



## Impact of Particle Length of Alfalfa Hay in the Diet of Growing Lambs on Performance, Digestion and Carcass Characteristics

M. Y. Al-Saiady, M. A. Abouheif\*, A. Aziz Makkawi<sup>1</sup>, Hafiz A. Ibrahim<sup>2</sup> and A. N. Al-Owaimer

Animal Production Department, College of Food and Agricultural Sciences, P. O. Box 2460,  
King Saud University, Riyadh 11451, Saudi Arabia

**ABSTRACT :** Thirty-six Najdi ram lambs, weighing an average of 24 kg and circa 3 months old, were utilized in this trial to evaluate the effects of various alfalfa hay particle lengths in the diet on growth performance, digestion coefficients, nitrogen retention and carcass characteristics. Lambs were randomly allotted to three dietary treatments: 9.5 and 14 mm diets, where alfalfa hay was processed to 9.5 and 14 mm particle lengths, respectively, mixed with 3 parts of concentrate and pelleted as a total mixed ration (TMR), and long hay diet, where one part of loose alfalfa hay (17.8±2.4 cm) was offered in combination with 3 parts of only-concentrate pellet. All dietary treatments were homogeneous in their ingredient composition. All lambs were slaughtered after a 14-week feeding trial. Although the results showed no significant effect of hay particle length on DMI, TDN and DCP, lambs fed the 9.5 mm pelleted diet had higher ( $p<0.05$ ) final body weight, ADG, gain efficiency and nitrogen retention than lambs fed the 14 mm and long hay diets. Altering the particle length of alfalfa hay in diets did not affect the digestibility of DM or CP, whereas digestibilities of ADF and NDF were 3.7% and 5.4% higher ( $p<0.05$ ), respectively, for the long hay diet versus the 9.5 mm pelleted diet. Hot carcass weight, percentage of separable lean from the 9-11<sup>th</sup> rib joint, and percentages of protein and EE in the separable lean increased ( $p<0.05$ ) as the particle length of alfalfa hay in the diet decreased. Under the conditions of this study, the reduction of particle length in the TMR played an important role in enhancing performance without altering DM consumption, and this may lead to more efficient productivity of lamb fattening compared with longer chopping lengths. (**Key Words :** Particle Length, Alfalfa Hay, Lambs, Intake, Digestibility, Carcass)

### INTRODUCTION

Pelleted total-mixed rations are increasing in popularity on many sheep enterprises, including those with relatively small flocks. The advantages for sheep production efficiency of a pelleted TMR over feed ingredients provided separately are thought to exist because concentrates and forages are mixed and offered together and are therefore fermented in the rumen simultaneously. Physical characteristics of the forage component of a pelleted TMR are important criteria in the animal's ability to utilize feedstuffs. Altering the physical properties of forages given separately in long or chopped form and in combination with other feeds or ground in a pelleted TMR have been shown

to govern the rate of digesta outflow from the rumen, thereby influencing the control of voluntary feed intake, energy utilization and digestibility (Waghorn et al., 1986; Shain et al., 1999; Hadjigeorgiou et al., 2003). The extents of these changes are influenced by fineness of grinding of the forage and the plane of nutrition at which the diet is fed. Several workers (Hunt et al., 1984; Kerley et al., 1985; Mooney and Allen, 1997) indicated that reduction of forage particle length by grinding and pelleting resulted in an increase in voluntary feed intake with variable effects on digestibility. Reduction in particle length of forages did not result in any effect on the pattern of digestion within the alimentary tract of sheep (Hogan and Weston, 1967; Thomson et al., 1972), whereas Woodford and Murphy (1988), Fischer et al. (1994) and Hadjigeorgiou et al. (2003) reported that reduction of particle length decreased DM and fiber digestibility. On the other hand, Moore (1964) found that reduction in particle length increased rate of DM and fiber digestion.

Forage particle length in sheep diets can vary extremely, and it is not clear what measurement of a forage physical

\* Corresponding Author: M. A. Abouheif. Tel: +966-1-467-8487, Fax: +966-1-467-8474, E-mail: abouheif@hotmail.com

<sup>1</sup> Department of Animal Production, College of Agricultural Studies, Sudan University of Science and Technology, Sudan.

