewes. This would imply that is would be possible to include yellowing propensity in a selection program, allowing producers to discriminate against those animals with a propensity to develop yellow discoloration. There was no significant difference between the yellowing propensity of the ram or ewe wool and fiber diameter.

Key Words: Wool, Yellowing Propensity, Rambouillet

Introduction

The U.S. sheep industry has experienced a decline in numbers for the past 60 years. Income from sheep is based almost entirely on wool and market lambs. Income derived from wool sales is subject to worldwide price structuring. Currently, approximately 70 percent of the U.S. wool clip is exported due to the lack of domestic-processing capability. This requires competition with countries that for decades have used wool color as a selection criterion in the production of wools for export. For example, Australian Wool Exchange Identification (AWEX-ID) (Padula, 2006) is a system for the appraisal and description of non-measured characteristics of greasy wool (of which color is a component). AWEX market reports analyze and present price information using these measured and appraised wool characteristics. AWEX-ID benefits the wool industry, by providing a better understanding of the relationship between wool characteristics and their effect on price.

Wool color is an important characteristic that influences value. As far as color is concerned, superior wool is generally a creamy white color (Botkin, et al., 1988). The discoloration of the wool may for example, limit the dyeing potential of that wool. Clean-color specification is becoming increasingly more important for wool marketing (Australian Wool Corporation, 1987). The color of greasy wool is determined not only by the inherent color of the wool, but also by the grease, suint, dirt, and vegetable matter the wool contains. The susceptibility of a fleece to yellowing is related to the amount and properties of the suint and yolk contained within the fleece (Aitken, et al., 1994).

Thornberry et al. (1980) suggested there was a relationship between fleece rot and wool wax and suint concentrations. Wilkinson (1982) was unable to identify a role in fleece discoloration of wool wax or suint. More recently, Winder et al. (1998) have found that the removal of both wool wax and suint by either detergent scouring or solvent/aqueous extraction resulted in less discoloration of wool. When evaluating the effects of wool wax and suint individually, Winder et al. (1998) found that removal of the wool wax by solvent extraction actually increased slightly the propensity of wool to yellow, which suggests that wool wax may in fact have a protective role with respect to yellowing. They also found that when suint alone was removed by a water wash, that otherwise resistant wool actually had increased yellowing. This suggests that it is the suint, not the wool wax which is responsible for the yellow discoloration of wool and that the genetic basis of the susceptibility of wool to yellowing is due to the variability in the suint from the sweat glands. Aitken et al. (1994) found a positive relationship between the potassium concentration in suint and yellowing propensity.

Temperature and humidity are also important factors in the yellowing of wool under laboratory conditions (Winder, et al., 1998). Thus, because of the influence of environmental conditions, the color of wool may vary depending on the location that it was grown and the season it was shorn (Reid, 1993). Maximum yellowness occurs when wool that is susceptible to yellowing is exposed to high temperatures and humidity – an environmental challenge (Reid, 1993). Therefore in most areas, sheep shorn in late summer and fall typically have greater yellowing than those shorn in the spring or winter. Two tests have been developed to predict the susceptibility of wool to yellowing, one an indirect method (Yellow Predictive Test) (Aiken et al., 1994) and the other a direct method (Yellow Challenge Test) (Aliagra et al., 1996). It has been suggested (Reid, 1993; Wilkinson and Aitken, 1985) that fleece yellowing at shearing might be reduced if the selection of flock replacements are made using the basis of the propensity of the wool to yellow discoloration as a choice criteria. Any reduction in the yellowness at shearing would potentially improve the acceptability of the wool to processors and thus increase the price received by the wool producer (Reid, et al., 1996). For selection and breeding strategies to be successful, the characteristic selected must be heritable and have repeatable phenotypic variation (Reid, et al., 1996). The predictive test has been used in New Zealand for several years as a commercial test for woolgrowers to select sheep for reduced propensity to develop yellow discoloration (Reid, 1993).

The purpose of this study was to collect preliminary data on the propensity to develop yellow discoloration in wool of Rambouillet sheep.

