Foreword

The 2000 Sheep and Goat/Wool and Mohair Consolidated Progress Report has been prepared by Texas Agricultural Experiment Station and Extension Service scientists to communicate current research activities and results to those involved in all phases of the sheep and goat industry. Our objective is to communicate results to the public as rapidly as possible. More detailed information on any subject in this report may be obtained by contacting the responsible scientist(s) directly.

Sheep and goat research in Texas is a consolidated effort involving scientists working at College Station, San Angelo, Sonora, Uvalde, and other research sites. These scientists maintain close communication with scientists at other Texas universities and in other states, including those with the USDA. Additionally, linkages are established with research organizations in other countries where sheep and goat research is being conducted. Through this network, we maintain a prompt awareness of new developments and emerging technology that may be useful in Texas. The research program maintains relationships with sheep and goat commodity groups and other private organizations involved with animal health care products; feed supplements; ration additives; growth promotants; wool mohair, and lamb processing and marketing; and other products and concepts that may be useful in sheep and goat production.

Texas leads the nation in both sheep and goats and needs to maintain a viable sheep and goat industry in order to efficiently utilize and manage a sustainable range resource. The current drought in West Texas has had a significant impact on sheep and goat numbers in the State, but when the rains return, the land will once again be best utilized when properly stocked with sheep, goats, and cattle. Since our last progress report, the section 201 import restrictions on foreign lamb imports has resulted in favorable lamb prices. There are about two years left in this import quota, at which point the U.S. sheep industry will need to have made adjustments to successfully compete with the imports. One way they will be able to accomplish this is to implement an appropriate combination of production technologies — many of which are presented in this and previous progress reports — to increase their efficiency of production. There are many opportunities to expand this industry by using sheep and goats as part of an integrated pest management strategy to help manage brush and weeds. As I like to point out at every opportunity, you can import the commodity, but you cannot import their impact.

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Heritability of Dietary Selection of Mountain Big Sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb) Beetle) in Rambouillet Sheep

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ABSTRACT

The heritability of diet selection for mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb) Beetle) by grazing sheep was estimated from fecal samples collected from 549 Rambouillet ewes. Fecal samples were collected in September and October during 1996 and 1997 from free-grazing ewes on intermountain sagebrush-bunchgrass rangelands at the U.S. Sheep Experiment Station in Idaho. The total number of fecal samples was 1,949. Fecal samples were evaluated for composition of big sagebrush by near-infrared spectroscopy. Percentage sagebrush in the diet was less in September than October (21.6 vs 31.7 %, respectively). Heritability estimates were similar between September and October sampling (0.25 and 0.28, respectively). The genetic correlation between September and October percentages of sagebrush in the diet was high (r_G = 0.91), implying that there is strong genetic similarity between September and October measurements and that an annual measurement may be sufficient for selection. These results contribute to a greater understanding of dietary preferences in freely grazing sheep, and suggest opportunities to improve production efficiency and forage management through selection for dietary preferences.

Sheep and Goat, Wool and Mohair CPR 2000:1-9

Introduction

Selection has long been used to develop different livestock breeds for production characteristics (milk, meat, fiber), behavior, color, size, and resistance to disease, pests, or environmental extremes (Lasley, 1987). However, to our knowledge, herbivores have not been purposefully bred to modify their diet characteristics. Selection and breeding of animals for specific diet characteristics could be used to develop herds and flocks of livestock for vegetation management such as weed control or improved forage utilization. Understanding inherited limitations of diet flexibility is important in designing interventions to boost animal nutrition and production even if selective breeding is not employed.

Although it is well established that species of livestock differ in diet selection (Grant et al., 1985), much less is known about the effect of variation within species. Two studies with limited numbers of observations have shown a significant sire effect for the botanical

composition of diets of free-grazing goats (Warren et al., 1983) and cattle (Winder et al., 1995).

The ability to modify diet selection by genetic selection deserves more attention because of the advantages of permanently incorporating the desired changes into an animal population. The objective of this study was to estimate the heritability for the percentage of mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. vaseyana (Rydb) Beetle) in the diet of Rambouillet sheep.

Materials and Methods

This research was conducted at the U.S. Sheep Experiment Station located 6 mi north of Dubois, ID (112° 10'W, 44° 21'N) which is a research unit of the USDA Agricultural Research Service. During the study, sheep grazed on sagebrush-grasslands that have been typically used as spring and fall range.

Animals and Management

This study estimated percentage sagebrush in the diet of Rambouillet sheep, a typical western white-faced fine-wool sheep breed. Percentage sagebrush in the diet was estimated for 549 ewes over 2 years in an unbalanced repeated measures design. The ewes originated from 100 sires. Live body weight of the animals averaged 158 to 164 lb (Table 1). Data were collected on the same animals in both years, resulting in a higher average age of the ewes in the second year (Table 1). Slightly fewer animals in the second year of the study reflects normal culling and death loss. Three genetic lines within the Rambouillet breed were considered for statistical analyses. Ewes are bred to single sires within selection lines.

Table 1. Average age (± SD), body weight and number of observations on Rambouillet ewes sampled in September and October of 1996 and 1997

			Number of observations		
Year	Age, yr	Live wt, lb	September	October	Total
1996	2.6 ± 1.5	158 ± 18	543	540	1083
1997	3.4 ± 1.3	164 ± 16	435	431	866

Sagebrush Grassland

The study was conducted on sagebrush bunchgrass communities predominated by loam-type soils dominated by mountain big sagebrush (*Artemisia tridentata* Nutt. ssp vaseyana; 15 to 45 % composition by weight). Other abundant woody species included threetip sagebrush (*Artemisia tripartita*) and bitterbrush (*Purshia tridentata*). The dominant herbaceous plant was bluebunch wheatgrass (*Pseudoregneria spicata*; 20 to 40 % composition by weight) with other grasses including Idaho fescue (*Festuca idahoensis*), sandberg bluegrass (*Poa sandbergii*), and thickspike wheatgrass (*Agropyron dasystachyum*).

Grasses contributed 50 to 60 % of the annual forage biomass and though dormant by the time of the study, they still constituted most of the available biomass. Forbs contributed 10 to 20 % of the annual forage biomass and consisted mainly of arrowleaf balsamroot (*Balsamorhyiza sagittata*) tapertip hawksbeard (*Crepis acuminata*), velvet lupine (*Lupinus leucophyllus*), and dozens of other species in trace amounts. By fall, when the trial was conducted, the forbs had senesced and decomposed and were largely unavailable.

These rangelands were grazed by ewes and their lambs under herded conditions in the spring (May and June) and again by the ewes after fall weaning (September and October). Although ewes were under constant surveillance of a herder, they had free access to the vegetation. Grazing constraints related to diet selection imposed by the herders were considered minimal because sheep were moved frequently (generally every 2 to 4 d) to new grazing sites within the rangeland (7,800 ac). The frequent moves prevented overgrazing and allowed the sheep free choice among existing vegetative species; therefore, diet selection for sagebrush was considered to be based on an individual animal's choice rather than being influenced by grazing pressure or forage availability. Average annual precipitation for the study area is 13 in.

Fecal Sample Collection and Analyses

Percentage sagebrush in the diet was determined by analysis of fecal samples with near infrared reflectance spectroscopy (NIRS) according to the procedure of Walker et al. (2000). Fecal samples were collected from the rectum of each ewe on 2 consecutive days in September and again in October. Fecal samples were collected mid-morning on September 24 and 25 and October 8 and 9 in 1996 and 1997. Within 6 h of collection, samples were dried in a forced air oven at 130° F for 48 h. Duplicate dried fecal samples were composited by individual animal within sampling month and year and stored at room temperature in paper bags.

Statistical Analyses

The statistical difference between September and October percentages of sagebrush in the diet was tested using the Tukey-Kramer method with the GLM procedure of SAS (1989). The model was an unbalanced repeated measures design. Samples from ewes were collected across months and years but not all ewes were present in both years or samples could not be collected. The fixed effects included months (September vs October), year of collection (1996 and 1997), genetic selection line (wool, maternal, and random control), and age of the ewe (2, 3, and >3 years of age). Body weight of the ewe at weaning was included as a linear covariate.

Genetic analyses of the data required identification of the genetic relationships among all ewes in the study. This was accomplished by using the MTDFNRM subroutine procedure found in the computer programs of Boldman et al. (1993). The genetic relationship matrix was generated from the Rambouillet pedigree file from 1975 to 1997 totaling 3,261 animals from 404 sires and 1,953 dams. The average inbreeding coefficient

was small (1.9 %); therefore, the effects of inbreeding on percentage sagebrush in the diet were assumed to be negligible.

Variance components for September and October percentages of sagebrush in the diet were estimated using a single- and two-trait statistical analyses. The two-trait analysis estimated genetic and environmental correlations between the sampling periods of September and October. Estimates of variance and covariance components were obtained using a derivative-free REML algorithm (Graser et al., 1987) with the computer programs of Boldman et al. (1993).

Single trait analyses were performed for each month of collection (September or October). The model included as fixed effects: year of collection (1996 and 1997), genetic selection line (wool, maternal, and random control), and age of ewe (2, 3, and >3 years of age). Body weight of the ewe at weaning was included as a linear covariate. Random effects included additive genetic effect of the ewe and permanent environmental effect of the ewe due to repeated measures. Because estimates of additive genetic variance component for percentage sagebrush in the diet were previously unknown, prior values for the analyses were initially based on a heritability estimate of 0.3 reported for diet selection in goats (Warren et al., 1983).

A two-trait analysis was performed to determine the genetic relationship between September and October percentages of sagebrush in the diet. The model included effects identical to those in the single trait model plus all possible covariances between additive genetic and permanent environmental effects for the two sampling periods.

Results and Discussion

Estimates of average percentage sagebrush in the diet as measured by NIRS on fecal matter did not differ across years of collection (P = 0.56; Table 2) but did differ between months of collection (P = 0.001). Sagebrush represented 21.6 % of the diet during September and increased to 31.7 % in October. All ewes consumed some sagebrush. The range between minimum and maximum percentage sagebrush in the diet was a two to three-fold magnitude.

Sagebrush has frequently been reported as an important forage plant for sheep. Cook et al. (1948) reported that Rambouillet sheep consumed 38.6 % sagebrush type browse in the northern central Utah mountains where sagebrush cover was estimated at 34 % during summer grazing (mid-July to mid-September). On sagebrush-grass rangelands where browse constituted 50 % of the herbage production big sagebrush comprised only 5 % of sheep diets from September to April (Cook and Harris, 1968). The higher percentage sagebrush in October compared to September diets was consistent with the generally observed increase in browse utilization by sheep as the season progresses on intermountain rangelands (Cook and Harris, 1968). The increased percentage sagebrush

in the diet presumably represented the increased value of this forage compared to other alternatives as the season progressed (Newman et al., 1995).

Table 2. Mean (± SD), minimum and maximum percentage sagebrush (*Artemisia tridentata*) in the diet of Rambouillet ewes

	September			October		
Year	Mean	Min.	Max.	Mean	Min.	Max.
1996	23.4 ± 2.4[a]	17.4	31.9	32.7± 2.9[b]	23.7	42.3
1997	19.5 ± 2.6[a]	10.3	28.4	30.4 ± 2.5[b]	23.6	39.6
Total	21.6 ± 3.2[a]	10.3	31.9	31.7 ± 3.0[b]	23.7	42.3

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).

Percentage sagebrush in the diet was not different among Rambouillet selection lines. Estimates of variance components from single trait analyses were similar to those from bivariate analysis; therefore, only estimates from the bivariate analysis are presented in Table 3. Heritability estimates were similar for September and October sampling periods (0.25 and 0.28, respectively). In a 2 yr study that investigated the heritability of diet selection of Spanish goats based on half-sib analysis of 155 goats from 14 sire groups in western Texas, Warren et al. (1983) concluded there was no sire effect for the preferred forage species. However, the average heritability for percent dietary composition of the non-preferred forage species was 0.30. Winder et al. (1995) investigated the genetic aspects of diet selection of Brangus cows in the Chihuahuan desert in New Mexico. They found significant sire effects for botanical composition of several plant species or genera in fall diets but not in winter or summer diets. Their heritability estimates, derived from a small number of sires (n = 12), ranged from 0.51 to 0.87 with large standard errors of about 0.5. Heritability estimates in our study were based on 1,949 diets from 549 ewes out of 100 sires. By comparison, heritability for weaning and yearling weight in ancestors to the sheep in this study were 0.45 and 0.57, respectively (Ercanbrack and Price, 1972).

Environmental effects represented approximately 70 % of the phenotypic variation each month. The large contribution of environmental effects to the variance for diet composition was expected because of the many biological factors influencing big sagebrush availability and palatability. The correlation between September and October environmental, or residual, effects was small (r = 0.16) inferring little overlap of environmental effects between the 2 months. Permanent environmental effects attributed to repeated observations on ewes were small and made up less than 4 % of the phenotypic variance.

Table 3. Estimates of components of variance and fractions[a] of total variance for percentage sagebrush in the diet in Rambouillet sheep from bivariate analysis

Month	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	h^2	pe^2	e^2
September	1.57	0.00	4.79	6.36	0.25	0.00	0.75
October	2.02	0.27	5.04	7.34	0.28	0.03	0.69

[a]σ^2_a, additive genetic variance; σ^2_{pe}, permanent environmental variance; σ^2_e, residual variance; σ^2_p, total variance; h^2, fraction of total variance represented by σ^2_a; pe^2, fraction of total variance represented by σ^2_{pe}; e^2, fraction of total variance represented by σ^2_e.

Genetic correlation between September and October intakes = 0.91.

Permanent environmental correlation = 0.00. Residual correlation = 0.16.