<sup>2</sup> ARASCO Research, Nutrition and Technical Services Department, P. O. Box 53845, Riyadh 11593, Saudi Arabia.

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characteristic would best predict the animal response. Therefore, the aim of this experiment was to evaluate and compare the influence of utilizing two particle lengths (9.5 and 14 mm) of alfalfa hay in pelleted total-mixed ration diets and long alfalfa hay in combination with a pelleted only-concentrate diet on growth performance, nutrient digestibility and carcass traits in growing Najdi lambs.

## MATERIALS AND METHODS

### Animals and housing

Thirty-six Najdi male weaner lambs, of average body weight  $24 \pm 0.6$  kg and *circa* 3 months old, were used in this experiment. Lambs were purchased from a local farm; upon arrival, lambs were individually weighed, identified, vaccinated, injected against internal and external parasites and vitamin A-D-E injections were given. Thereafter, lambs were assigned randomly to one of three equal groups with twelve lambs in each group. Each group contained four replicates (pens) with three lambs per pen; pen was used as the experimental unit for feed performance data. Pens were  $1.7 \times 3.0$  m and constructed of metal gates and concrete floors, and were located under a roof in an open-sided barn.

### Preparation of diets

The three experimental diets utilized in this study were homogeneous in their ingredient composition, with the only variable being the particle length of the alfalfa hay used in each diet (Table 1). All diets were formulated to meet daily energy and protein requirements (NRC, 1985). A single batch of alfalfa hay was processed to yield three particle lengths: 9.5 mm, 14 mm and long hay. The 9.5 and 14 mm particle lengths were prepared by feeding the hay through a chopper machine equipped with 9.5 and 14 mm screens, respectively, whereas the long hay was used directly from the bale without any processing. The average length of long hay stems was  $17.8 \pm 2.4$  cm (ranged from 8.4 to 25.6 cm). A sample from each designated particle length was uniformly selected to determine the distribution of particle length. The estimates of particle length distribution were determined on five 120-g subsamples using a dry-sieving technique. Each subsample was placed on top of a vibrating sieve stack (stainless steel; 200 mm i.d.) and shaken for 10 minutes. The sieve stack contained sieves in descending order of pore size of 21, 16.3, 10.1, 6.4 and 3.8 mm. The particulate fractions retained on each sieve and the pan were weighed for the determination of the weight distribution of each respective fraction (Table 2).

A master batch of all dietary concentrate ingredients was ground through a 4.76-mm screen, mixed thoroughly in a stainless steel vertical mixer and divided into three equal portions to be mixed subsequently with the hay of specific particle length. Diets 9.5 and 14 mm were prepared as

**Table 1.** Ingredients<sup>1</sup> and chemical composition of the experimental diets

Item	TMR	Concentrate	
Ingredient			
Alfalfa hay	25.00		
Barley	59.44	79.25	
Wheat bran	7.50	10.00	
Soybean meal	2.94	3.92	
Salt	0.38	0.51	
Limestone	1.73	2.31	
Acid buf <sup>2</sup>	0.38	0.51	
Molasses	2.25	3.00	
Lignobond <sup>3</sup>	0.23	0.30	
Trace minerals and vitamin <sup>4</sup>	0.15	0.20	
ME Mcal/kg DM <sup>5</sup>	2.78	3.06	
Chemical composition			
	9.5 mm <sup>6</sup>	14 mm <sup>6</sup>	Long hay <sup>7</sup>
DM	95.68	95.87	95.35
CP	14.53	14.43	13.92
EE	1.16	1.16	0.83
ADF	14.22	14.77	16.96
NDF	24.91	24.55	28.29
Ash	7.46	7.23	6.92

<sup>1</sup> TMR = Pelleted total-mixed ration; Concentrate = Pelleted- only concentrate; DM basis, %.

<sup>2</sup> Natural buffer derived from seaweed (CelticSea Company, Ireland).

<sup>3</sup> Calcium lignosulfate as pellet binder.

<sup>4</sup> Contained 10,000 (IU/kg) vitamin A, 1,000 (IU/kg) vitamin D, 20 (IU/kg) vitamin E, 300 mg/kg of Mg, 24 mg/kg of Cu, 0.6 mg/kg of Co, 1.2 mg/kg of I, 60 mg/kg of Mn, 0.3 mg/kg of Se, 60 mg/kg of Zn, of finished feed.