Materials and Methods

Fiber Samples

One hundred greasy side samples of Rambouillet ewes were collected in the spring of 2007 from the University of Wyoming Rambouillet flock. In addition, one hundred and forty-two greasy side samples were collected from Rambouillet rams during the October 2006 Ram test. The side samples represented wool from 22 different producers located in four different states. Average-fiber diameters were determined for each wool sample.

Determination of Fiber Diameter

The Sirolan-Laserscan (AWTA, Sydney; ASTM D6466-99, 2003) was used to measure the fiber diameter of the wool samples. A sub-sample of each wool sample was mini-cored to obtain small (2 mm) fiber snippets that were utilized to determine average-fiber diameter, standard deviation, and coefficient of variation of the sample.

Determination of Yellowing Propensity

The indirect method–the yellow predictive test (YPT) involves incubating wool samples for five days under high humidity. Supernatant is then extracted, and the color of the liquid can be used as an indicator for the yellow discoloration of the wool. Propensity to yellow utilizing the yellow predictive test was determined according to Aitken et al. (1994) except that one-gram samples of fiber were used. Samples were placed in individual 10cm diameter petri dishes and incubated for five days at 98-percent to 99-percent humidity. Increasing absorbance of the supernatant liquid is an indication of increasing susceptibility to yellowness. Quadruplicate samples of wool were tested.

Statistical Analyses

Statistical analyses were conducted in accordance with procedures outlined by SPSS (SPSS, 2006). Frequencies, descriptive statistics, and T-tests were used to determine differences in yellowing propensity of grease wool.

Results and Discussion

Table 1 shows the mean results for quartiles of yellowing propensity of ram wool and average fiber diameters. The averages of the yellowing propensity for each quartile were 0.143 (range .096 to .171), 0.186 (range .171 to .202), 0.237 (range .206 to .283) and 0.330 (range .286 to .473), respectively. Fiber-diameter averages for each quartile were 24.8, 24.9, 24.9 and 24.7 microns, respectively. The yellowing-propensity color range for all the ram wools was 0.096 to 0.473. The largest yellowing variability occurred in those wools that had the highest yellowing propensity. Each quartile average for yellowing propensity is significantly different from the others, $P < 0.001$. There was no significant difference between the average-fiber diameters of each of the quartiles.

Table 1. Yellow Predictive Test Value Quartiles (Absorbance) and Average Quartile Fiber Diameters of Rambouillet Ram wool.

Quartile	Yellowing Propensity		Average Fiber Diameter (microns)	
	Mean	Std. Dev.	Mean	St. Dev.
1	0.143a	0.019	24.8a	1.7
2	0.186b	0.008	24.9a	1.9
3	0.237c	0.028	24.9a	2.3
4	0.330d	0.044	24.7a	1.7

Means with unlike superscripts differ, *P<.001*

Table 2 shows the mean results for quartiles of yellowing propensity of ewe wool and average-fiber diameters. The averages of the yellowing propensity for each quartile were 0.088 (.051 to .107), 0.128 (range .108 to .147), 0.177 (range .151 to .219) and 0.284 (range .220 to .401), respectively. Fiber-diameter averages for each quartile were 25.1, 24.9, 25.1 and 24.7 microns respectively. The yellowing propensity range for all the ewe wools was 0.051 to 0.401. The largest yellowing variability of the ewe wool also occurred in those wools that had the highest yellowing propensity. Each quartile average for yellowing propensity is significantly different from the others, $P < 0.001$. There was no significant difference between the average fiber diameters of each of the quartiles. The range of the yellowing propensities suggest that it should be possible to select Rambouillet sheep for breeding based on their propensity to develop yellow discoloration. It has been shown that selecting sheep based on their propensity to develop yellowness is possible. Reid et al. (1996) studied wool samples from 28 Merino wethers, 31 Corriedale ewes, 37 Perendale ewes and 30 Coopworth ewes. They found correlations between propensity-to-yellow, Y-Z (yellowness index) and mean-fiber diameter were low in the Corriedale, Perendale and Coopworth samples, but high in the Merinos.