The genetic correlation between September and October percentages of sagebrush in the diet was 0.91. A genetic correlation greater than 0.85 strongly infers that the two traits are genetically similar (Robertson, 1959). Therefore, percentage sagebrush in the diet appears to be genetically similar between September and October although October's average percentage sagebrush in the diet was one-third greater than in September. Response to selection for percentage sagebrush in the diet should not differ whether genetic selection is based on observations made in September or in October. Also, the correlation between the random permanent environmental effects of the ewe was inconsequential (r = 0.003), indicating that the non-genetic effects associated with the ewe across sampling months were not important.

Genetic influences on diet selection have been investigated in mice (McClearn and Rodgers, 1961; Lush, 1981), humans (Krondl et al., 1983), goats (Warren et al., 1983), and cattle (Winder et al., 1995). However, genetic mechanisms affecting diet selection are only beginning to be understood. Studies are indicating that genes play an important part in physiological mechanisms affecting food preferences such as taste sensitivity, enzyme deficiencies associated with nutrient intolerance, and detoxification of chemicals. Studies in mice have demonstrated that genetic influences on dietary intake can be additive, recessive, dominant, or pleiotrophic (Bachmanov et al., 1996, 1997). Gene mappings are identifying loci in mice associated with the neural response to sensory taste factors for several chemicals including sweetness of the amino acid phenylalanine (Nimomiya et al., 1991), saccharin, sucrose and quinine (Blizard et al., 1999). In humans, genetic factors influence dietary preference via taste sensitivity. Acceptance or rejection for broccoli by humans has been linked to strong genetic influences on taste sensitivity to its bitter flavor associated with phenylthiocarbamide (Krondl et al., 1983). Genetics have also been found to influence preference for hamburger, cottage cheese, chicken, and orange juice by humans (Falciglia and Norton, 1994). In humans, the inability to digest certain foods has been linked to genetic influences on enzyme deficiencies; the most well known human enzyme deficiency being lactase (Lisker, 1984) but may also include fructose intolerance and galactosemia. Research to identify such genetic factors influencing the grazing

ruminant's preference is needed with potential application in animal nutrition, forage utilization, and biological control of noxious weeds.

In a practical sense, the heritability estimate for percentage sagebrush in the diet (0.25 to 0.28) is moderate, inferring that the trait will respond to selection pressure. The rate of response depends upon the selection pressures placed on the trait. A one percentage point increase of sagebrush in the diet per generation can be achieved when 20 animals out of a population of 100 are selected for breeding based upon their October percentage sagebrush in the diet (where selection intensity = 1.4, standard deviation of October sampling = 2.7, and October heritability estimate = 0.28).

The concept of diet selection as a heritable trait is relatively new (Walker, 1995; Launchbaugh et al., 1999). Selective breeding for diet selection characteristics could be used to improve the value of livestock for vegetation management. Use of livestock to control undesirable plants is dependent upon their utilizing the target plant at a level that will place that species at a competitive disadvantage relative to other plants in the community. For example, sheep grazing is routinely used to help manage leafy spurge (*Euphorbia esula L.*; Johnston and Peake, 1960) and three-tip sagebrush (*Artemisia tripartita* Rydb; Laycock, 1967).

As the economic and social importance of noxious weeds increases, use of livestock to help control these weeds can become an important selection criteria for breeders. In the U.S., the annual cost of controlling noxious weeds and lost production as a result of weed infestation is estimated to be $12 billion (Babbitt, 1998), compared to a total estimated value of sheep and lambs of $640 million (USDA-NASS, 1999). Thus, the direct cost of noxious weeds is 18 times greater than the total value of the sheep industry. Although sheep may never be the sole solution to the noxious weed problem, if they reduced it by only 5 %, they would double their total economic value.

Implications

This study confirms that genetic factors significantly influence the dietary preferences of grazing sheep for a single plant species, mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb) Beetle). Selective breeding to manipulate dietary preferences of ruminants may lead to improved animal production by producing animals with inherent preferences for more nutritional plants. Genetic manipulation of dietary preferences for target plant species may also result in more desirable forage utilization and biological control of noxious plants. Whereas ruminants have long been utilized as harvesters of forage, our perspectives could change to that of greater utilization of ruminants as managers of forage through their selective dietary preferences. The ultimate value of sheep production in the U.S. may depend on the sheep's ability to ecologically control the $12 billion cost of noxious weeds.

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Mechanisms of Vitamin D_3 on Tenderness of Lamb

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ABSTRACT

The objectives of the experiment were to determine the delivery system of vitamin D_3 (VITD) on Ca blood serum and 2) whether VITD supplementation improves Warner-Bratzler shear (WBS) values of chops from the *longissimus lumborum* (LL), *semitendinosus* (ST), *semimembranosus* (SM), and *biceps femoris* (BF) from each of 40 carcasses. Forty feedlot lambs were assigned randomly to one of two treatments of a control (CONT) (n=20) or 750,000 IU of VITD (n=20) and fed in a mock feedlot environment for 4 d before slaughter. There were no differences ($P > 0.05$) for ionized blood Ca levels in blood serum. Vitamin D_3 content in livers and kidneys differed ($P < 0.01$) between VITD vs. CONT (livers - 504.54 vs. 27.13 and kidneys - 1530.20 vs. 21.18 ng/g vitamin D_3). Carcasses from VITD treated lambs had less ($P < 0.05$) average fat thickness (AFT) (0.27 vs. 0.33 in) and an increase ($P < 0.05$) in overall conformation score (OCS). The four muscles were removed, fabricated into chops, and assigned randomly to a postmortem aging day of 5 (AG5), 10 (AG10), or 15 (AG15) for WBS determination. Chops from the LL did not differ ($P > 0.05$) for WBS values for CONT vs. VITD for all aging days; however, chops from the SM and ST had ($P < 0.05$) lower WBS values for VITD vs. CONT at 5 d aging. No other day differed for WBS values. Activation and acceleration of calpain dependent proteases could be responsible for lower WBS values for AG5 chops however, VITD regulators are most likely preventing VITD from increasing Ca levels in blood.

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Introduction

Several researchers have reported that injecting calcium chloride in lamb primals after slaughter resulted in acceleration of postmortem tenderization and increased overall tenderness (Koohmaraie et al., 1989, 1990; Koohmaraie and Shackelford, 1991; Clare et al., 1997). This effect on tenderness is thought to be a result of calcium dependent proteases (CDP), m and μ calpains, degrading the z-line in the muscle cell. These CDP's are thought to be accelerated when calcium can be placed into the muscle in greater quantities.

Studies have been performed to evaluate the elevation of serum calcium in blood on lactating dairy cows with low blood calcium through the supplementation of 5.0 or 7.5 x 10^6 IU of vitamin D_3 (VITD) to aid in the prevention of milk fever (Hibbs et al., 1946;

Hibbs et al., 1951; Hibbs and Pounden, 1955). These authors indicated that supplementing VITD to dairy cows prepartum for 7 to 14d resulted in increased serum calcium in the blood.

Recent studies have been performed to evaluate the effects of supplemented or bolused VITD on beef tenderness (Montgomery et al.,1997; Swanek et al., 1999; Hill et al.; 1999; Scanga et al., 1999) and one study evaluating pork (Enright et al., 1998) with the premise of supplementing VITD in large amounts increase calcium because VITD functions as a regulator of calcium and is required for active absorption of calcium (DeLuca, 1979). These studies have revealed conflicting reports. Montgomery et al. (1997) and Swanek et al. (1999) concluded that VITD could be responsible for increased tenderness of beef due to the activation of calpain proteases. However, both Hill et al. (1999) and Scanga et al. (1999) showed no differences in tenderness comparing the control vs. treated.

The present experiment was conducted to determine the effectiveness of supplementing VITD to feedlot lambs to ultimately improve meat tenderness through the activation of calpains.

Materials and Methods

The Institutional Agriculture Animal Care and Use Committee (IAACUC) of Texas A&M University approved the use and treatment of the rams and feedlot lambs in this study according to established guidelines (AUP #9-248AG). The lamb product harvested from the lambs used in Trial 2 was authorized as consistent with public health by the Department of Health & Human Services and could be placed into market as human food (Investigational New Drug File 010550 A0000).

The treatment level of VITD used in the trial was 750,000 IU supplemented (S750). This treatment level was determined by an initial trial studying the effects of varying levels of supplemented and bolused VITD on ionized blood calcium, weight gain, and percent intake. Forty lambs were purchased from Kothmann Commission Company and transported to the Texas A&M University Sheep Center. The 40 head were assigned randomly to eight pens with five lambs per pen. These lambs were fine-wool and fine-wool-cross sheep and consisted of both ewe and wether lambs. Breed types were determined by a panel of experts. Twenty lambs in four of the eight pens were assigned to a treatment of 750,000 IU of VITD, and 20 lambs in the remaining four pens served as the control.

The lambs were fed in a mock feedlot environment at the Texas A&M University Sheep and Goat Center located at the Animal Science Teaching, Research and Extension Center. The lambs were fed and given free access to a hay supplement for 7 d without VITD supplementation to allow adjustment to the new environment. The ration the lambs were fed was purchased from the Kothmann Commission Company (Menard, TX).

After the 7 d feeding adjustment, each pen was fed 10 lb of feed, with pens one, three, five, and seven supplemented with VITD. The VITD used in Trial 2 was Rovimixâ D_3 500 (500,000 IU/g) purchased from Rocheâ Vitamins, Inc. (Parippany, NJ). Before feeding, the refused feed was removed, weighed and recorded.

Slaughter and bleeding procedures

The first 20 lambs were transported to the Rosenthal Meat Science and Technology Center at Texas A&M University for slaughter. Lambs were slaughtered by approved humane techniques. Blood was collected immediately prior to exsanguination for later measurement of Ca levels. During slaughter, liver and kidney samples were removed, wrapped individually in aluminum foil and placed into an Harris Ultralow Temperature Freezer (Model # 21V-85, Harris Manufacturing, Asheville, NC) for later analysis of Ca.

Collection of grade data

After slaughter, carcasses were chilled for 24 h, ribbed between the 12^{th} – 13^{th} rib interface, and graded according to USDA (1992) guidelines prior to fabrication. Data were collected for dressing percent (DP), Adjusted fat thickness (AFT), longissimus muscle area (LMA), bodywall thickness (BWT), percent boneless, closely trimmed retail cuts (BCTRC), flank streaking (FS), skeletal and lean maturity (MAT), leg conformation score (LCS), and overall conformation score (OCS).

Fabrication and Warner-Bratzler shear (WBS) procedures

Loin and leg sections were removed from the right side of the carcass and used for WBS force after aging at 35.6° F for 5, 10, or 15 d. Individual muscles from these sections that were used for shear force determination were the *longissimus lumborum* (**LL**), *semitendinosus* (**ST**), *semimembranosus* (**SM**), and *biceps femoris* (**BF**). Each of these muscles was removed and fabricated into 1.25-in-thick chops and randomly assigned to one of the three aging treatments. Following the procedure outlined by Carpenter and King (1965), the LL was cut into six, 1.25-in-thick chops and trimmed free of fat and bone. Two loin chops were assigned randomly to one of the three aging treatments. The ST, SM, and BF muscles each were cut into three, 1.25-in-thick chops, trimmed free of fat and bone and assigned randomly to one of the three aging d. These chops were broiled and cooked to an internal temperature of 158°F on a Farberware Open-Hearth Broiler (model 450N, Kidde, Inc; Bronx, NY) according to AMSA (1995) guidelines. These chops were chilled for 24 h, after which three cores were removed from each chop parallel to the muscle fiber orientation.

Measuring VITD in livers and kidneys

Vitamin D_3 was measured in the livers and kidneys by the National Animal Disease Center (Ames, IA).

Statistical Analysis

Data from ionized blood Ca concentrations in blood serum, percent intake, weight gain, tissue calcium, liver calcium, and kidney calcium from Trial 2 were analyzed by analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS

(1988). Main effects were treatment levels (0 and 750,000 IU of VITD). Significant differences between lest squares means were determined at the $P < 0.05$ level.

Data for WBS values from Trial 2 were analyzed as a split-split plot design using the GLM procedure of SAS (1988). Main effects of interest were treatment, muscle, and aging d. The whole plot was treatment with animal identity as the error team. The split plot was muscle and its interaction with treatment, with animal identity nested within the interaction of treatment and muscle as the error term. For the split-split plot aging, day and its interaction with all other main effects were the effects of interest. The true error was utilized in the split-split plot analysis. All interactions of the main effects found to be non-significant ($P > 0.05$) were pooled into the error term. Additionally, cooking loss was utilized as a covariate in the WBS analysis. Least squares means were separated using a pair wise *t*-test using a predetermined p-value of $P < 0.05$.

Results and Discussion

Least squares means for ionized blood calcium in serum are presented in Table 1. It should be highlighted that there was no difference comparing the control vs. treated. However, VITD in livers and kidneys were highly significant ($P < 0.01$) (livers - 504.54 vs. 27.13 and kidneys - 1530.20 vs. 21.18 ng/g vitamin D_3) comparing treated to control. The high levels of VITD in the kidney could be a direct result of secretion of the hormone calcitonin. Calcitonin is secreted when there is an unusual rise in calcium in blood. Calcitonin reabsorbs VITD from the blood and stores it in the kidney (McDowell, 1989).

Table 1. Least squares means of ionized blood calcium concentrations in blood serum comparing treatment for Trial 2[a]

	Ionized Blood Calcium			
Item	Control	Vitamin D_3	SEM	$P <$
Initial[b]	9.85	10.10	0.16	0.25
Final[c]	9.90	10.00	0.16	0.62
Difference[d]	0.05	-0.10	0.15	0.50

[a] Lambs were supplemented vitamin D_3 at 750,000 IU's per d for 4 d before slaughter.
[b] Initial calcium was measured 1 d before the initiation of the treatment.
[c] Final calcium was measured the day of exsanguination.
[d] Difference was determined by subtracting the initial calcium from the final calcium.