<sup>5</sup> Tabulated.

<sup>6</sup> Alfalfa hay was chopped to either 9.5 or 14mm lengths and incorporated into the pelleted TMR.

<sup>7</sup> Loose alfalfa hay with an average length of 17.8 cm was mixed with pelleted only-concentrate in a ratio of 1: 3, respectively.

pelleted total-mixed rations (TMR), each with a ratio of concentrate ingredient to alfalfa hay of 3:1 (DM basis); the mixed ingredients were put directly into the pelleting unit in front of the hammer mill. Steam was used to enhance the process of pelleting. The concentrate ingredients used with

**Table 2.** Distribution of alfalfa hay particle lengths<sup>1</sup>, as percentage of total mass

Aperture size	Chopping length	
	9.5 mm	14 mm
21.0 mm	0	1.2
16.3 mm	0.4	23.9
10.1 mm	32.6	54.6
6.4 mm	44.8	11.1
3.8 mm	16.7	3.9
Pan	5.5	5.3

<sup>1</sup> Average of five samples.

the long hay diet were pelleted without mixing with hay to form only-concentrate pellets (Table 1). All pellets retained their stability throughout the experiments.

### Feeding trial

Animal groups were randomly allotted to three dietary treatments to evaluate the effects of particle length of alfalfa hay contained in the diet on growth performance, nutrient digestibility, nitrogen balance and carcass characteristics. All lambs were fed the experimental diets, namely 9.5 mm and 14 mm pelleted TMR and long hay diets, *ad libitum* at 09:00 h after discarding the residue from the previous day. To maintain a ratio of loose hay intake in the long hay diet equivalent to 25% of the ration, offerings of the only-concentrate pellet were partially withheld until each lamb consumed the hay portion. Refusals were removed, weighed, sampled for DM determination and then discarded. Feed samples were collected weekly for DM determination and 4-week samples were pooled for chemical analysis. The feeding trial lasted for 14 weeks during which DM consumption and lamb weight data were recorded weekly; lamb weight was recorded after 12 h without feed. Fresh drinking water was available at all times.

### Apparent digestibility and nitrogen balance

A digestibility trial was started on day 90 of the feeding trial on twelve lambs to determine digestibility coefficients, nutritive values and nitrogen balance of each experimental diet. Lambs were randomly selected and withdrawn from the feeding trial at the rate of one lamb per replicate. The digestibility trial lasted for 8 days (i.e., 3 d adaptation followed by 5 d of sample collection) during which daily feed intake and output of feces and urine were collected and recorded. Lambs were individually confined in false-bottom metabolic crates to facilitate separate collection of total feces and urine. Total feces voided were collected, weighed and a 10% aliquot was dried at 65°C for 24 h. The dried samples were ground through a 1-mm screen and stored for later analyses. Total daily urine output of each lamb was collected in a plastic bucket containing 100 ml 6 N HCl to prevent nitrogen losses, recorded and a 10% aliquot was sampled; at the end of the collection period, samples of urine from each lamb were mixed for nitrogen determination.

### Carcass measurements

At the end of the feeding trial, all lambs were slaughtered after 12 h without feed. At slaughter, the live body weight, hot carcass weight and dressing percentage were recorded. Then, the 9-11<sup>th</sup> rib joint was separated from the right side of each carcass and physically separated into bone, fat and lean. The lean tissues were ground through a 4-mm plate, mixed and reground again. During the second

grinding, 5 subsamples (10-12 g) were taken from each carcass to obtain a 50-60 g sample that was placed in a plastic bag, frozen and stored at -20°C pending chemical analysis.

### Chemical and statistical analysis

Samples of the experimental diets, feces, urine and ground lean tissues were analyzed for DM, ash, ether extract and crude protein according to AOAC (1995). NDF and ADF were determined according to Goering and Van Soest (1970). Data for growth performance, chemical composition, apparent digestibility coefficients and carcass characteristics were statistically analyzed by ANOVA using GLM procedures of SAS (1998). Duncan's multiple range test was used to test for significant differences between means. A significance level of 5% was used to express statistical difference between means.