Other studies (Aitken, et al., 1994; Raadsma and Wilkinson, 1990; Wilkinson and Aitken, 1985; James, et al., 1990) have shown that the propensity to develop yellow discoloration is dependent upon the breed of sheep and ranges from low heritability (0.19) to moderate (0.51). For example, James et al. (1990) found the heritability in South Australian merinos of the Collinsville family group to be 0.42. This indicates that measurement of yellowing propensity could be useful as a selection criterion in Rambouillets that are similar genetically to Australian Merinos.

Table 2. Yellow Predictive Test Value Quartiles (Absorbance) and Average Quartile Fiber Diameters of Rambouillet Ewe wool.

Quartile	Yellowing Propensity		Average Fiber Diameter (microns)	
	Mean	Std. Dev.	Mean	St. Dev.
1	0.088[a]	0.014	25.1[a]	2.4
2	0.128[b]	0.014	24.9[a]	2.1
3	0.177[c]	0.021	25.1[a]	2.2
4	0.284[d]	0.049	24.7[a]	1.2

Means with unlike superscripts differ, *P<.001*

Yellow discoloration of wool can be classified as scourable and non-scourable, however, there is no clear distinction between the two (Aitken, et al., 1994). Non-scourable yellow discoloration develops during growth, storage, and processing of wool fiber (Winder, et al., 1998). Genetic and environmental factors have been implicated in the yellow discoloration of wool. Wilkinson (1982) found that animals could be classified according to their genetic predisposition to yellow but that environmental factors, such as warmth, humidity, and dampness, tended to promote yellowness in genetically susceptible sheep. Non-scourable yellowing was also shown to be prevalent in sheep susceptible to fleece rot (Wilkinson, 1981).

It has been shown that yellow fleeces suffer a significant price discount in international markets (Cottle, et al., 1992). During the three wool seasons 1996-97 through 1998-99, New Zealand wools had Y-Z values ranging from -1.6 to 9.5 (higher values indicate greater yellow color). During this three-year period, price reductions of up to $NZ 0.10 were observed per Y-Z unit increase (Cottle, et al., 1992). This translated to an overall price reduction of 16.6 percent for a Y-Z of ≥6 compared to those wools with a Y-Z <6 (Cottle, et al., 1992). Thus, there is the potential for significant economic gain if it can be shown that U.S. wools do not have a propensity to yellow.

Conclusion

Clean color of wool is of major importance to the wool industry. Wool fabric is used primarily in the garment industry in the United States today. Discolored or especially yellow wools cannot, for example, be used in pastel shade apparel. This study has shown that there are differences in the yellowing propensity of the Rambouillet breed and that is could be possible to select sheep based on this data to improve wool. There was no correlation between fiber diameters and the yellowing propensity observed in this study.

Further research should be conducted to investigate the heritability and repeatability of the propensity to yellow discoloration of the Rambouillet. Once this has been established, the impact of selective breeding on the propensity of yellowing of progeny should be evaluated. There is potential for economic gain if wool does not have a propensity to develop yellow discoloration. We expect that through the use of a simple test, Rambouillet sheep can be selected to improve wool color. Additionally, future studies should include measurement of grease and suint content and composition of the samples in attempts to explain the observed yellowing propensities.

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Feeding of DDGS in lamb rations

Feeding dried distillers grains with solubles as 60 percent of lamb finishing rations results in acceptable performance and carcass quality[1]