Table 2 shows the least squares means for the main effect of VITD and control. Even though VITD did not affect carcass characteristics in previous beef trials (Duckett et al., 1998; Hill et al., 1998; Scanga et al., 1999), two traits differed ($P < 0.05$) between VITD and control treatments. AFT was less in the VITD lambs (0.27 in) compared to the

control (0.33 in). These results could be attributed to treated lambs not consuming the treated feed resulting in a lack of intake. There was also a ($P < 0.05$) difference in OCS for VITD compared to the control. The carcasses with less fat would display a more muscular shape over the leg, loin, rack, and shoulder resulting in a higher OCS.

Table 2. Least squares means for the main effect of treatment on simple carcass traits from supplemented vitamin D_3 in Trial 2[a]

Trait	Control	Vitamin D_3	SEM	$P =$
Dressing percent, %	58.97	59.01	0.50	0.96
Adjusted fat thickness, in	0.33	0.27	0.06	0.05
Longissimus muscle area, in^2	2.37	2.45	0.53	0.51
Bodywall thickness, in	1.11	1.06	0.11	0.55
Boneless, closely trimmed retail cuts, %[b]	44.86	45.27	0.35	0.39
Flank streaking[c]	380.44	383.41	8.30	0.79
Overall maturity[d]	153.81	157.12	2.54	0.34
Leg conformation score[e]	388.10	400.85	8.25	0.26
Overall conformation score[f]	379.21	394.50	5.00	0.03

[a]Lambs were supplemented vitamin D_3 at 7.5×10^5 per d for 4 d before slaughter.

[b]Percentage of boneless, closely trimmed retail cuts: determined by formula using adjusted fat thickness, longissimus muscle area, belly wall thickness, and carcass weight as factors. The equation: = 49.936 – (.0848 x carcass weight, pounds) – (4.376 x adjusted fat thickness, inches) – (3.530 x (bodywall thickness, in) + (2.456 x longissimus muscle area, $inches^2$)

[c]Flank streaking: 300 to 399 and 400 to 499 = USDA Choice and USDA Prime, respectively.

[d]Total maturity: 100 to 199 = red, youthful color of lean in flanks and red, round ribs.

[e]Leg conformation score: 300 to 399 and 400 to 499 = USDA Choice and USDA Prime, respectively.

[f]Overall conformation score: 300 to 399 and 400 to 499 = USDA Choice and USDA Prime, respectively.

The treatment effect of VITD to feedlot lambs on WBS values is shown in Table 3. The table summarizes the WBS values for each of the four individual muscles at the defined postmortem aging d. The muscles originating from the leg region of the carcasses revealed encouraging results. The 5 d postmortem aging WBS values for the SM and the BF revealed lower ($P < 0.05$) WBS values for treated compared to control, but there was no significant difference. In general, for the leg muscles, as postmortem d increased in regard to the leg muscles, the control displayed lower WBS values or narrowed the range of the WBS values when compared to the treated. This also was evident in the overall WBS values of treated versus control. Day 5 comparisons of WBS values resulted in lower values for the treated versus the control ($P = 0.13$). However, 10 and 15 d postmortem aging revealed lower WBS values for the control versus the treated with a significant reduction ($P < 0.05$) at d 15. These WBS value differences, in regard to postmortem aging of VITD versus control product also were noted by Swanek et al. (1999). These

steaks from the LL had lower WBS values for the treated at 7 d, but steaks aged at 14 and 21 d revealed no WBS difference. The results from this study and Swanek et al. (1999) suggests that VITD could accelerate the postmortem aging process, however, after a duration of approximately 4 to 7 d, this acceleration is halted. However, the LL muscle displayed lower ($P < 0.05$) WBS values for the control versus the treated at aging d of 5 and 15. Day 10's WBS values also revealed a decrease in WBS values for the control, but these results were not significant ($P = 0.13$).

Table 3. Least squares means for the main effect of treatment on tenderness of the *longissimus lumborum*, *semitendinosus*, *semimembranosus*, and *biceps femoris* muscles using Warner-Bratzler Shear Values (lb.) in Trial 2[a]

	Treatment			
Muscle	Control	Vitamin D_3	SEM	$P <$
Longissimus lumborum				
Shear force, d 5	5.16	5.84	0.07	0.01
Shear force, d 10	5.07	5.42	0.07	0.13
Shear force, d 15	4.59	5.23	0.07	0.01
Semitendinosus				
Shear force, d 5	6.81	6.57	0.12	0.54
Shear force, d 10	6.68	6.44	0.12	0.56
Shear force, d 15	5.95	5.53	0.12	0.26
Semimembranosus				
Shear force, d 5	8.36	7.74	0.07	0.01
Shear force, d 10	7.21	8.09	0.07	0.01
Shear force, d 15	6.68	7.12	0.07	0.06
Biceps femoris				
Shear force, d 5	6.46	5.73	0.10	0.02
Shear force, d 10	5.97	5.95	0.10	0.99
Shear force, d 15	5.38	6.02	0.10	0.06
Overall				
Shear force, d 5	6.70	6.48	0.05	0.12
Shear force, d 10	6.22	6.48	0.05	0.09
Shear force, d 15	5.64	5.97	0.05	0.03

[a]Lambs were supplemented vitamin D_3 at 750,000 IU per d for 4 d before slaughter.

Table 4 displays WBS values of the four studied muscles at 5, 10, and 15 d. WBS values decreased as aging d increased. The LL had a lower ($P < 0.05$) WBS values than each of the other three muscles at all aging d. The values of 5.16, 5.07, and 4.59 lb. were much lower than the results published by Carpenter and King (1965). These authors had WBS values of 9.74 in, but had a zero aging period for the chops. The three muscles

analyzed in the leg displayed variation in tenderness results. Even though the BF muscle did display lower WBS values than the ST, these values were only significant ($P < 0.05$) at 10 and 15 d. The BF muscle had lower ($P < 0.05$) WBS values at each d when compared to the SM. The SM displayed lower WBS values at all three aging d, but it was only significant ($P < 0.05$) at d 5. These results differ from the results recorded by Jeremiah et al. (1971) who found the SM to have the most desirable tenderness rating, followed by the BF, and the SM in lamb, but Ramsbottom et al. (1945) results on beef tenderness muscles found the same ranking of WBS values as this study.

Table 4. Least squares means of tenderness on muscle type at 5 , 10, and 15 d aging of the control lambs from the *longissimus lumborum, semitendinosus, semimembranosus*, and *biceps femoris* muscles using Warner-Bratzler Shear Force (lb) in Trial 2

	Muscle Type				
Shear force, aging day	*Longissimus lumborum*	*Biceps femoris*	*Semitendinosus*	*Semimembranosus*	SEM
Shear force, d 5	5.16[a]	6.46[bc]	6.81[c]	8.36[d]	0.09
Shear force, d 10	5.07[a]	5.97[b]	6.68[cd]	7.21[d]	0.09
Shear force, d 15	4.59[a]	5.38[b]	5.95[cd]	6.68[d]	0.09

[a,b,c,d]Within a row, least squares means lacking a common superscript letter differ ($P < 0.05$).

Implications

The hormone calcitonin is most likely being secreted when lambs are supplemented high dosage levels of VITD. Because of this, high levels of VITD to increase tenderness in lamb meat is not unlikely to work. However, further studies should be implemented to determine what level of VITD stimulates the release of calcitonin. There could be the possibility of supplementing VITD just below this level to increase plasma calcium without antagonistic release of calcitonin.

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Pre-chilled Versus Chilled Carcass Grading of Ovine Carcasses

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ABSTRACT

The objective of this experiment was to determine if Ovine carcasses could be graded pre-chilled (hot) to the same degree of accuracy as they are presently graded chilled (cold). Lamb carcasses were collected for the study on three consecutive days (d 1, n = 219; d 2, n = 206; d 3, n = 155) at a commercial slaughter facility in San Angelo, TX. Carcass sampling was established by the order each lamb carcass arrived on the slaughter floor, although an effort was made to obtain carcasses with variation in subcutaneous fat thickness. Each lamb carcass was graded hot at an average time of 15 min post stunning. Following a 20 h average chill, each carcass was graded a second time for the cold grade. Three experienced evaluators (USDA Meat Grading Supervisors) independently graded each unribbed carcass to closely simulate industry conditions. These grades were assigned without the aid of a measuring device. Correlation coefficients were 0.125, 0.200, 0.440, 0.604 and 0.771 for hot bone, hot lean, hot flank streaking, hot quality grade and hot yield grade, respectively. R^2 values were 0.015, 0.039, 0.0004, 0.003, and 0.595. for hot bone, hot lean, hot flank streaking, hot quality grade, and hot yield grade, respectfully. Grader training will be required to evaluate the hot carcasses. Hot grading does not appear to be feasible in the establishment of maturity or quality of the carcass but may be adequate in the determination of yield grades.

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Introduction

Cold carcass grading is the normal, accepted method of evaluating Ovine carcasses for grade assignments. Currently, Ovine carcasses are graded after an average 20 h chilling period. After chilling, the carcasses are graded by trained USDA personnel, and the carcasses are sorted by grade and an inventory of the previous days processing is created. Plant personnel do not actually know how many carcasses of any one yield grade are on hand until grading, sorting and inventory have been completed. The purpose of this study was to establish the accuracy of assigning the subjective grade of Ovine carcasses hot vs cold.

The primary interest in hot carcass grading is one of improving plant efficiency through decreased labor requirements. If a facility could place a grader at the end of the processing line, the carcasses could then be sorted off of the slaughter floor into graded

coolers. Currently, the carcasses are graded the morning following slaughter and subsequently sorted by grade. Grading the carcasses hot would enable the processor to accomplish several efficiency goals simultaneously. The carcasses would be graded as they came off of the processing line and could then be sorted by grade into coolers. The processor could maintain a running inventory of each grade of carcass throughout the day. This inventory would strengthen the ability of the packer to market the carcasses throughout the day as they became available. The ability to grade hot would decrease plant personnel requirements because the need to resort entire coolers following grading would be eliminated. The ability to grade hot could also possibly shorten the time in the cooler for each carcass. The processor could ship the carcasses sooner because there would no longer be a need to wait on the graders to complete grading before shipping.

There has been substantial research with methods of objectively grading using various types of instrumentation. The primary problem arises with the transfer of technology from the laboratory to industrial application. Subjective grading is rooted in tradition and has relied on visual appraisals for evaluating and grading live animals and carcasses for the last 50 years. To change methods of evaluating, carcass composition will require a major adjustment in philosophy (Forrest and Judge, 1994).

Scientific evaluation of a potential grading technology is often overly concerned with equipment accuracy and neglects the operational needs of the packing plant. Sim (1983) stated that "The bottom line is in productivity." Therefore, a particular piece of equipment has no chance of incorporation into an integrated on-line system if it slows chain speed, has the potential to produce "down time", requires additional personnel, or necessitates extra time for operation. Electronic technology has little chance for on-line application if it does not generate monetary gain by replacing plant personnel, improving carcass classification, or by more accurately pricing the carcass relative to yield of lean.

Therefore, there has been a great deal of interest in hot carcass grading as an alternative to mechanical means of grading to improve efficiency. Hot carcass grading can increase the turnaround time of the carcass by decreasing the time the carcass is in the cooler before being shipped. Hot grading will eliminate the extra sorting after cold grading because the carcasses will be sorted according to grade as they are put into coolers. Hot carcass grading will provide the packer with a running inventory of each grade continuously throughout the day. Hot carcass grading will remain a subjective score assigned by trained personnel. The same personnel that have been assigning grades to chilled carcasses.

The purpose of this study is to answer the question of whether hot grading can be accomplished on the processing floor and if hot grading may be done as accurately as cold grading.

Materials and Methods

Lamb carcasses (n = 578) were collected for the study on three consecutive days (d 1, n = 219; d 2, n = 206; d 3, n = 153) at a commercial slaughter facility in San Angelo, TX. Carcass sampling was established by the order each lamb carcass arrived on the slaughter floor, although an effort was made to obtain carcasses with variation in subcutaneous fat thickness. Lamb carcasses with pulled fell membranes or distorted fat coverings were excluded from the study. Each lamb carcass was individually identified with the plant slaughter tag according to the d of harvest.

Each lamb carcass was evaluated hot with the carcass temperatures ranging from 103 to 106 °F at an average time of 15 min post stunning. Following a 20-hr average carcass chill, each lamb carcass was evaluated a second time at 32 °F. This second evaluation was recorded as the cold grade assigned to each carcass.

Visual estimates

Three experienced evaluators (USDA Meat Grading Supervisors) independently evaluated each unribbed carcass, and recorded estimates on bone maturity, lean maturity, flank streaking, conformation, and USDA yield grade. Each carcass was evaluated hot and cold with the cold estimate being designated the "actual" measurement because it is the current method accepted by the industry in grading lamb carcasses. These estimates were made without the aid of a measuring device to facilitate determination of the efficacy of assigning grades to the aforementioned factors using visual assessments by the graders of hot and cold carcasses.

External Fat Measurements

Measurements of external fat thickness were obtained by an experienced evaluator (USDA Grading Supervisor) using a metal ruler. The evaluator obtained two measurements on each unribbed carcass over each ribeye. External fat thickness was measured at a point over the center of each ribeye, between the 12^{th} and 13^{th} ribs. The average of the two fat thickness measurements (obtained on the left and right side of each carcass) was recorded as the fat thickness value for that individual carcass.

Maturity

Differentiation between lamb, yearling mutton, and mutton carcasses is determined on the basis of differences in the development of their muscular and skeletal systems. Lamb carcasses have slightly wide and moderately flat rib bones and light red color and fine texture of lean. Typical yearling mutton carcasses have moderately wide rib bones that tend to be flat and a slightly dark red color and slightly coarse texture of lean. Typical mutton carcasses have wide, flat rib bones and a dark red color.