## RESULTS AND DISCUSSION

### Composition of diets

Chemical composition of the 9.5 mm, 14 mm and long hay diets is presented in Table 1. Although all ingredients were the same and were obtained from the same sources, slight differences existed in chemical composition between pelleted and long hay diets. There was no effect of chop length on the chemical composition of the pelleted total-mixed ration diets as contents of DM, CP, EE, ADF and NDF were similar for the 9.5 and 14 mm diets. The long hay diet had slightly lower CP and EE, and higher ADF and NDF percentages compared with the 9.5 and 14 mm pelleted diets. This is consistent with other studies by Sudweeks et al. (1979) and Ehle (1984) who reported that percentage NDF of roughages might be affected by the size of particle subjected to fiber analysis. Kerley et al. (1985) found that fibrous contents of ground corncobs were less than that of corncobs not ground and suggested a possible reaction between the starch and fiber components of diets as mean particle size decreased. In our study, variations in fibrous ADF and NDF concentrations among varying particle length diets were possibly due to more uniform sampling of the pelleted diets as compared to the long hay diet. Another possible explanation that might contribute to the difference in ADF and NDF contents between pelleted and long hay diets could be related to the fibrous component that could vary in its susceptibility to the conditions of steam and pressure imposed by the pelleting process, resulting in a feedstuff that reacts differently from normal to the traditional assays used (Kerley et al., 1985).

### Distribution of particle length

Distributions of various particle lengths of chopped alfalfa hay used in the 9.5 and 14 mm diets are presented in

Table 2. Distribution of particle lengths, as percentage of total mass, on the five screens and the pan, were 0, 0.4, 32.6, 44.8, 16.7 and 5.5 for the 9.5 mm chopped hay and 1.2, 23.9, 54.6, 11.1, 3.9 and 5.3 for the 14 mm chopped hay. Loose alfalfa hay in the long hay diet consisted mostly of particles with mean length of 17.8 cm. However, it was obvious that over 77% of the chopped alfalfa hay used in the 9.5 and 14 mm diets was distributed between >6.4 to <16.3 mm and >10.1 to <21 mm lengths, respectively. There was no general difference between 9.5 and 14 mm chop length in the percentage of the smaller particle lengths (<3.8 mm) which remained on the pan. Santini et al. (1983) found that forages with particle length <5 mm have been associated with reduced chewing activity relative to larger particles. Also, Krause et al. (2002) reported that a mean particle size of 13.6 mm was considered to be above the threshold of 6.4 mm that was found to reduce rumination time when dairy cows were fed chopped alfalfa hay as forage (Woodford et al., 1986). Therefore, our data suggest that chopped alfalfa hay lengths contained in either the 9.5 or 14 mm diets might have been appropriate to stimulate normal rumen function.

### Growth performance

The effects of mean particle length on feeding performance of growing lambs are presented in Table 3. Despite there being no effect ( $p>0.05$ ) of the particle length of alfalfa hay in pelleted TMR diets and long alfalfa hay diet on daily DM intake, lambs fed the 9.5 mm diet had higher ( $p<0.05$ ) final body weight, ADG and food conversion ratio than comparable lambs fed the 14 mm and long hay diets. Various studies have been conducted testing the effect of different forage lengths on DMI. The results to this point have been contradictory. Krause et al. (2002) and Leonardi et al. (2005) reported no significant effect of forage particle size on DMI. Lack of effect of chop length on DMI has been observed also in earlier studies by others feeding diets containing more than 50% concentrate