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Summary

Little scientific documentation is available that evaluates maximum levels of dried distiller grain with solubles (DDGS) in lamb-finishing rations. The objective of this research was to evaluate the effect of feeding increasing levels of DDGS in lamb-finishing rations on lamb performance and carcass characteristics. Two-hundred forty Western, white-faced Rambouillet wether and ewe lambs (31.7 ± 0.6 kg BW) were stratified by weight and sex, randomly allotted to one of 16 pens, and assigned to treatment (n = 4). Diets were balanced to meet CP, energy, and Cu requirements; however, treatments were not formulated to be isocaloric or isonitrogenous. The basal diet consisted of alfalfa hay, soybean meal, barley, and a trace mineral supplement. Dried distillers grains with solubles replaced barley and soybean meal at 0 percent, 20 percent, 40 percent, and 60 percent of the diet, respectively (DM basis). Sulfur concentrations of diets were 0.22 percent, 0.32 percent, 0.47 percent, and 0.55 percent for the 0 percent , 20 percent , 40 percent , and 60 percent diets, respectively. Thiamin was included at 142 $mg \cdot hd^{-1} \cdot d^{-1}$ (DM basis) in all rations for the prevention of polioencephalomalacia. Rations were mixed, ground, and provided ad-libitum. Lambs were weighed on day 0, 32, 56, 83, and 111. Lambs were harvested after the 111 d feeding trial and carcass data collected. Performance and carcass data were analyzed as a completely randomized design. The model included the fixed effect of DDGS treatment and the random effect of pen nested in treatment. Contrast statements included 1) 0 percent vs DDGS inclusion; 2) linear effect of DDGS inclusion; and 3) quadratic effect of DDGS inclusion. Final weight, ADG, G:F, 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 treatment ($P \geq 0.15$). Feed intake increased in a linear manner ($P < 0.001$) as level of DDGS inclusion increased. Additionally, flank streaking increased quadratically ($P = 0.09$) as level of DDGS inclusion increased. Dried distillers grains with solubles maintained lamb performance and had no negative effect on lamb carcass traits. Maximizing the use of DDGS may become economically feasible for lamb feeders when prices become favorable compared to conventional dietary ingredients; however, the level of use of supplemental thiamin for the prevention of potential S-induced polioencephalomalacia in lambs needs to be further evaluated.

Key Words: dried distillers grains with solubles, lamb, sulfur, thiamin

Introduction

Co-products from the ethanol industry are increasingly available in the northern Great Plains. A primary ethanol industry co-product, dried distillers grain with solubles (DDGS), is an excellent source of energy and protein for beef cattle and sheep (Lardy, 2003). Historically, research conducted in beef-cattle diets report that DDGS can be fed as a source of both supplemental protein and energy to cattle during backgrounding and finishing, with optimum inclusion levels at approximately 20 percent of the diet-dry matter (Lardy, 2003). A trend to formulate ruminant-finishing diets at higher inclusion levels of DDGS will continue, due to favorable economic substitution for conventional feedstuffs and animal performance responses. However, DDGS are high in potassium, phosphorus, and sulfur; therefore, caution is needed when formulating DDGS into diets to avoid nutritional health disorders.

To prevent polioencephalomalacia in sheep, current recommendations are to keep dietary concentrations of S below 0.3 percent DM when animals are fed concentrate diets or below 0.5 percent DM when fed high-forage diets (NRC, 2007). Recent research results in cattle indicate the diet may include up to 50 percent DDGS (DM basis) when 150 $mg \cdot hd^{-1} \cdot d^{-1}$ supplemental thiamin is provided (Huls et al., 2008). Little research has evaluated the inclusion of DDGS as a replacement for concentrate in lamb finishing rations, especially as inclusion rates rise to the point where S becomes potentially toxic. Schauer et al. (2005, 2006) and Huls et al. (2006) reported that DDGS can be included at levels up to 22.5 percent of a finishing ration with no negative effect on lamb performance or carcass traits. Thus, the objectives for this trial were to evaluate the influence of increasing levels of DDGS in lamb finishing rations on performance and carcass characteristics, specifically when S concentrations become potentially toxic.