Skeletal maturity is determined by the presence of break or spool joints located on the forelimb. Trotters have an important role in determining the classification of a carcass. A carcass with two break joints on both front trotters or one "spool" joint and a break joint on the other front trotter will be classed as lamb or yearling mutton based on its other

evidences of maturity. A carcass with "spool" joints on both front trotters will be classed as yearling mutton or mutton based on other maturity indicators. A carcass with two "spool" joints will result in the yearling mutton or mutton classification on other maturity indicators. Mutton carcasses must have two "spool" joints on both forelimbs.

In determining the maturity class of Ovine carcasses, more consideration is given to the characteristics of the flesh than is given to the characteristics of the skeleton. Carcasses from young (A maturity) lambs have moderately narrow, slightly flat rib bones; moderately red moist and porous break joint(s); and a slightly dark pink color of inside flank muscle. Carcasses from more mature lambs (B maturity) have slightly wide, moderately flat rib bones; slightly red, but slightly dry and hard break joint(s); and a light red color of inside flank muscles.

Flank Streakings and Firmness

The quality of the lean flesh is most effectively evaluated by consideration of its texture, firmness, and marbling, in a lean cut surface. However, lamb carcasses are not ribbed in the industry, thus, lean cut surfaces are not typically present. Therefore, the quality of lean is evaluated indirectly by evaluating the quantity of fat streaking within and upon the inside flank muscles in relation to the apparent evidences of maturity. Within each grade, the requirements for flank fat streaking increase progressively with evidences of advancing maturity. The relationship between flank fat streaking, maturity, and quality is shown in Table 1.

Table 1. Flank fat streaking and firmness scores for lamb

Quality Trait	Scores	
Flank fat streaking	Abundant	Small
	Moderately abundant	Slight
	Slightly abundant	Traces
	Moderate	Practically devoid
	Modest	Devoid
Firmness	Extremely firm	Tends to be slightly firm
	Tends to be extremely firm	Tends to be slightly soft
	Firm	Slightly soft
	Tends to be firm	Tends to be moderately soft
	Moderately firm	Moderately soft
	Tends to be moderately firm	Soft
	Slightly firm	Very soft

USDA, 1992.

Conformation

Conformation is defined as the manner of formation of the carcass with particular reference to the relative development of the muscular and skeletal systems, in addition to the quantity and distribution of external finish. However, external fat in excess of that normally left on retail cuts is not to be considered in evaluation of conformation.

The conformation descriptions included in each of the grade specifications refer to the thickness of muscling and to an overall degree of thickness and fullness of the carcass. The conformation of a carcass is evaluated by averaging the conformation of its various component parts, giving consideration not only to the proportion that each cut is of the carcass weight, but also to the general desirability of each cut as compared to the other cuts.

Superior conformation implies a high proportion of edible meat to bone and a high proportion of the weight of the carcass in the more demanded cuts, and is reflected in carcasses that are very thick muscled, very wide, and thick in relation to their length, and possess a very plump, full, and well rounded appearance. Inferior conformation implies a low proportion of edible meat to bone and a low proportion of the weight of the carcass in the more demanded cuts, and is reflected in carcasses that are very thinly muscled, very narrow in relation to their length, and that have a very angular, and thin, appearance. Table 2 gives the basic description of each grade. Table 3 illustrates the extent to which superiority in quality may compensate for deficiencies in conformation, and vice versa, indicated for each grade in the official standards.

USDA Yield Grades

The USDA yield grade equation for lamb is an estimation of percent closely trimmed (.10 in or less) semi-boneless, major retail cuts from the leg, loin, rack, and shoulder. The yield grade of an Ovine carcass is determined on the basis of adjusted fat thickness over the ribeye muscle between the 12^{th} and 13^{th} ribs. The USDA yield grade equation is as follows: USDA Yield Grade = .4 + (10 X Adjusted fat thickness, 12^{th} rib, in). The range of fat thickness for each yield grade is reflected in Table 4.

Statistical Analysis

Statistical evaluation of the utility of hot grading will be based on comparison of (1) simple coefficients of correlation between hot carcass evaluations and cold evaluations, and (2) Least Squares estimates of visual hot carcass evaluations regressed on cold carcass evaluations. Each carcass was evaluated hot and cold by each evaluator. The objective of this study was not to evaluate the accuracy of the evaluator but evaluate the effectiveness of the grading procedure. Therefore, the grade assigned by each grader for each carcass was combined for a composite score for each factor considered. These composite scores were then used for statistical analysis.

Table 2. Conformation equivalents for lamb carcasses

Grade	Description
Minimum Prime	Moderately wide and thick in relation to their length Moderately plump and full legs Moderately wide and thick backs Moderately thick and full shoulders
Minimum Choice	Tend to be slightly wide and thick in relation to their length Tend to have slightly plump and full legs Tend to have slightly wide and thick backs Tend to have slightly thick and full shoulders
Minimum Good	Moderately narrow in relation to their length Slightly thin and tapering legs Slightly narrow and thin backs Slightly narrow and thin shoulders
Minimum Utility	Very angular and very narrow in relation to their length Thin and slightly concave legs Very narrow and sunken backs Narrow and sharp shoulders Hip and shoulder joints are plainly visible
Minimum Cull	Extremely angular and extremely narrow in relation to their length Extremely thin-fleshed throughout Extremely thin and concave legs Extremely sunken and thin backs Very thin and sharp shoulders Hip and shoulder joints, ribs and bones of the spinal column are clearly outlined

USDA, 1992.

Table 3. Examples of the extent to which superiority in quality may compensate for deficiencies in conformation, and vice versa, indicated for each grade in the official standards

Grade	Example
Prime	Superior conformation will not compensate for deficient quality, thus a lamb must have at least low Prime quality. Superior quality will compensate for inferior conformation on an equal basis to the extent of a combination of low Choice conformation and high Prime quality. The lean flesh and external fat must be not less than moderately firm and a carcass must have a thin covering of external fat.
Choice	Superior conformation (avg. Choice) will compensate for 1/3 grade of deficient quality (high Good). Superior quality will compensate for inferior conformation on an equal basis to the extent of a combination of low Good conformation and high Choice quality. The lean flesh and external fat must be not less than tends to be slightly firm and a carcass must have a thin covering of external fat.
Good	Superior conformation (avg. Good) will compensate for 1/3 grade of deficient quality (high Utility). Superior quality compensates for inferior conformation on an equal basis to the extent of high Utility conformation and average Good quality. The lean flesh and external fat must not be less than slightly soft.

USDA, 1992.

Table 4. USDA yield grade for lamb and fat thickness ranges

Yield Grade	Fat thickness range in inches
1	.00 to .15
2	.16 to .25
3	.26 to .35
4	.36 to .45
5	.46 or greater

USDA, 1992.

Results and Discussion

Lean and Bone

The purpose of evaluating the bone and lean of the carcass in to aid in the determination of maturity of the carcass. This study revealed very low correlation's (0.125 and 0.200) for bone and lean evaluation. R^2 values were indicative of the inability of the hot assessment to predict the cold score. The R^2 value is an indicator of how well the hot carcass grade was at predicting the cold carcass grade. Therefore, a higher R^2 value indicates a better prediction of the cold grade.

However, in an industrial setting, the maturity questions of the carcass are most often handled on the processing line. As the carcass proceeds on the chain, the trotters are evaluated, if the break joint is indicative of a mutton carcass, the carcass is transferred to another rail. The ability or inability of the grader to evaluate maturity of the carcass on the basis of bone and/or lean is insignificant due to the mechanism of assessing maturity on the processing line.

All carcasses were assigned to either an A or B classification as well as a numerical score. Numerical scores reflected the position of the carcass within either the A or B maturity group. All carcasses in this study were classified as A maturity carcasses both hot and cold, the differences resulted from the numerical assignments which are not used in the industry. Table 5 illustrates the regression analysis for hot bone and hot lean as a predictor of cold bone and cold lean.

Table 5. Regression equations to predict cold bone or lean grade based on hot evaluation

	Intercept		Slope		R^2		MSE		N	
Model	Bone	Lean	Bone	Lean	Bone	Lean	Bone	Lean	Bone	Lean
Day 1	45.119	39.175	0.146	0.191	0.029	0.033	34.384	46.838	219	219
Day 2	40.853	23.546	0.160	0.440	0.057	0.215	17.644	22.775	206	206
Day 3	43.575	26.939	0.181	0.499	0.028	0.089	34.611	48.238	153	153
Overall	41.012	39.112	0.195	0.197	0.015	0.039	31.167	43.923	578	578

Flank Streaking

Flank streaking is used as an indicator of the quality of the lean flesh and is most effectively evaluated by consideration of its texture, firmness, and marbling, in a lean cut surface. However, lamb carcasses are not ribbed in the industry, thus, lean cut surfaces are not available for evaluation. Flank streaking is also used as an indicator of maturity as the apparent evidences increase with maturity.

There were no predictable relationships between hot evaluation of flank streaking and cold flank streaking. The correlation coefficient for hot flank streaking was 0.440. R^2

from regression for hot flank streaking to predict cold was 0.0004. These two values combine to reiterate the assess ability of the subjective hot score to predict the cold score for flank streaking.

Variability is most likely due to differences in the visibility of the fat within the inside of the flank muscles. As a carcass dehydrates, water is lost primarily from the fat of the carcass thus changing the appearance of the fat deposits. While the carcass is hot, the fat appears transparent; whereas, when the carcass dehydrates and the fat compresses, the fat assumes a white color that enhances visibility.

Quality Grade

Quality grades of an Ovine carcass are based on separate evaluations of two general considerations. First the quality, or palatability indicating characteristics of the lean, and the conformation of the carcass.

Conformation is the state of the carcass with reference to the relative development of the muscular and skeletal systems. The conformation of the carcass may be influenced somewhat by the quantity and distribution of external finish.

Findings of this study indicate that the graders were unable to satisfactorily grade the quality of a hot carcass. The correlation coefficient was 0.604 which can be considered moderately correlated, R^2 values were 0.003 which indicate that the percentage of the occurrence of the hot grade predicting the cold was low. However, in this study, each grader also assigned a numerical value within each quality grade. A numerical value was an effort to be more precise in the placement of the carcass within any given grade. The primary reasoning behind the variation in quality grade is due to the differences in appearance of the carcass when hot. As the carcass cools, the lean and fat assume a more compact and fuller state with differences in color as well. These factors all contribute to the variation between hot and cold carcass grades. However, the overwhelming majority of the lambs slaughtered in the United States all grade choice. One must question if the low correlation's and low R^2 values are really significant in the commercial setting.

Accuracy of hot quality evaluation would increase with experience of the grader. The appearance of the carcass is different when hot than cold. The appearance of the fat and the appearance of the texture and firmness of the lean provide the largest variance in appearance from hot to cold. When cold, the fat will be primarily transparent while after chilling, the fat will assume a white appearance which dramatically increases the visibility. The appearance of the texture and firmness of the lean appear more placid and not as firm when hot. When the carcass has chilled, the fat has solidified and much of the muscle has chilled which causes some expansion of the lean tissue, which gives a fuller, more rounded appearance.

When the grade is based on a subjective score, then the subtle appearance differences become major factors in determining the grade of the carcass. The correlation coefficient for hot quality grade was 0.604. R^2 from regression for hot quality grade to predict cold was 0.003. As with the other factors considered in this study, the grade assigned to the

hot carcass was compared with the grade assigned to the same carcass cold. Table 6 illustrates regression analysis for hot quality grade to predict cold quality grade.

Table 6. Regression equations to predict cold quality grade based on hot evaluation

Model	Intercept	HQG	R^2	MSE	N
Day 1	266.634	0.011	0.000	165.174	219
Day 2	239.316	0.150	0.071	144.434	206
Day 3	117.313	1.015	0.072	249.958	153
Overall	248.962	0.115	0.003	193.156	578

Yield Grade

Yield grades for an Ovine carcass are based on the amount of external fat present. The amount of fat is evaluated in terms of its actual thickness over the center of the ribeye muscle and is measured perpendicular to the outside surface between the 12th and 13th ribs. The fat thickness may be adjusted at the discretion of the grader. When carcasses do not have a normal distribution of external fat, the fat thickness over the ribeye may be adjusted to reflect unusual amounts of fat on other parts of the carcass.

Table 7 gives the correlation coefficients for yield grade. The overall correlation coefficient for hot yield grade was 0.771. Table 8 illustrates the regression analysis for hot yield grade to predict cold yield grade. Hot and cold yield was moderately correlated and the hot carcass yield grade accounted for 59% of the variation between the two evaluations. The next question is how accurate is the cold grade compared with the actual yield grade calculated from the actual fat thickness measurement using the metal probe. The R^2 value for the cold yield grade to predict the actual yield grade was 0.530. While the R^2 value for hot yield grade to predict actual yield grade was 0.355. There is about a 20% difference between the two grades in the ability to predict the actual yield grade determined from the metal probe measurement. The graders have been trained to grade carcasses cold. In this study, the graders were able to correctly grade hot yield in lamb carcasses correctly 35% of the time when compared to actual yield grade but were accurate in grade placement of cold carcasses 59% of the time when compared with the subjective cold yield grade. An assumption could be made that with further training, the graders could easily improve on hot yield grade accuracy with further experience and training.