(DeBoever et al., 1993; Clark and Armentano, 1997). On the other hand, Hunt et al. (1984) found that lambs fed 2.5 cm wheat straw had greater DM intake than with a 10 cm wheat straw diets. Fischer et al. (1994) found that increasing alfalfa mean particle length from 3.02 to 9.57 mm decreased DMI in cows. In contrast, Krause and Combs (2003) reported that decreasing forage particle size from 5.3 to 2.7 mm decreased DM intake in mid-lactation cows. These discrepancies between experiments are explained mainly by differences in mean particle length, forage quality, dietary energy concentration and animal age. Thus, it appears that the small response obtained from chopping and pelleting in this study can be ascribed to the high concentrate content (75%) and the good quality of alfalfa hay utilized in experimental diets, which may have reduced the potential for improvement in feed intake. This conclusion agrees with earlier studies by Beardsley (1964), Shaver et al. (1986) and Woodford et al. (1986) who reported that the effect of particle size and pelleting tends to diminish in diets high in concentrate and with improvement in herbage quality of the diet. The results that ADG and gain efficiency increased, but DMI remained unchanged when alfalfa hay particle length decreased need some explanation. It seems that chopping alfalfa hay to 9.5 mm particle length is nutritionally important because of relatively high surface areas, which promotes rapid fermentation by ruminal bacteria and, therefore, generally yields more energy to the lambs fed a 9.5 mm diet than fed longer particles. Also, it has been shown in various experiments that decreasing particle size of consumed forages decreased time spent chewing and ruminating per kilogram of DMI (Soita et al., 2000; Hadjigeorgiou et al., 2003; Krause and Combs, 2003; Leonardi et al., 2005). Shaver et al. (1986) found that when chewing activities for diets with smaller alfalfa particle size decreased, growth of the many fiber-digesting ruminal microorganisms was depressed, which allowed for an increase in the propionate-producing microbes and a decreased acetate-to-propionate

**Table 3.** Effect of particle length of alfalfa hay on feeding performance of growing lambs

Parameter	Diets			SEM
	9.5 mm <sup>1</sup>	14 mm <sup>1</sup>	Long hay <sup>2</sup>	
No. of lambs	12	12	12	
Initial weight (kg)	23.9	24.0	23.9	0.76
Final weight (kg)	51.3 <sup>a</sup>	48.3 <sup>b</sup>	47.4 <sup>b</sup>	1.47
Average daily gain (g/d)	278 <sup>a</sup>	251 <sup>b</sup>	240 <sup>b</sup>	12.52
DM intake				
kg/d	1.39	1.37	1.35	0.19
% body weight	3.70	3.79	3.79	0.09
Conversion ratio (kg/kg)	5.00 <sup>c</sup>	5.46 <sup>b</sup>	5.63 <sup>a</sup>	0.16

<sup>1</sup> Alfalfa hay was chopped to either 9.5 or 14 mm lengths and incorporated into a pelleted TMR.

<sup>2</sup> Loose alfalfa hay with an average length of 17.8 cm was mixed with pelleted only-concentrate in a ratio of 1:3, respectively.

<sup>a, b, c</sup> Means in the same row bearing different superscripts differ ( $p<0.05$ ).

ratio. Differing efficiencies of utilization of VFA have been reviewed by Thomas and Clapperton (1972) who concluded that the efficiency of utilization of propionic acid was much higher than of acetic acid. Therefore, these probable shifts in ruminal fermentation patterns may play an important role in improving the ADG of lambs fed the 9.5 mm diet. Another possible explanation for the improved ADG in lambs fed the 9.5 mm diet would be that the energy expenditure for eating and ruminating was lower, leaving more available energy for growth than their counterparts on the 14 mm and long hay diets, who probably spent more time in eating and ruminating. Similar results were reported by Osuji (1974) who reviewed the literature indicating a close relationship between time spent eating and energy cost of eating activity, and noted physiological processes contributing to this relationship such as jaw skeletal muscle work for biting, chewing and swallowing and energy use by the liver and gastrointestinal tract. Accordingly, Lachica et al. (1997) found that the energy cost of eating in goats ranged from 45 to 144 J/kg body weight per minute, depending on the physical form of the feed.

#### Digestibility coefficient

The effects of mean particle length of alfalfa hay on total-tract nutrient digestibility coefficients and nutritive values are given in Table 4. Digestion coefficients of DM, CP and NFE were not affected by particle length of alfalfa hay in the experimental diets. Lack of effect of chopping forages on digestibility of DM and CP has been observed by Hogan and Weston (1967) and Thomson et al. (1972) who did not observe any effect of altering the physical form of the dried alfalfa on the pattern of digestion within the