Materials and Methods

Animals and Treatments

This trial was conducted at the North Dakota State University Hettinger Research Extension Center, Hettinger, N.D. All procedures were approved by the North Dakota State University Institute for Animal Care and Use Committee. Two-hundred forty Western, white-faced Rambouillet wether and ewe lambs (31.8 ± 0.6 kg initial BW) were stratified by weight and sex and assigned randomly to 16 outdoor pens (15 lambs/pen) with continuous access to water and shade. Pens were then assigned randomly to one of four dietary treatments, with pen serving as experimental unit (n = 4 per treatment): dried distillers grains with solubles replaced barley and soybean meal at 0 percent, 20 percent, 40 percent, and 60 percent of the diet, respectively (DM basis). Diets were balanced to meet or exceed crude protein, energy, and copper requirements (NRC, 2007); however, they were not formulated to be isocaloric or isonitrogenous as the level of DDGS inclusion increased (Table 1). The 0 percent diet was balanced to have equal CP concentration to the 20 percent diet (Table 1). The basal diet consisted of alfalfa hay, soybean meal, barley, and a trace mineral supplement (Table 1). The calcium (Ca):phosphorous (P) ratio was 1.77:1 or higher in all diets and ammonium chloride (0.5 percent, DM basis) was added to all diets to aid in the prevention of urinary calculi resulting from increasing concentrations of P in the

Table 1. Dietary ingredient and nutrient composition of lamb finishing diets.

	Diets[1]			
Item	**0%**	**20%**	**40%**	**60%**
Ingredient		DM basis		
Barley, %	76.5	61.5	41.5	21.5
DDGS, %	---	20.0	40.0	60.0
Alfalfa hay, %	12.5	12.5	12.5	12.5
Soybean Meal, %	5.0	---	---	---
Ammonium Chloride, %	0.5	0.5	0.5	0.5
Trace Mineral[2], %	5.0	5.0	5.0	5.0
CTC[3], %	0.5	0.5	0.5	0.5
Nutrient Concentration				
CP, %	20	20	25	27
$NE_{maintenance}$, Mcal/kg[4]	1.87	1.94	2.02	2.02
NE_{gain}, Mcal/kg[4]	1.25	1.30	1.34	1.34
Crude Fat, %	2.50	4.03	6.69	8.34
ADF, %	10.20	9.72	10.90	12.50
Sulfur, %[5]	0.22	0.32	0.47	0.55
Calcium, %	2.14	1.77	1.17	1.38
Phosphorus, %	0.48	0.55	0.66	0.67
Calcium:Phosphorus	4.46	3.09	1.77	2.06
Copper, ppm	12	10	11	10
Zinc, ppm	73	75	86	63
Thiamin, $mg \cdot hd^{-1} \cdot d^{-1}$	142	142	142	142

[1] 0% = 0% replacement of barley with dried distillers grains with solubles; 20% = 20% dried distillers grain with solubles in ration replacing barley and SBM; 40% = 40% dried distillers grain with solubles in ration replacing barley and SBM; 60% = 60% dried distillers grain with solubles in ration replacing barley and SBM.
[2] Trace mineral: 0.12 % S, 0.31% P, 1.2% K, 1.45% Mg, 17.47% Ca, 2.82% Na, 509 ppm Fe, 375 ppm Mn, 50 ppm Cu, 715 ppm Zn, 5 ppm Se, 1960 mg/kg Thiamine, 95.15 KIU/kg Vitamin A, 9.46 KIU/kg vitamin D3, 9504 IU/kg Vitamin E, 946 mg/kg lasalocid.
[3] CTC (chlorotetracycline - 4G) was formulated to provide 48 g/ton chlortetracycline.
[4] Calculated analysis.
[5] Sulfur may be toxic at levels of 0.30% of diet (DM basis; NRC, 2007).