Table 7. Simple correlation coefficients for hot and cold yield grade

	Hot Yield Grade				Cold Yield Grade			
	Day 1	Day 2	Day 3	All Days	Day 1	Day 2	Day 3	All Days
Hot Yield	1.000	1.000	1.000	1.000	0.652	0.823	0.787	0.771
Cold Yield	0.652	0.823	0.787	0.771	1.000	1.000	1.000	1.000

Table 8. Regression equations to predict cold yield grade based on hot evaluation

Model	Intercept	HYG	R^2	MSE	N
Day 1	0.844	0.653	0.4255	0.086	219
Day 2	-0.427	1.029	0.674	0.087	206
Day 3	-0.962	1.151	0.618	0.164	153
Overall	-0.132	0.933	0.595	0.126	578

Implications

Low correlation and low R^2 values for all factors except yield grade seem to indicate that Ovine carcasses may not be graded hot with any degree of certainty. However, maturity is assessed in the commercial facility on the kill floor. There is not a need for the grader to be able to determine the maturity of the carcass based on lean and/or bone evaluation of the carcass. The grader will be able to determine maturity of the carcass by the trotters. The graders in this study correctly placed all carcasses into either A or B maturity groups 100% of the time. The effort to assess flank streaking, quality grade, and yield grade will require experience and training of the graders to be better able to evaluate the thickness of the fat covering over the ribeye.

It is also possible that hot grading could be coupled with a measuring device that would enhance the accuracy and decrease the subjectivity of grading Ovine carcasses. Implementation of this technology within the industry could prove difficult, as change is slow in a business so steeped in tradition. However, if instrumentation were developed which would not slow the chain, produce down time, or require additional personnel, implementation would be more likely.

A large amount of the variation in this study can be attributed to the graders in that they are not accustomed to evaluating the factors set forth in this study on a daily basis. If training and practice were provided, much of the between grader variation could possibly be removed. Any other work in this area should be done with the USDA graders

at the plant. These are the graders who grade on a daily basis and are more accustomed to the unique colors and physiology of the lamb carcass.

Hot carcass grading has the potential to change the standard operating procedure of lamb facilities across the United States. If hot carcass grading were implemented, the processor would be able to decrease labor requirements. If a facility could place a grader at the end of the processing line, the carcasses could then be sorted on the rail as the carcasses exit the kill floor area into graded coolers. Currently, the carcasses are graded the morning following slaughter and subsequently sorted by grade. Grading the carcasses hot would enable the processor to accomplish several efficiency goals simultaneously. The processor could maintain a running inventory of each grade of carcass throughout the d. This inventory would strengthen the ability of the packer to market the carcasses throughout the d, as they became available. The ability to grade hot would decrease plant personnel requirements because the need to resort entire coolers following grading would be eliminated. The ability to grade hot could also possibly shorten the time in the cooler for each carcass. The processor could ship the carcasses sooner because there would no longer be a need to wait on the graders to complete grading before shipping. The combination of the aforementioned factors would increase the labor and plant resource utilization, which could ultimately increase the profitability of the plant.

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Frankfurters Made with Lamb and Other Meats and/or Fats

K.S. Rhee and S.U. Bohanan

ABSTRACT

This study was conducted to determine sensory and chemical properties of reduced-fat frankfurters made with lean lamb or lean lamb/pork in combination with lamb fat, pork fat or high-oleic sunflower oil. Reduced-fat frankfurters with lean beef/pork plus pork fat as well as high-fat frankfurters with lamb/pork or beef/pork plus pork fat were also made for comparison. Actual fat contents of reduced-fat and high-fat products formulated for 15% and 30% fat were 17 to 18% and 28 to 31%, respectively, after processing. Fat content and processing yield were not significantly different among all reduced-fat products. Trained sensory panelists rated reduced-fat lamb/pork frankfurters with pork fat less intense in lamb flavor when compared to similar products with sunflower oil or lamb fat. Off-flavor intensity scores increased as lamb-flavor intensity scores increased, whereas frankfurter-flavor intensity scores decreased as lamb-flavor and off-flavor intensity scores increased. Consumer panel results indicated that the reduced-fat product made with lean lamb/pork and pork fat was as desirable in flavor as the reduced-fat product made with lean beef/pork and pork fat or their high-fat counterparts. Little lipid oxidation occurred in any of the products when vacuum-packaged samples were stored at 4°C for 12 wk.

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Introduction

Frankfurters provide convenience for the consumer and are widely consumed. Traditional (regular-fat) frankfurters, however, are fairly high in fat content (and calories), saturated fatty acids and cholesterol. There have been research efforts to decrease saturated fatty acids in frankfurters by increasing monounsaturated fatty acids (St. John et al., 1996; Park et al., 1989,1990). The fatty acid changes have been achieved either by using meat with an elevated level of monounsaturated fatty acids or by simply replacing knife-separable animal fats with a high-oleic acid vegetable oil. The impetus of such efforts was the advantage reported of dietary monounsaturated fatty acids over other fatty acid groups – decreasing the undesirable (LDL) cholesterol level in plasma without affecting the desirable (HDL) cholesterol level (Grundy, 1986). Currently, no lamb-based frankfurters are available at supermarkets or large retail stores in the United States. This is consistent with the low annual consumption of lamb (USDA, 1998). The distinct species-related flavor of lamb (Rhee and Ziprin, 1996) and relatively high prices could be some of the reasons

for the low consumption. This study was conducted to document whether the "lamby" flavor can be masked by the curing/smoking process and spices, or by using lamb in combination with other types of meat and/or fat, in the manufacture of reduced-fat frankfurters. Our specific objectives were: (a) to determine sensory and chemical traits of reduced-fat frankfurters made with lean lamb or lean lamb/pork (50%/50%) and fat from three different sources (pork fat, lamb fat, or high-oleic sunflower oil); (b) to compare such products with a similar reduced-fat product made with lean beef/pork (50%/50%) and pork fat; and (c) to compare all the reduced-fat products with high-fat products made with lean beef/pork (50%/50%) plus pork fat or lean lamb/pork (50%/50%) plus pork fat. According to the Nutrition Labeling and Education Act of 1990, which was implemented in 1994, the fat content of a "reduced"-fat product, when compared to that of the respective reference product, should be at least 25% less, i.e., the fat content must be reduced by 25% or more (Mermelstein, 1993).

Materials & Methods

Beef trimmings, lamb legs and shoulders (not mutton), and pork boston butt and backfat were obtained locally. High-oleic sunflower oil (So) from SVO Enterprises (Columbus, Ohio) was composed of >85% oleic acid (monounsaturated), <10% polyunsaturated fatty acids and <10% saturated fatty acids. Frankfurter seasoning (blend of white pepper, coriander, mustard, ginger, and mace) was from A. C. Legg Packing Co., Inc. (Birmingham, Alabama). Frankfurter batter preparation, stuffing, and heat processing were done as described by Park et al. (1990). The batters prepared for 30% and 15% fat after processing contained 10% and 25% added water, respectively. Processing (cooking) yield was determined by weighing products before and after heat processing. Products were chilled at 2°C overnight, peeled, and vacuum-packaged. Product designations, along with lean meats used, added fats and product target fat levels, are shown in Table 1. Processing of each product was done in two replications conducted over 2 d.

Table 1. Frankfurter formulations

Product abbreviation	Lean meat[a]	Source of added fat	Target fat level (%) of finished product
BP-P-30	50% Beef/50% Pork	Pork	30
LP-P-30	50% Lamb/50% Pork	Pork	30
BP-P-15	50% Beef/50% Pork	Pork	15
LP-P-15	50% Lamb/50% Pork	Pork	15
LP-So-15	50% Lamb/50% Pork	Sunflower oil	15
LP-L-15	50% Lamb/50% Pork	Lamb	15
L-P-15	100% Lamb	Pork	15

[a]Lean percentages on a fat-free basis.

Total fat content, moisture, protein content, and lipid oxidation were determined as described previously (Park et al., 1989, 1990). Sensory evaluations were conducted utilizing a trained panel as well as a consumer panel. The trained sensory panel consisted of 11 panelists who had been trained by the procedures of Meilgaard et al. (1991). Panelists were trained for a 0 - 15 (0 = absent) flavor intensity scale using scale-anchoring reference standards, including various commercial frankfurters. Additionally, cooked ground meat patties (lamb, pork, and beef) were used to train the panelists for species-related flavors. The flavor attributes evaluated were frankfurter-flavor, lamb-flavor and off-flavor intensities. Test products were evaluated in two sessions (one session/d), with seven samples (one processing replication of the seven test products) served in each session. Frankfurters were steeped in hot water (95°C) for 7 min, sliced into 2.5 cm-long pieces, wrapped in aluminum foil, and held (no more than 15 min) in a conventional oven preheated to 80°C until the start of each session. Panelists were seated in individual booths with incandescent lighting, and samples were passed through hooded domes separating the sample preparation and testing areas. Panelists were provided with distilled water at room temperature to cleanse their palates between samples and were instructed to expectorate samples in cups provided. A consumer-type (untrained) panel consisted of faculty, staff, and students at Texas A&M University. Samples from each processing replication were evaluated by 50 panelists, with a total of 100 panelists used to evaluate samples from all (two) processing replications. Sample preparation, serving, and test settings were identical to those of the trained panel evaluation. Samples, however, were evaluated on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely) for appearance, flavor, juiciness, texture, and overall palatability. The SAS (1995) program was used for all data analyses. Data were analyzed by the General Linear Models Procedure and Student-Newman-Keuls multiple-range test. The Correlation Procedure was also used where appropriate. Significance was established at $P \leq 0.05$.

Results and Discussion

All products were similar in protein content (Table 2). Fat content was not significantly different among the five reduced-fat products. Likewise, processing yield was similar for all the reduced-fat products, regardless of the source of added fat. However, both yield and moisture were higher for the two high-fat products (BP-P-30 and LP-P-30) than for all the reduced-fat products. The correlation coefficient between yield and product moisture was 0.92 ($P < 0.05$).

Results from the trained panel flavor evaluation are shown in Table 3. For products with lamb/pork used as lean meat source (LP-P-15, LP-So-15 and LP-L-15), the type of fat added had marked effects on their flavors. Frankfurter-flavor intensity scores were lower (although less than 1 unit difference on a 0 - 15 scale) when sunflower oil or lamb fat was added (LP-So-15 and LP-L-15, respectively) than when pork fat was added (LP-P-

15 and L-P-15). Conversely, LP-So-15 and LP-L-15 were given higher (< 1 unit difference on a 0 - 15 scale) lamb-flavor intensity scores than LP-P-15. Since species-related flavors are associated, either directly or indirectly, with the fat portions of meats (Jamora and Rhee, 1999), one would expect LP-L-15 (containing both lamb meat and added lamb fat) to be higher in lamb-flavor intensity. As for the lamb/pork franks with sunflower oil (LP-So-15), the species-related flavor of lamb meat (knife-separable lean) might have been stronger than the pork meat flavor and the vegetable oil flavor (not distinct). The ground lean lamb used in this study contained about 4% fat, which might have been sufficient to contribute a lamby flavor to products. Using pork fat (rather than lamb fat or the vegetable oil) with lean lamb/pork combination significantly reduced lamb-flavor intensity. Since the panelists were informed that some test products contained lamb, some of them gave lamb-flavor intensity scores for products containing no lamb (either lean meat or fat). However, the lamb-flavor intensity scores for such products (BP-P-30 and BP-P-15) were extremely low, and of no practical significance, as shown by mean scores of 0.08 and 0.06 on a 0 - 15 scale (Table 3). Off-flavor intensity scores for reduced-fat products tended to be higher when lamb fat or sunflower oil was added (LP-L-15 and LP-So-15). Products with added pork fat were rated low in off-flavor intensity, regardless of fat content. It should be noted, however, that the differences among all the products in frankfurter-flavor, lamb-flavor and off-flavor intensities, although statistically significant, were very small (on a scale of 0 - 15). Correlation analysis revealed the nature of the association between the flavor attributes evaluated. Correlation coefficients were -0.90 for frankfurter-flavor intensity versus off-flavor intensity, -0.88 for frankfurter-flavor intensity versus lamb-flavor intensity, and 0.80 for lamb-flavor intensity versus off-flavor intensity. In other words, as lamb-flavor and off-flavor intensity increased (the two changing in tandem), frankfurter-flavor intensity decreased.

Table 2. Processing yields and proximate composition

	Products						
	BP-P-30	LP-P-30	BP-P-15	LP-P-15	LP-So-15	LP-L-15	L-P-15
Processing yield (%)	88.08^{a}	86.51^{a}	79.90^{bc}	82.74^{b}	78.26^{c}	80.88^{bc}	79.11^{b}
Fat (%)	31.07^{a}	27.82^{b}	17.88^{c}	17.86^{c}	17.57^{c}	16.20^{c}	16.98^{c}
Moisture (%)	47.73^{a}	44.36^{b}	34.98^{c}	34.79^{c}	35.12^{c}	35.38^{c}	35.20^{c}
Protein (%)	13.05^{a}	12.95^{a}	14.45^{a}	15.45^{a}	14.75^{a}	14.50^{a}	14.20^{a}

^{a,b,c}Within a row, means without a common superscript letter differ ($P < 0.05$).

Table 3. Trained panel flavor scores for reduced-fat and high-fat frankfurters made with different types of meat and fat

	Product						
Flavor intensity[c]	BP-P-30	LP-P-30	BP-P-15	LP-P-15	LP-So-15	LP-L-15	L-P-15
Frankfurter flavor	8.07^{ab}	7.86^{ab}	8.23^{a}	8.33^{a}	7.45^{b}	7.49^{b}	8.24^{a}
Lamb flavor	0.08^{b}	0.53^{ab}	0.06^{b}	0.10^{b}	0.90^{a}	0.91^{a}	0.51^{ab}
Off-flavor	0.39^{b}	0.35^{b}	0.40^{b}	0.22^{b}	0.80^{ab}	1.02^{a}	0.30^{b}

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).
[c]Scored on a 0 - 15 scale.