alimentary tract of sheep. Generally, the obtained values for total-tract digestibility coefficients of ADF and NDF were relatively high considering the type of diets fed in this trial (low fibrous). These results, however, agreed well with the findings reported by Krause et al. (2002) for a TMR with a ratio of concentrate to alfalfa of 61:39 (DM basis). The digestibility of ADF and NDF were 3.7 and 5.4 percentage units higher ( $p < 0.05$ ), respectively, for long-hay diet versus 9.5 mm pelleted-diet, whereas no significant differences were noted between 9.5 and 14 mm diets. Hinders and Owen (1968) showed a reduction from 90 to only 60% of dietary fiber being degraded in the rumen of sheep when long alfalfa was ground and pelleted. Reduction in total-tract ADF and NDF digestibility has also been observed with fine chopping of alfalfa hay and silage (Woodford and Murphy, 1988; Hadjigeorgiou et al., 2003). Depression of ADF and NDF digestibility with chopping and pelleting (9.5 mm diet) was probably attributable to faster passage of digesta through the digestive tract, resulting in less time available for microbial digestion in the rumen. Similar results were reported by Shaver et al. (1986) who found that smaller forage particles spent less time in the rumen and were less available for microbial digestion; this decreased digestibility, particularly of fiber, because of the relatively slow rate of digestion and decreased ruminal pH. High concentrate feeding has been shown to shift the microbial population, resulting in increased lactate production, depressed rumen pH, and reduced cellulolytic activity (El-Shazly et al., 1961). Because cellulolytic activity is sensitive to acidity (Stewart, 1977), it is suggested that the primary mechanism for the depression in ADF and NDF

**Table 4.** Effect of particle length of alfalfa hay on nutrient digestion and nitrogen utilization by growing lambs

Parameter	Diets			SEM
	9.5 mm <sup>1</sup>	14 mm <sup>1</sup>	Long hay <sup>2</sup>	
Apparent digestibility (%)				
DM	77.2	75.6	75.5	1.61
CP	83.4	83.1	83.7	1.04
ADF	45.2 <sup>b</sup>	47.0 <sup>ab</sup>	48.9 <sup>a</sup>	2.43
NDF	47.1 <sup>b</sup>	47.8 <sup>b</sup>	52.5 <sup>a</sup>	2.00
NFE	82.4	82.0	80.7	1.27
Nutritive value:				
TDN	72.3	71.0	71.1	2.76
DCP	12.0	12.1	11.8	0.29
Nitrogen balance				
N intake (g/d)	28.9	28.7	28.7	1.35
Fecal N excretion (g/d)	4.5	5.1	4.3	0.94
Urinary N excretion (g/d)	5.7 <sup>b</sup>	6.4 <sup>ab</sup>	6.8 <sup>a</sup>	0.53
N-retained (% intake)	64.7 <sup>a</sup>	59.9 <sup>b</sup>	61.3 <sup>b</sup>	3.14

<sup>1</sup> Alfalfa hay was chopped to either 9.5 or 14 mm lengths and incorporated into a pelleted TMR.

<sup>2</sup> Loose alfalfa hay with an average length of 17.8 cm was mixed with pelleted only-concentrate in a ratio of 1:3, respectively.

<sup>a, b</sup> Means in the same row bearing different superscripts differ ( $p < 0.05$ ).

digestibility noted on 9.5 and 14 mm pelleted-diets is associated with the high concentrate diets used in this study, reducing cellulolytic activity due to acidic conditions from rapid grain fermentation. Kerley et al. (1985) observed reductions in ruminal pH and digestion of NDF as forage particle size decreased. Consequently, dietary pelleted-concentrate with added long hay may have increased the time spent chewing, thereby increasing the volume of saliva produced that acts to buffer ruminal contents and causing a trend toward increased ruminal pH, resulting in improved fiber digestibility (Woodford and Murphy, 1988). Although there was no effect ( $p>0.05$ ) on calculated TDN and DCP of particle length of alfalfa hay in pelleted TMR diets or long hay diet, lambs fed the 9.5 mm diet grew faster and more efficiently ( $p<0.05$ ) than comparable lambs which consumed similar amounts of DM from either 14 mm or long hay diets. However, this finding is in accordance with an earlier study by Thomson et al. (1972) who reported that when equal quantities of digestible energy were offered to growing lambs, a ground and pelleted alfalfa diet was utilized more efficiently for growth, carcass gain and wool production compared with chopped and long alfalfa diets. Further, N retention expressed as percent of intake was higher ( $p<0.05$ ) in lambs fed 9.5 mm pelleted TMR diet than in lambs fed either 14 mm pelleted diet or long hay diet. Variation in N retention among the three particle length treatments was due to variation in urinary N excretion; urinary N excretion increased ( $p<0.05$ ) with increasing particle length of alfalfa hay in the diets. The increased urinary-N in lambs fed the long hay diet may be a result of a longer retention in the rumen because of the long hay component (Weston and Hogan, 1967). With more retention time, greater absorption of ammonia through the rumen wall was probable, and this leads to increased urinary

excretion of nitrogen. Increased urinary excretion of nitrogen with increased nitrogen solubility has been demonstrated (Cummins et al., 1982). On the other hand, increased N retention in lambs fed the 9.5 mm diet might be interpreted as evidence that by-pass occurred and that protein quality and quantity was improved in the small intestine.