ration. Thiamin was included at 142 mg·hd^{-1}·d^{-1} (DM basis) in all rations for the possible prevention of polioencephalomalacia. Lambs were adapted to a 75 percent barley and 25 percent alfalfa-based ration prior to the initiation of the trial. Rations were mixed and ground through a grinder-mixer and provided ad libitum via bulk feeders. Weight of each feed delivery and feed remaining at the end of the trial was recorded for the determination of feed intake and gain efficiency (G:F). Feeders were checked daily and cleaned of contaminated feed (fecal contamination, moisture contamination, etc.). Lambs were observed twice daily for the symptoms of acidosis, urinary calculi, and polioencephalomalacia. Grab samples of the ration were collected on d 0, 56, and 111, dried at 55° C for 48 h, and analyzed by a commercial laboratory (Midwest Laboratories Inc., Omaha, Neb.) for DM, CP, calculated energy, crude fat, ADF, S, mineral concentrations, and thiamin (Table 1). Sulfur concentrations of diets were 0.22 percent, 0.32 percent, 0.47 percent, and 0.55 percent for 0 percent, 20 percent, 40 percent, and 60 percent, respectively. Water was sampled on d 56, and samples were analyzed by a commercial laboratory (Stearns DHIA, Sauk Centre, Minn.) for sulfate (141 ppm), nitrate-N (0.07 ppm), pH (8.90), calcium (47.86 ppm), Mg (10.34 ppm), Na (54.28 ppm), Fe (0.18 ppm), Mn (< 0.13 ppm), Cu (< 0.02 ppm), water hardness (162 ppm, calculated value), chloride (12.60 ppm), and total dissolved solids (296 ppm).

Feedlot Performance and Carcass Data Collection

Lambs were fed the treatment diets for 111 d. Lambs were weighed on d 0, 32, 56, 83, and 111. Initial and final weights were an average of two-day weights, with lambs having continuous access to feed and water. Gain efficiency (G:F) was calculated as the ratio of weight gain to DMI. Lambs, regardless of treatment, were marketed at a common time endpoint, when the average weight of the wethers reached a market weight of 60 kg; if lambs did not reach the 60 kg market weight, carcass data was not collected. Following the 111-d finishing period, lambs were transported 805 km for harvest and subsequent carcass data collection at Iowa Lamb Corp, Hawarden, Iowa. Of the original 240 lambs 205 lambs (85.42 percent) were shipped for slaughter. Treatment distributions were as follows; 46 head of the 0-percent treatment, 53 head of the 20-percent treatment, 51 head of the 40-percent treatment, and 55 head of the 60-percent treatment. Hot-carcass weight (HCW) was recorded on the day of slaughter. Leg score, conformation score, fat depth, body wall thickness, longissimus muscle area, and USDA quality and yield grades were recorded after carcasses were chilled at 4°C for 24 h. Percent boneless, closely trimmed, retail cuts (%BCTRC) were calculated (Savell and Smith, 1998).

Statistical Analysis

Feedlot-performance data were analyzed as a completely randomized design using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.Y.) with pen serving as the experimental unit. Because pen served as the experimental unit, we did not test for differences between ewe and wether lambs. Carcass data were analyzed similarly, with missing data points from the underweight lambs not included in the data set, but with pen still serving as experimental unit. The linear model included the fixed effect of treatment, and the random effect of pen nested in treatment. Contrast statements included 1) 0 percent vs DDGS inclusion; 2) linear effect of DDGS inclusion; and 3) quadratic effect of DDGS inclusion.

Results and Discussion

The effects of treatment on feedlot performance and carcass traits are shown in Table 2. Final weight, ADG, G:F, mortality, HCW, leg score, conformation score, fat depth, body wall thickness, ribeye area, quality grade, yield grade, and %BCTRC were not affected by treatment ($P \geq 0.15$). Intake increased in a linear manner ($P < 0.001$) as level of DDGS inclusion increased. While a significant difference was not observed for G:F, it appears that G:F is trending downward as level of DDGS inclusion increases. This trend is supported by the increase in DM intake with no change in ADG as DDGS inclusion increased. Additionally, flank streaking increased ($P = 0.09$) in a quadratic relationship to the 0-percent dietary treatment as level of DDGS inclusion increased, with all DDGS treatments having greater ($P = 0.02$) flank streaking than 0-percent treatment. During the 111-d finishing trial, lambs were not observed to exhibit symptoms of acidosis, urinary calculi, or polioencephalomalacia, regardless of dietary treatment (data not shown). The mortality cases were attributed to the following: two lambs with chronic rectal prolapses and three lambs with pneumonia-respiratory complications. These mortality cases do not appear to be treatment related.