Results from the consumer sensory evaluation are shown in Table 4. For flavor desirability, LP-P-15 was rated as high as BP-P-15 and the two high-fat products (BP-P-30 and LP-P-30). LP-So-15, LP-L-15 and L-P-15 received lower flavor desirability scores than the other two reduced-fat products (LP-P-15 and BP-P-15). The two high-fat products (beef/pork and lamb/pork products, both with added pork fat) were rated similar in flavor desirability, reinforcing the positive effect of added pork fat on the flavor of frankfurters containing lamb meat. These consumer panel results on flavor desirability were generally in line with the results from the trained panel evaluation. For both juiciness and texture desirability, two of the reduced-fat products – lamb/pork franks with added pork fat (LP-P-15) and beef/pork franks with pork fat (BP-P-15) – were rated as high as their high-fat counterparts (LP-P-30 and BP-P-30, respectively). The same trend was observed for overall palatability as well.

Table 4. Consumer panel hedonic scores for reduced-fat and high-fat frankfurters made with different types of meat and fat

	Products						
Sensory attributes[d]	BP-P-30	LP-P-30	BP-P-15	LP-P-15	LP-So-15	LP-L-15	L-P-15
Appearance	6.22^{a}	6.37^{a}	6.37^{a}	6.24^{a}	5.93^{a}	6.17^{a}	6.01^{a}
Flavor	6.06^{a}	5.68^{ab}	5.99^{a}	5.78^{a}	5.20^{b}	5.13^{b}	5.08^{b}
Juiciness	5.62^{ab}	5.80^{a}	5.84^{a}	5.96^{a}	5.17^{b}	5.24^{b}	5.23^{b}
Texture	5.98^{a}	5.85^{a}	5.64^{ab}	5.59^{ab}	5.13^{bc}	4.93^{c}	5.02^{c}
Overall palatability	6.08^{a}	5.86^{a}	6.02^{a}	5.88^{a}	5.24^{b}	5.00^{b}	5.19^{b}

[a,b,c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[d]Scored on a 9-point scale.

There was no notable lipid oxidation in any of the products during a 12-wk storage, regardless of fat content, lean or fat sources, or storage time. Apparently, the nitrite (a

well-known antioxidant for meat) in these products and the vacuum-packaged (oxygen-excluded) storage at 4°C were sufficiently effective for inhibition of lipid oxidation.

Conclusions

When considering results from both consumer panel and trained panel evaluations of the test products, flavor seemed to be the most important sensory attribute for lamb-containing frankfurters. The use of frankfurter spice mixture (consisting of several spices) and curing process apparently did not completely mask the species-related lamb flavor in reduced-fat frankfurters made with lean trimmings of lamb legs and shoulders/pork boston butts (50%/50%) plus lamb fat or high-oleic sunflower oil. Added pork fat had a positive effect on the flavor of products containing lamb meat. In general, there were no marked differences between any of the products containing lamb meat and the products not containing lamb meat as long as added fat was from pork. Within each fat content category (reduced-fat or high-fat), frankfurters made with lamb/pork meats plus pork fat were as acceptable as the corresponding frankfurters made with beef/pork meats plus pork fat. Using high-oleic sunflower oil, rather than lamb fat, in reduced-fat lamb/pork frankfurters – which may be desirable from a nutritional point of view – did not improve the product flavor and acceptability.

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Fatty Acid Profiles of Goat Diets and Their Effects on Meat Fatty Acids

K.S. Rhee, D.F. Waldron, Y.A. Ziprin, and K.C. Rhee

ABSTRACT

Boer x Spanish kids were either fed a high concentrate diet or grazed on rangeland. The concentrate diet consisted of sorghum grain, cottonseed hulls, dehydrated alfalfa meal, cottonseed meal, soybean meal, molasses, and mineral and vitamin supplements. Animals were slaughtered at 206-234 d of age. Lipid extracts from goat muscle tissue and representative samples of the concentrate diet and the parts of range plants that goats were expected to have consumed were analyzed for fatty acid profiles. The range plant samples were much higher in the percentage of total saturated fatty acids when compared to the concentrate diet. Conversely, the percentage of total unsaturated fatty acids was higher for the concentrate diet (81% vs. 62-73%). Muscle tissue fat from animals grazed on pasture was more saturated than the fat from animals fed the concentrate diet, reflecting the fatty acid saturation differences between the two diets. The major unsaturated fatty acids in range plants were linoleic (18:2) and linolenic (18:3) acids, while in the concentrate diet the major unsaturated fatty acids were oleic (18:1) and linoleic acids. Regardless of diet type, oleic acid was the major unsaturated fatty acid in goat muscle tissue. Distinct differences among the range plant types (grass, forb, or browse) were found in some fatty acids, such as stearic (18:0), linoleic and linolenic acids.

Sheep and Goat, Wool and Mohair CPR 2000:38-43

Introduction

The fatty acid composition of meat is not only an important diet/health concern to consumers, but also is a primary factor determining the stability of the stored product (Rhee, 1992). The fatty acid composition of tissues of ruminants is less affected by dietary lipid composition than that of nonruminants, because of the hydrogenation of dietary lipids by rumen microbes (Byers and Schelling, 1993). However, the ruminal conversion of dietary unsaturated fatty acids to saturated fatty acids normally is not complete. Beef cattle studies (Westerling and Hedrick, 1979; Melton, 1983; Marmer et al., 1984; Chilliard, 1993) have shown that dietary fatty acid composition differences can cause differences in tissue fatty acid composition. In this study, we evaluated fatty acid profiles of goat diets and muscle tissue from the goats produced on two different diets to

understand the relationship between the fatty acid composition of animal diets and that of meat.

Materials & Methods

Animal feeding was done in San Angelo, Texas. Twenty castrated, male goats (Boer x Spanish), ranging in age from 90-118 d, were assigned to two dietary treatments. Ten were placed on rangeland and 10 were fed a high concentrate diet. The rangeland/pasture was populated with multiple species of native grasses, browses and forbs. The high concentrate diet was given ***ad libitum*** for 116 d before slaughter. It contained sorghum grain (67.5%), cottonseed hulls (12%), dehydrated alfalfa meal (5%), cottonseed meal (4%), soybean meal (4%), molasses (4%), and mineral and vitamin supplements.

Range plant samples (the parts of each plant that goats were expected to have consumed) were obtained toward the end of the period the goats were on pasture, and were placed in airtight plastic bags and frozen. Animals were slaughtered at a commercial facility in San Angelo, at 206-234 d of age. Muscle (*semimembranosus*) samples were removed from carcasses at ~60 h postmortem and frozen in Ziploc® freezer bags. The muscle samples and range plants and concentrate diet samples were shipped frozen with dry ice to College Station. All samples were kept at -20°C until analyzed.

Total fat extraction and fatty acid analysis were done as described previously (Rhee et al., 1997). Results for each fatty acid were expressed as a percentage of the sum of all identified fatty acids. Analysis of each diet specimen was performed on two subsamples. The General Linear Models Procedure of the SAS (1995) program was used for data analysis. A mean separation (Student-Newman-Keuls test) was used to test for differences between samples. The data were analyzed as a completely randomized design, and significance was defined at $P \leq 0.05$.

Results and Discussion

The range plant samples were much higher in the percentage of total saturated fatty acids when compared to the concentrate diet (27-38% for the range plant samples vs. 19% for the concentrate diet) (Table 1). Conversely, the percentage of total unsaturated fatty acids was higher for the concentrate diet (81% vs. 62-73%). Polyunsaturated fatty acids (18:2 and 18:3) made up 71-92% of total unsaturated fatty acids in range plants, whereas 18:1 (monounsaturated fatty acid) and 18:2 constituted 37% and 59%, respectively, of the total unsaturated fatty acids in the concentrate diet. Distinct differences among the range plant types were found in 18:2 and 18:3. Grasses (sideoats grama, common curlymesquite and sand dropseed) and forb (globe mallow) were about 2 folds higher in 18:2 percentage when compared to browses (littleleaf sumac and catclaw acacia). The percentage of 18:3, however, was higher in the browses and forb than in the grasses. Differences in total fatty

Table 1. Fatty acid composition (%)[a] of range plants and concentrate diet

		Range Plants					
		Grasses			Browses		Forb
Fatty acids	Concentrate diet	Sideoats grama	Sand dropseed	Common curly-mesquite	Littleleaf sumac	Catclaw acacia	Globe mallow
12:0	0.04	1.28	1.08	1.12	0.10	0.37	0.19
14:0	0.17	1.90	1.84	2.46	1.84	1.10	0.94
15:0	0.06	0.28	0.20	0.36	- - -	0.34	- - -
16:0	15.72	23.55	22.58	22.69	20.18	22.62	21.38
16:1	0.68	1.06	0.48	0.56	0.27	0.54	0.42
17:0	0.12	0.59	0.64	3.72	0.66	0.77	0.29
18:0	2.04	5.70	3.26	4.82	3.27	7.22	2.31
18:1	30.21	17.82	9.20	14.51	11.57	7.68	5.35
18:2	48.34	24.09	22.94	28.86	10.26	12.88	21.68
18:3	2.26	21.14	36.00	18.48	48.82	44.19	45.61
20:0	0.20	0.62	0.43	0.54	0.32	0.54	0.36
21:0	0.13	0.72	0.50	0.86	0.94	0.65	0.87
23:0	- - -	0.32	0.27	0.27	0.30	- - -	0.22
24:0	0.10	0.72	0.59	0.78	1.49	1.13	0.38
Total saturated	18.58	35.68	31.38	37.60	29.08	34.72	26.94
Total unsaturated	81.50	64.10	68.62	62.40	70.91	65.27	73.06
Total monounsaturated	30.89	18.88	9.68	15.06	11.84	8.21	5.77
Total polyunsaturated	50.60	45.22	58.94	47.33	59.08	57.06	67.29

[a]Percentage based on a total of identified fatty acids listed.

acid unsaturation between the intramuscular fat from range goats and that from concentrate-fed goats (Table 2) were not as large as the differences observed between the range plants and the concentrate diet (Table 1). In intramuscular fat, whether from range goats or concentrate-fed goats, 18:1 constituted more than two-thirds of total unsaturated fatty acids. In comparison, 18:1 made up only 7-28% of the total unsaturated fatty acids in range plants and 37% in the concentrate diet.

Table 2. Fatty acid composition (%)[c] of goat muscle (*semimembranousus*) samples

	Muscle samples from	
Fatty acids	Range goats	Concentrate-fed goats
14:0	1.78[a]	1.78[a]
14:1	0.30[a]	0.43[a]
16:0	20.51[a]	20.99[a]
16:1	1.62[b]	2.71[a]
17:0	1.29[b]	1.75[a]
17:1	0.94[b]	2.32[a]
18:0	16.27[a]	10.24[b]
18:1	42.43[b]	51.00[a]
18:2	7.74[a]	5.74[b]
18:3	1.16[a]	0.18[b]
20:3	0.21[a]	0.08[b]
20:4	3.43[a]	2.27[b]
21:0	1.17[a]	0.15[b]
24:0	1.17[a]	0.38[b]
Total saturated	42.19[a]	35.28[b]
Total unsaturated	57.82[b]	64.72[a]
Total monounsaturated	45.29[b]	56.46[a]
Total polyunsaturated	12.54[a]	8.27[b]

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).
[c]Percentage based on a total of identified fatty acids listed.

There is little published information available on the effect of diet/feeding regimen on fatty acid composition of goat muscles/intramuscular fat. In our previous study (Rhee et al., 1997) on goat meat patties made with knife-separable lean composite (with some, though minimal, visible external fat), patties from concentrate-fed animals within the same breed type were higher in the 18:1 percentage when compared to the respective patties from animals grazed on rangeland without grain supplementation, while the 18:0 percentage was higher in the latter. As for other ruminants, diet effects on fatty acid composition of beef have been extensively studied. Westerling and Hedrick (1979) reported that the 16:0 percentage in intramuscular fat was similar between animals fed an

82.4% corn diet and those grazed on predominantly fescue grass, whereas the 18:1 percentage was greater in grain-fed animals and 18:0, 18:2 and 18:3 percentages were higher in forage-fed animals. In the study by Marmer et al. (1984), however, the 18:2 percentage of intramuscular fat was higher in animals fed a 79% corn diet than in animals fed a forage diet (primarily winter wheat). The differences between these studies may be related to fatty acid composition differences that could have been present between the two grain diets and/or the two forage diets. Fatty acid profiles of diet samples were not determined in these studies. As for lambs, grazing reportedly increases the 18:0 concentration in adipose tissue, while grain concentrates increasing 18:1 and 18:2 (Enser, 1995).

In conclusion, our results indicated that intramuscular fat from Boer x Spanish goats grazed on pasture without any grain supplementation was more saturated than intramuscular fat from goats fed a high concentrate diet. Such trend with intramuscular fat seemed to generally reflect the fatty acid saturation or unsaturation differences between the two diets. Further studies are needed on the relationship between the fatty acid profiles of diet specimens (different grain diets and various range plants) and those of tissue samples from goats that have undergone the dietary treatments. Effects of time-on-feed also need to be investigated.

