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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.

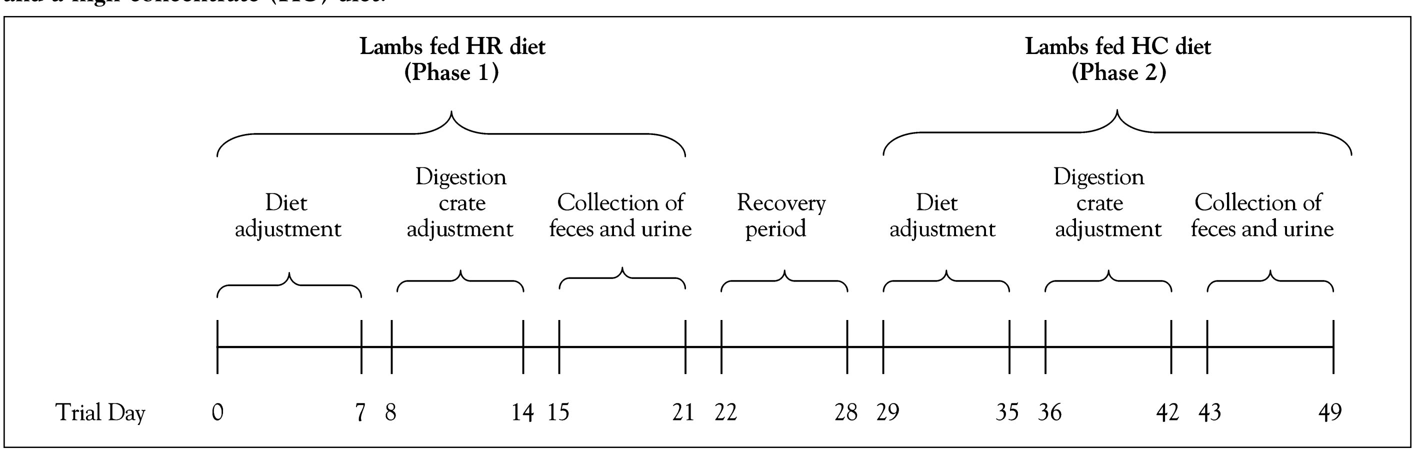

Table 1. Chemical composition of high-roughage (HR) and high-concentrate (HC) diets fed to lambs.

	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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