Replacing up to 60 percent of the ration in a barley and alfalfa-hay-based finishing diet with DDGS had no effect on lamb-growth performance. Water did not significantly contribute to S intake of feedlot lambs. Feed intake increased linearly as level of DDGS inclusion increased. The increase in intake was surprising, as crude fat was 8.34 percent of the diet for the 60-percent treatment, well above industry recommendations for fat concentrations in feedlot diets. Although intake increased, a significant increase in ADG was not observed. However, a numerical increase in ADG of approximately 6 percent was observed for all DDGS treatments when compared to the 0-percent-DDGS inclusion diet. Other researchers suggest that DDGS can be an effective replacement of concentrate with no adverse effect on livestock performance compared to control diets. Erickson et al. (1989) provided up to 28 percent of a finishing diet as DDGS and observed no negative affects on lamb performance. Similarly, Schauer et al. (2005) incorporated DDGS at levels up to 15 percent of the total diet and Huls et al. (2006) substituted up to 22.9 percent of the finishing diet with DDGS and found no difference in lamb performance or carcass traits. However, Schauer et al. (2006) reported an increase in performance from increasing DDGS levels up to 22.5 percent of the diet. In both Schauer et al. (2006) and the current trial, CP levels of the DDGS diets are in excess of the requirements for lambs (NRC, 2007). This, combined with a trend for increasing intake and increased caloric density of the diets containing DDGS due to increasing fat concentrations may

Table 2. The influence of dried distillers grains with solubles (DDGS) on feedlot lamb performance and carcass characteristics.

	Treatment[1]						P-value[3]		
Item	0%	20%	40%	60%	SEM[2]	P-value	Linear	Quadratic	0% Vs. DDGS
Initial Weight, kg	31	32	32	32	0.6	0.55	0.47	0.22	0.22
Final Weight, kg	60	62	62	62	0.9	0.27	0.15	0.25	0.06
ADG, kg/d	0.26	0.28	0.28	0.28	0.01	0.21	0.11	0.41	0.05
DM Intake, $kg \cdot hd^{-1} \cdot d^{-1}$	1.68	1.78	1.83	1.91	0.03	0.001	< 0.001	0.71	< 0.001
G:F	0.16	0.16	0.15	0.15	0.005	0.53	0.20	1.00	0.39
Mortality, %	0.75	0.25	0.25	0	0.30	0.38	0.12	0.68	0.12
Hot Carcass Weight, kg	30	32	31	31	0.45	0.27	0.19	0.16	0.06
Leg score[4]	10.3	10.5	10.5	10.5	0.3	0.89	0.56	0.66	0.45
Conformation score[4]	10.3	10.3	10.5	10.5	0.27	0.83	0.42	1.0	0.60
Fat Depth, cm[5]	0.74	0.81	0.76	0.81	0.05	0.57	0.36	0.69	0.24
Body Wall Thickness, cm	2.44	2.16	2.57	2.59	0.08	0.47	0.13	0.87	0.22
Ribeye Area, cm^2	14.96	15.35	15.16	15.42	0.32	0.72	0.43	0.83	0.35
Flank Streaking[6]	324	357	342	345	8	0.08	0.19	0.09	0.02
Quality Grade[4]	10.3	10.8	10.8	11	0.2	0.15	0.04	0.57	0.04
Yield Grade[5, 7]	3.26	3.57	3.42	3.55	0.18	0.63	0.39	0.65	0.26
%BCTRC[8]	45.1	44.9	44.9	44.8	0.21	0.76	0.35	0.70	0.31