Acknowledgment

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Effects of Prenatal Shearing of Ewes on Lamb Birth Weight and Neonatal Lamb Survivability

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ABSTRACT

Shearing pregnant ewes in cold environments has been shown to increase lamb birth weights and survival rates. This is supported by research that has demonstrated that maternal cold exposure enhanced brown fat thermogenesis and cold tolerance of newborn lambs. This study was designed to determine the effect of late-gestation shearing on lamb birth weight and survival rates during the neonatal period in typical West Texas conditions. Rambouillet ewes of mixed ages were randomly assigned, within sire family and year of birth, to one of two shearing treatments, prenatal shorn or unshorn. The ewes remained on the same treatment for all 3 years. The prenatal shorn ewes were shorn in early January, 2 to 54 d prior to lambing (mean = 20 d). The unshorn ewes were shorn after lambs were an average of 96 d old. Lamb survival rates for 480 lambs were analyzed using a model that included fixed effects of shearing (prenatal or unshorn), year, sex of lamb, type of birth (singles, twins, triplets), age of dam (2, 3-5, 6+), significant 2 way interactions ($P < .2$), and linear and quadratic effects of birth weight and minimum temperature. Lamb survival rates were not affected by age of dam, but were lower ($P < 0.02$) on day 3 for triplet compared to twin and single lambs (74.3, 88.0 and 89.2 ± 5%, respectively). There was an interaction between sex of lamb and shear treatment ($P < 0.05$) for lamb survival. Male lambs from shorn ewes had 12% lower survival rates at one day of age than male lambs born to unshorn ewes ($P < 0.01$), whereas prenatal shear treatment did not affect the survival rate of female lambs. Lamb birth weight ranged from 3.5 to 15.4 lb and was not affected by shear treatment ($P > .5$). Lamb survival rates increased quadratically as both birth weight ($P < 0.05$) increased and as minimum temperature on day of birth ($P < 0.01$) increased. Predicted survival rates at 3 days of age for 4, 6, 8, 11, and 13 lb birth weight lambs were 57.6, 73.8, 85.4, 94.0, and 94.0 ± 6%, respectively. Predicted survival rates at 3 days of age for 20, 30, 40, and 50° F minimum temperature were 71.6, 87.5, 91.5, and 83.5 ± 5%, respectively. These results demonstrate that prenatal shearing of ewes 20 d prior to lambing did not increase birth weight or improve lamb survival rate.

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Introduction

Lamb deaths are a considerable economic loss to the sheep industry each year. A 1996 USDA report estimated that 9.4% of lambs born alive died prior to weaning. In Michigan flocks, Rook (1989) reported mortality rates of 15 to 20%, and found that the majority of these deaths occurred within the first three days of life.

Simpson (1995) found that weather related causes were responsible for 40.5% of the lamb deaths, with only predators responsible for a greater number. Weather losses include deaths from lightning, drowning, and chilling. Other post-mortem studies suggest that 30% of all neonatal deaths may be the result of hypothermia, starvation, or the combination of the two (McCutcheon et al., 1981). Hypothermia and starvation share physiological mechanisms and each condition may contribute to the other. Lambs in a cold environment must increase heat production to avoid hypothermia. This increased heat production depletes body reserves and can lead to starvation unless the lamb receives adequate energy from nursing. As lambs' body temperatures decline their ability to suckle is impaired. Failure to suckle, whether from mismothering, central nervous system injury due to dystocia, or discomfort will result in starvation thereby contributing to hypothermia because the lamb has less energy to utilize for heat production. This phenomenon is called the starvation-exposure syndrome (McCutcheon et al., 1981).

A 1993 study by Azzam et al. in Nebraska examined the effects of environmental conditions on neonatal calf survival rate. Utilizing over 70,000 calving records, they reported that as the environmental temperature decreased calf mortality rates increased. Mortality rates of non-dystocia calves in a dry environment increased from less than 4% at 86° F to over 18% when the ambient temperature was -4° F. Precipitation also negatively affected the calf survival rate, particularly at lower temperatures. In the same study it was also found that low birth weight calves (birth weights 1.5 standard deviations below the mean) had higher mortality rates, particularly at lower temperatures.

Low birth weight lambs also have increased mortality rates. Alexander and McCance (1958) reported that the rectal temperatures of lambs that died within 72 h of birth were significantly lower at 6 h of age than the temperatures of lambs that survived.

Management practices that are able to reduce the incidence of low birth weights of lambs will likely increase lamb survival rates. Rutter et al. (1971) demonstrated that by shearing pregnant ewes 7 weeks prior to parturition lamb birth weights increased by 16% compared with unshorn ewes. The lamb mortality rate was also decreased from 35.8% in the unshorn group to 18.5% in the shorn group. When ewes were shorn and exposed to cold temperatures (34 to 43° F) 5 weeks prior to lambing, birth weights of single lambs were increased 27% compared to unshorn ewes housed at 59° F (Thompson et al., 1982).

There is substantial evidence of benefits to prenatal shearing from studies done outside the United States. The objective of this experiment was to determine if shearing pregnant

ewes in late gestation would increase birth weight and improve lamb survival in a west Texas flock.

Materials and Methods

A three-year study was conducted with a flock of mixed-age Rambouillet ewes. Prior to mating in the first year of the study, ewes were randomly assigned within sire family and year of birth to one of two shearing treatments. The treatments consisted of shearing prior to lambing (prenatal shorn ewes) and shearing after lambing (unshorn ewes). The ewes in the prenatal shorn treatment were shorn in January each year an average of 20.1 ± 12.6 d prior to lambing, whereas, the unshorn ewes were not shorn until April, 96.2 ± 15.1 d after lambing. As young ewes were added to the flock each year they were assigned to a shearing treatment prior to mating. Once assigned to a shearing treatment, ewes were kept on the same treatment in subsequent years. There were a total of 276 parturitions over the three-year period resulting in 480 lambs. The average body weight of the ewes at time of mating was 132.7 ± 1.3 lb.

Upon shearing of the prenatal shorn ewes in January, both groups were housed in a common pen (150 x 300 ft) with access to a three-sided shed. Ewes and lambs remained in this pen until lambs were 7 to 14 days of age, at which point they were returned to pasture. While housed in this pen, ewes were fed a diet consisting of 30% sorghum grain, 40% peanut hulls, 16.5% cottonseed meal, 8% molasses, 3% salt, 1% calcium carbonate, 1% urea, and 0.5% ammonium chloride.

Data collected at lambing included lamb birth weight, sex, type of birth (single, twin, or triplet), and age of ewe. Minimum and maximum temperatures on the day of birth were also recorded. Lamb survival was observed for up to 7 days of age. Data was analyzed using general linear model procedures in SAS (1996) to examine factors affecting birth weights. Variables in the model were shearing treatment, year, sex of lamb, type of birth, and age of dam. The age of dam was categorized as 2 year olds, 3- to 5-yr olds or 6- to 7-yr olds. All interactions were examined in initial models and remained in the final model if $P < 0.2$, but there were no significant interactions in this model.

Survival rate on day 1 was coded as 0 if a lamb died at birth or during the first day of life or 1 if the lamb survived through the first day of life. Lamb survival rates through days 3 and 7 were likewise coded. This model included shearing treatment, year, sex of lamb, type of birth, and age of dam. The interaction of shearing treatment x sex of lamb had a $P < .20$ so it was also utilized in the model. In addition, linear and quadratic effects of day-of-birth minimum temperature and birth weight were included in the model.

Results

The average litter size was not affected by shearing treatment (1.69 and 1.74, for unshorn and shorn, respectively). Age of dam affected litter size. The 2-yr-old ewes had smaller litters ($P < 0.01$) than did the 3- to 5-yr-old or 6- to 7-yr-old ewes (1.53, 1.81, and 1.79, respectively).

Type of birth significantly affected the birth weight of lambs (Table 1). Single lambs were 22.5% heavier than twin lambs ($P < 0.001$), and twin lambs were 17.8% heavier than triplet lambs ($P < 0.001$). Survival rates for triplet lambs were lower ($P < 0.05$) on days 1, 3, and 7 compared to single and twin lambs. Yapi et al. (1992) also found a positive correlation between litter size and lamb mortality, which is probably due to heavier birth weights (McCutcheon et al., 1983) and increased cold resistance (Stott and Slee, 1987) of single lambs compared to twin and triplet lambs. There was not a significant difference, however, between survival rates of single and twin lambs in this study.

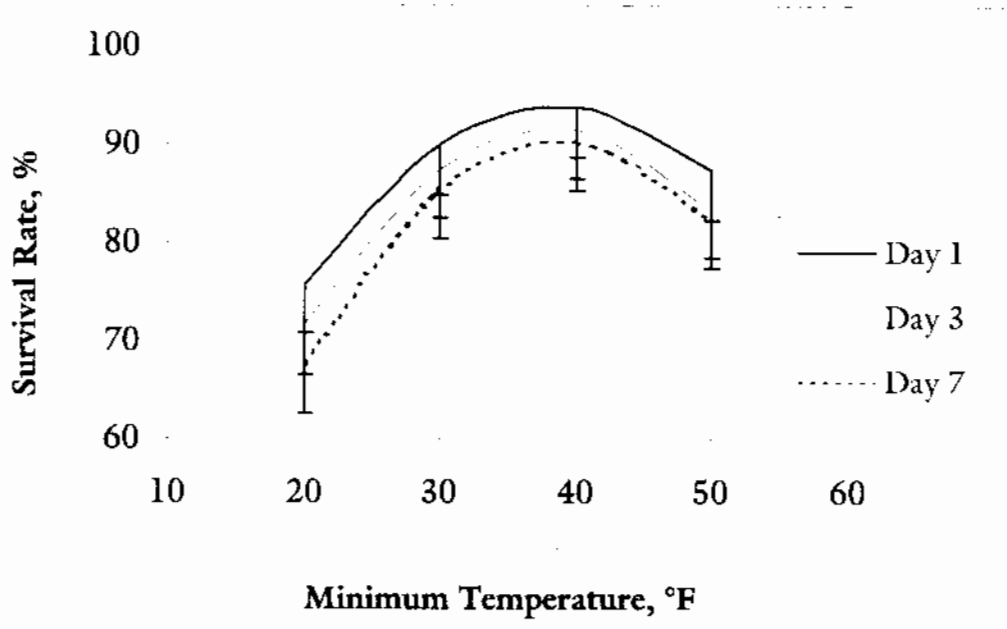
Table 1. Effects of sex of lamb and type of birth on lamb birth weights and survival rates

Factor	Birth Weight[a]	Survival Rate[b] Day 1	Day 3	Day 7
Sex of Lamb				
Female	7.63	88.1	83.1	82.1
Male	8.25	90.2	84.5	80.6
SE	.11	2.2	2.7	2.9
P-Value	.001	.39[c]	.65[c]	.66[c]
Type of Birth				
Singles	9.48	94.6	89.2	87.5
Twins	7.74	93.5	88.0	83.6
Triplets	6.57	79.3	74.3	72.9
SE	.18	3.8	4.7	5.1
P-Value	.001	.01	.02	.09

[a]Birth weight of lambs, lb.
[b]Lamb survival rates: percentage of lambs alive after the first, third, or seventh d of age.
[c]Sex of lamb x shear treatment was significant for lamb survival rates (see Fig. 3 and text).

Minimum temperature had a significant ($P < 0.01$) quadratic effect on survival rates for day 1, day 3, and day 7 (Figure 1). The optimum minimum temperature range was from 39 to 43° F. Below 39° F there was a decline in lamb survival rates. Compared to survivability at 39° F, survival rates declined 5% when temperatures decreased to 30° F and 23% when temperatures decreased to 21° F.

Figure 1. The effect of minimum temperature on day of lambing on lamb survival.



Lamb birth weight had a significant quadratic effect on lamb survival rates on day 1 ($P < 0.01$) and also tended to affect survival rates on day 3 ($P = 0.06$) and day 7 ($P < .10$). The effect of lamb birth weight on survival rate is illustrated in Figure 2. There was a 10% reduction in day-1 survival rates when birth weights decreased from 8 to 6 lb, and a 25% reduction when birth weights decreased from 8 to 4 lb. Similar effects were noted for survival rates on days 3 and 7. At heavier birth weights, survival rates declined slightly, reflecting possible complications from dystocia. Gama et al. (1991) found that birth weight was the best predictor of lamb mortality rates.

Age of dam had a significant effect on lamb birth weights (Table 2). Lambs from the 6- to 7-yr-old ewes were 4.7% heavier than lambs from 3- to 5-yr-old ewes and 14.1% heavier than lambs from 2-yr-old ewes. Age of dam was not a significant factor affecting survival on days 1, 3, or 7. This corresponds with Hanrahan (1986) who found no effect of ewe age on lamb survivability when adjusted for litter size.

Regardless of prenatal shear treatment, the majority of lamb deaths for 7 d mortality rates occurred within the first day of life. Deaths within the first day of life accounted for 61.8 and 53.4% of the 7 d mortality rates of prenatal shorn and unshorn treatments, respectively.

Figure 2. Effect of birth weight on lamb survival.