#### Carcass characteristics

Effects of mean particle length of alfalfa hay on carcass characteristics are presented in Table 5. Hot carcass weight and percentage of separable lean from the 9-11<sup>th</sup> rib joint increased significantly ( $p<0.05$ ) as the particle length of alfalfa hay contained in the diets decreased. This pattern closely followed the trends recorded for body weight gain and nitrogen retention. These results are not consistent with Fluharty et al. (1999) and Shain et al. (1999) who found that altering alfalfa hay particle size had no effect on hot carcass weight and yield grade. Dressing percentage and separable fat percent (assumed to be subcutaneous and intermuscular fat) from lambs fed varying particle lengths of alfalfa hay did not differ ( $p>0.05$ ). On the other hand, percentages of protein and ether extract (assumed to be intramuscular fat) in lean tissue of the physically separated 9-11<sup>th</sup> rib joint increased significantly ( $p<0.05$ ) with decreasing particle length of alfalfa hay in the diet. These results suggested that the increased carcass weight of lambs fed the 9.5 mm pelleted TMR diet was due to increases in lean weight and intramuscular (marbling) fat. The most likely reason for this would be increased nitrogen retention and associated increases in energy available for growth as opposed to the lambs fed the long hay diet.

The creation of various particle lengths of alfalfa hay by processing the hay through a chopper machine had

**Table 5.** Effect of particle length of alfalfa hay on carcass characteristics of growing lambs

Parameter	Diets			SEM
	9.5 mm <sup>1</sup>	14 mm <sup>1</sup>	Long hay <sup>2</sup>	
No. of lambs	12	12	12	
Hot carcass weight (kg)	26.2 <sup>a</sup>	25.3 <sup>b</sup>	25.4 <sup>b</sup>	0.62
Dressing (%)	51.0	52.1	51.2	1.62
Separable lean (%) <sup>3</sup>	45.7 <sup>a</sup>	44.3 <sup>ab</sup>	43.0 <sup>b</sup>	1.23
Separable fat (%) <sup>3</sup>	35.1	35.4	35.0	1.30
Chemical composition: <sup>4</sup>				
Moisture (%)	65.7 <sup>b</sup>	67.8 <sup>ab</sup>	69.0 <sup>a</sup>	2.83
Protein (%)	19.3 <sup>a</sup>	18.4 <sup>b</sup>	18.2 <sup>b</sup>	0.71
Ether extract (%)	14.1 <sup>a</sup>	12.8 <sup>ab</sup>	11.9 <sup>b</sup>	0.88
Ash (%)	0.9	1.0	0.9	0.07

<sup>1</sup> Alfalfa hay was chopped to either 9.5 or 14 mm lengths and incorporated into a pelleted TMR.

<sup>2</sup> Loose alfalfa hay with an average length of 17.8 cm was mixed with pelleted only-concentrate in a ratio of 1:3, respectively.

<sup>3</sup> Physical separation of 9-11<sup>th</sup> rib joint. <sup>4</sup> Chemical analyses of the separated lean from 9-11<sup>th</sup> rib joint.

<sup>a, b</sup> Means in the same row bearing different superscripts differ ( $p<0.05$ ).

differential effects on the performance response of growing lambs. Offering lambs a pelleted TMR which contained alfalfa hay of 9.5 mm particle length did not alter daily feed intake, but average daily gain increased by 15.8% and feed conversion ratio by 11.2% in comparison with lambs fed a long hay diet. Similarly, N-retention and hot carcass weight, increased with decreasing alfalfa hay particle length in the diet. Lambs fed a long hay diet had higher ADF and NDF digestibility coefficients than those lambs fed diets which contained hay of shorter particle lengths, but the net effects on DM digestibility and TDN and DCP were negligible.

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