[1] 0% = 0% replacement of barley and SBM with dried distillers grains with solubles; 20% = 20% dried distillers grain with solubles in ration replacing barley and SBM; 40% = 40% dried distillers grain with solubles in ration replacing barley and SBM; 60% = 60% dried distillers grain with solubles in ration replacing barley and SBM.
[2] Standard Error of Mean; n = 4.
[3] *P*-value for 0% vs DDGS treatments and linear and quadratic affect of dried distillers grains with solubles inclusion.
[4] Leg score, conformation score, and quality grade: 1 = cull to 15 = high prime.
[5] Adjusted fat depth and yield grades.
[6] Flank streaking: 100-199 = practically devoid; 200-299 = traces; 300-399 = slight; 400-499 = small; 500-599 = modest.
[7] Yield Grade = 0.4 + (10 x adjusted fat depth).
[8] % Boneless closely trimmed retail cuts (% BCTRC) [49.936 - (0.0848 x Hot Carcass Weight, in.) - (4.376 x Fat Depth, in.) - (3.53 x BW, in.) + (2.456 x Ribeye Area, in^2)].

explain subtle increases in ADG as DDGS inclusion increased. Additionally, supplemental fat from the DDGS may have affected intake and performance in both trials. Future research is needed to determine if adequate lamb performance can be maintained while utilizing lower quality forages than alfalfa with DDGS replacing a portion of the concentrate in the diet.

The majority of carcass traits were not affected by increasing levels of DDGS in the ration. These results are supported in research conducted by Schauer et al. (2005, 2006) and by Huls et al. (2006). In the current trial only marginal increases in flank streaking were observed. This response could potentially be the result of the increased-energy density in the rations with higher levels of DDGS inclusion.

In this trial supplemental thiamin was provided to aid in the prevention of S-induced polioencephalomalacia. Current research suggests that S toxicity in lambs can be expected to occur when S concentration is greater than 0.3 percent DM in high-concentrate diets, and 0.5 percent DM in high-forage diets (NRC, 2007). As concentrate levels increase in lamb diets, ruminal pH decreases and excessive production of rumen sulfide can result (Gould, 1998). While decreases in ruminal pH have not been found to decrease the microbial production of thiamin (Alves de Oliveira et al., 1996), a lower ruminal pH favors bacteria that produce thiaminase—a compound that in turn destroys the thiamin (Morgan and Lawson, 1974; Boyd and Walton, 1977; Thomas et al., 1987). In diets containing greater than 0.3 percent sulfur, the combination of increased dietary-S concentration, increased-ruminal-sulfide production, and increased-thiaminase production may result in an increase in polioencephalomalacia (Gould, 1998). Sulfur toxicity may additionally result in decreased intake and performance, as well as health problems associated with S binding to copper, resulting in secondary copper deficiencies. One potential remedy for excessive dietary S is to include supplemental thiamin in the diet (NRC, 2007). Recent beef-cattle research has reported mixed results using supplemental, orally administered thiamin. Huls et al. (2008) successfully fed 50 percent of the diet as modified DDGS while supplementing with 150 $mg \cdot hd^{-1} \cdot d^{-1}$ thiamin, noting no change in performance when compared to control diets. However, a 50-percent DDGS treatment had to be discontinued by Buckner et al. (2007), when multiple steers exhibited signs of polioencephalomalacia, even though they were providing 150 $mg \cdot hd^{-1} \cdot d^{-1}$ supplemental thiamin. In this trial, no increases in mortality or morbidity were observed, indicating that the lambs on increasing levels of DDGS had no deleterious effects from increasing dietary-S concentrations. Additional research is needed to further quantify the supplemental-thiamin needs of lambs fed high- DDGS rations or to elucidate the reasons that lambs are less likely than cattle to develop polio based on S-induced affects in the rumen.

Conclusion

The expansion of the ethanol industry in the United States may result in an increase in the availability of dried distillers grains with solubles for lamb feeders. Maximizing the use of dried distillers grains with solubles may become economically feasible for lamb feeders, especially in relation to the current price trends for more traditional feedstuffs. When appropriately priced relative to energy feedstuffs, dried distillers grains with solubles supplemented with thiamin at 142 $mg \cdot hd^{-1} \cdot d^{-1}$ may effectively replace up to 60 percent of a lamb-finishing ration with no negative effects on feedlot performance or carcass traits.

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