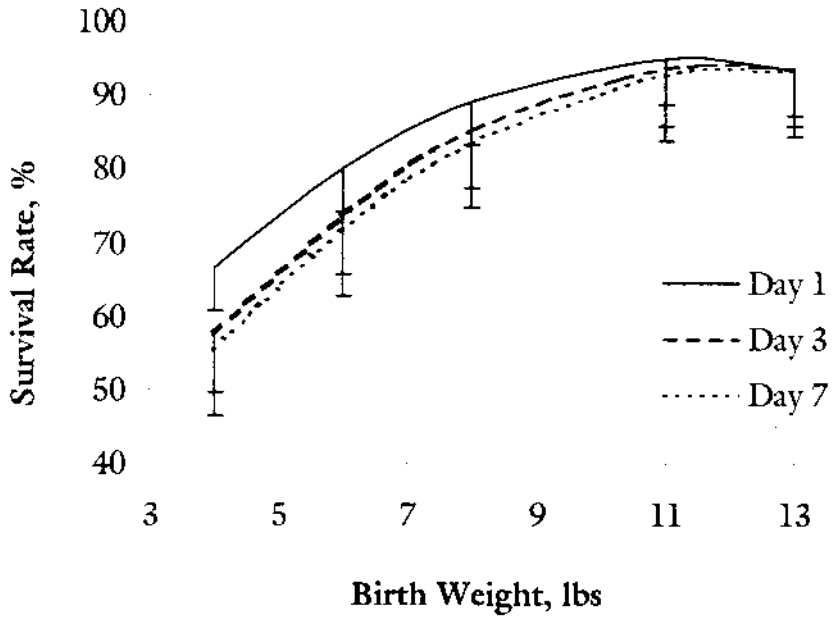


Table 2. Effects of prenatal shearing treatment and age of dam on lamb birth weight and survival rates

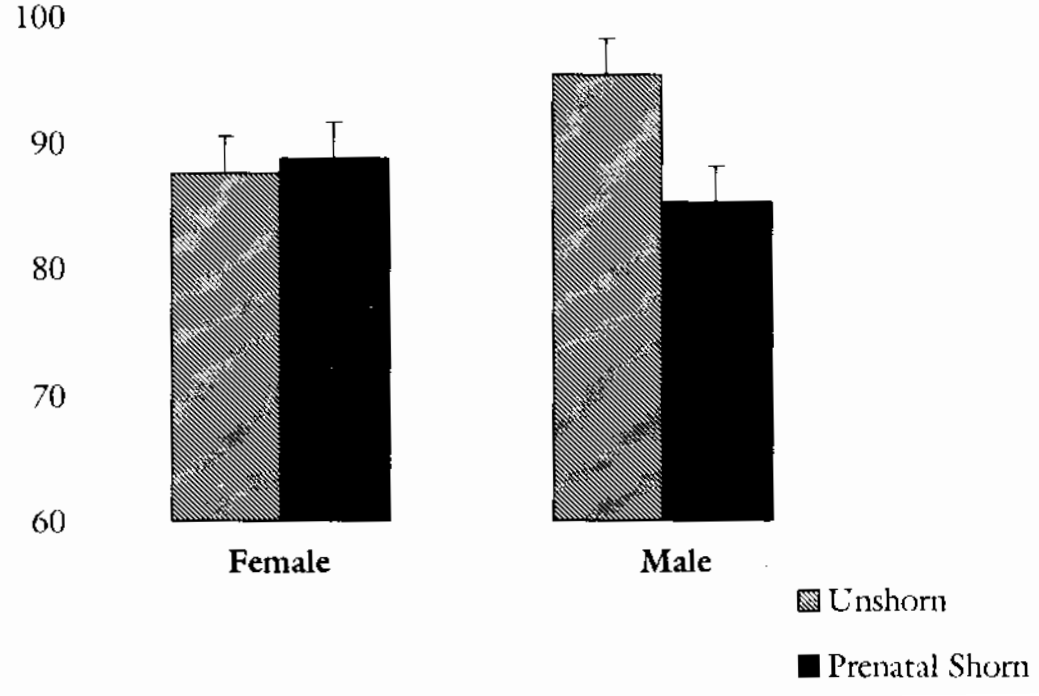
Factor	Birth Weight[a]	Survival Rate[b]		
		Day 1	Day 3	Day 7
Shear Treatment				
Prenatal Shorn	7.89	86.9	81.3	78.8
Unshorn	7.96	91.4	86.4	83.9
SE	.11	2.1	2.6	2.9
P-Value	.50	.06	.09	.11
Age of Dam				
2-yr olds	7.36	86.3	83.5	79.2
3- to 5-yr-olds	8.03	88.8	84.1	83.1
6- to 7-yr-olds	8.40	92.4	83.9	81.8
SE	.15	3.1	3.9	4.2
P-Value	.001	.32	.99	.67

[a]Birth weight of lambs, lb.

[b]Lamb survival rates: percentage of lambs alive after the first, third, or seventh d of age.

Lamb birth weight was not affected by prenatal shear treatment (Table 2). There was a significant interaction between prenatal shear treatment and sex of lamb for survival rates on days 1 ($P < 0.05$), 3 ($P < 0.01$), and 7 ($P < 0.01$). Prenatal shearing did not affect day 1 survival rates of female lambs, however, male lambs born to shorn ewes had lower ($P < 0.01$) survival rates than male lambs born to unshorn ewes (Figure 3). This was also the case for day 3 and 7 survival rates. The possibility was considered that prenatal shearing increased birth weights of male but not female lambs, thereby increasing the incidence of dystocia in male lambs. This was not likely the case, however, since the interaction between prenatal shear treatment and sex of lamb for birth weight was not significant ($P > .25$). An interaction between sex of lamb and prenatal shear treatment for lamb birth weights or survival rates has not been reported in other studies. The finding that male lambs born to shorn ewes had lower survival rates than male lambs born to unshorn ewes is contrary to results from previous studies (Table 3). In studies that have reported beneficial effects of prenatal shearing on lamb survivability it was also found that prenatal shearing increased birth weights. Therefore, the lack of a positive prenatal shearing effect on lamb survival in the present study is not surprising given that birth weight was not affected. It remains unclear as to why prenatal shearing has a negative impact on survivability of male lambs in this study.

Figure 3. Effect of shearing on day 1 survival rate of male and female lambs (prenatal shear x sex of lamb interaction).



One possible explanation as to why prenatal shear treatment did not increase birth weight or improve survivability of lambs in this study, is that the length of time from shearing to lambing may have been too short. Only five of the 17 studies reviewed in Table 3 found no effect of prenatal shearing on lamb birth weight. In these five studies, the time from prenatal shearing to lambing ranged from 21 to 36 d, whereas, in the studies that did report a birth weight response, the length of time from shearing to lambing generally was greater than 40 d. Two studies have examined the timing of prenatal shearing on lamb birth weights (Black & Chestnutt, 1990; Morris & McCutcheon, 1997). In these two studies, the smallest increases in birth weights due to prenatal shearing were found when the time from shearing to lambing was less than 30 d (Table 3).

A second reason for a lack of a prenatal shear effect may be that the ambient temperatures during late gestation were too mild. The 3-yr average minimum temperature on the day of lambing in this study was 36.3 ± 8.1° F (range of 17.1 to 59.0° F), and the average maximum temperature on day of lambing was 64.6 ± 11.7° F (range of 23.0 to 84.9° F). Surprisingly, few authors have reported the ambient temperature conditions that existed during their studies (Table 3). The studies that did report ambient temperatures were not extremely cold compared to the temperatures reported in the current study. Collectively, the results of studies presented in Table 4 clearly demonstrate that prenatal cold exposure enhances and prenatal heat exposure suppresses lamb birth weights, thereby potentially impacting lamb survival rates.

Discussion

Despite the fact that prenatal shearing treatment did not increase lamb survivability in this study, the majority of prenatal shearing experiments have shown beneficial responses (Tables 3 and 4). There are a number of possible mechanisms whereby prenatal shearing may improve lamb survival rates. Prenatal shearing affects ewe behavior at lambing. When ewes are not housed during lambing, prenatal shearing has been shown to increase the likelihood that ewes will lamb in sheltered areas, thereby increasing the chance of lamb survival, particularly in inclement weather (Lynch and Alexander, 1976). Another benefit could be increased colostrum consumption by lambs due to less wool around the ewes' udders.

Several studies have reported an increase in dry matter intake of ewes that were shorn prior to lambing (Austin and Young, 1977; Vipond et al., 1987; Symonds et al., 1992; Black and Chestnutt, 1990; Dabiri et al., 1996). This increase in intake was thought to be a factor in increasing lamb birth weights by increasing the total supply of nutrients available to the developing fetus. However, because cold exposure increases rate of passage in ruminants, digestibility is decreased, so metabolizble energy intake is similar to that of unshorn ewes (Symonds et al., 1986). In one trial prenatal shorn and unshorn ewes were

fed equal amounts of dry matter and the shorn ewes still had heavier lambs (Thompson et al., 1982).

Cold exposure may alter the way nutrients are partitioned in the ewe. Plasma glucose levels increase in cold exposed ewes (Symonds et al., 1992; Clarke et al., 1997) and in fetuses as well (Thompson et al., 1982). Infusion of glucose into the fetus during the last 4 weeks of pregnancy has been shown to increase fetal weight compared with saline-infused controls (Stevens et al., 1990).

Another benefit to shearing pregnant ewes in late gestation may be a reduction in thermal load. Shelton and Huston (1968) examined the effects of heat stress during late gestation. Control ewes were housed at 75° F, whereas warm-treated ewes were exposed to 90° F for 12 (partial) or 24 (full) h per day. The partial heat treatment lowered birth weights by 16% and increased mortality rates to 20%. The full heat treatment had a 40% reduction in birth weight compared with control and a mortality rate of 45% (Table 4).

Besides increasing birth weight, prenatal shearing has been shown to enhance brown fat metabolism in newborn lambs. Brown fat is present in newborn lambs and functions to produce heat through nonshivering thermogenic mechanisms to help prevent hypothermia. Stott and Slee (1985) conducted a study where ewes were exposed to either warm (79° F, full fleece) or cold (42.8° F, shorn) treatments 14 d prior to lambing. Brown fat metabolism, measured as an increase in oxygen consumption in response to a norephinephrine challenge, was found to be 2.8 times thermoneutral metabolism in lambs from cold-exposed ewes, but only 1.7 times thermoneutral metabolism in lambs from warm-exposed ewes. Likewise, Symonds et al. (1992) found that lambs from cold-exposed ewes had 40% greater brown fat thermogenic activity than control lambs.

Implications

Although prenatal shearing of ewes has been shown to increase lamb birth weights and improve survival rates in several studies, no increases were observed under the present study. The beneficial effects of prenatal shearing appear to be influenced by the degree of cold exposure and the length of time between shearing and lambing.

Table 3. Influence of prenatal shearing of ewes on lamb birth weights and survival rates

Reference	Experimental Conditions	Prenatal Temperature	Prenatal Treatment Days	Birth Weight	Survival Rate	Other
Rutter et al. (1971)	shorn vs unshorn	Not reported	105	↑ 16%	↑ (81.5 vs 64.2%)	
Rutter et al. (1972)	shorn vs unshorn	Not reported	105	↑ 21%	↑ (91 vs 78%); nonsignificant	
Austin & Young (1977)	shorn vs unshorn	33 to 57°F	70	↑ 14%	↑ (98 vs 93%); nonsignificant	↑ ewe intake
Maund (1980)	shorn vs unshorn	Not reported	70	↑ 7.5% twins ↑ 22.5% triplets	↑ for twins & triplets	↑ ewe intake
Symonds et al.(1986)	shorn vs unshorn	53°F	56	↑ 16%	Not reported	↑ ewe glucose levels
Vipond et al. (1987)	shorn vs unshorn	Not reported	40 to 66 3-yr study	↑ 15% (avg)	↑ (94 vs 88%); nonsignificant	↑ ewe intake ↑ gestation length
Black & Chestnut (1990)	shorn vs unshorn	Not reported	28, 42, 63 or 84	↑ 5% – 28 d ↑ 22% – 42 d ↑ 15% – 63&84 d	Not reported	↑ gestation length ↑ ewe intake ↑ ewe plasma glucose
Fernandez et al. (1991)	shorn vs unshorn	Not reported	25 to 30	No effect	No effect	
Boer (1994)	shorn vs unshorn	Not reported	56	↑ 14%	↑ (91.4 vs 82.4%)	

Table 3. Influence of prenatal shearing of ewes on lamb birth weights and survival rates (cont'd)

Reference	Experimental Conditions	Prenatal Temperature	Prenatal Treatment Days	Birth Weight	Survival Rate	Other
Cloete et al. (1994)	shorn vs unshorn	44 to 66°F	14 – Yr 1 28 – Yr 2	↑ 3.9% – Yr 1 No effect – Yr 2	↑ (73 vs 67%) – Yr 1 No effect – Yr 2	↑ lamb growth to 8 wks; ewes on pasture
Dabiri et al. (1994)	shorn vs unshorn	Not reported	21 to 28	No effect	Not reported	ewes on pasture
Cueto et al.(1995)	shorn vs unshorn	Not reported	30	↑ 5%	Not reported	
Dabiri et al. (1995)	shorn vs unshorn	Not reported	36	No effect	Not reported	
Cueto et al.(1996)	shorn vs unshorn	Not reported	35	↑ 8%	Not reported	
Dabiri et al. (1996)	shorn vs unshorn	Not reported	32	No effect	Not reported	
Husain et al. (1997)	shorn vs unshorn	46°F	35	↑ 14%	Not reported	↓ ewe rectal temperature
Morris & McCutcheon (1997)	shorn vs unshorn	39 to 54°F	20, 50, or 80	↑ 7% – 20 d ↑ 9% – 50 d ↑ 16% – 80 d	Not reported	Shearing affected birth weight of twin, but not single lambs

Table 4. Effects of prenatal shearing and (or) temperature exposure of ewes on lamb birth weights and survival rates

Reference	Experimental Conditions	Prenatal Temperature	Prenatal Treatment Days	Birth Weight	Survival Rate	Other
Slee & Samson (1982)	cold + shorn vs warm + unshorn	35 to 46°F (shorn) Thermoneutral (unshorn)	42	↑ 1.5 lb – Study 1 ↑ 0.9 lb – Study 2	Not reported	↑ gestation length
Thompson et al. (1982)	cold + shorn vs warm + unshorn	34 to 43°F (shorn) 59°F (unshorn)	35	↑ 27 % singles ↑ .9% twins	Not reported	↑ plasma glucose in lambs and ewes
Stott & Slee (1985)	cold + shorn vs warm + unshorn	43°F (shorn) 79°F (unshorn)	14	No effect	Not reported	↑ norepinephrine-induced metabolic response
Shelton & Huston (1968)	24-h warm; 12-h warm vs control	90°F (shorn) 75°F (unshorn)	50 to 75	↓ 40% – 24-h warm ↓ 20% – 12-h warm	55% – 24-h warm 80% – 12-h warm 100% – control	↑ weak lambs
Brown et al. (1977)	warm – housed vs pastured	82° to 100°F (warm) Pasture – Not reported	50	↓ 30%	↓ (66 vs 96%)	
Bell et al. (1989)	warm vs control	104°F (warm) 68°F (control)	70	↓ 17%	Not reported	

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Comparative Productivity of Angora, Meat, and Crossbred Goats under Identical Management

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ABSTRACT

A 2-yr study was conducted to determine total production (fiber and meat) of Angora and meat goat females bred to either Angora or meat goat males (AA, AM, MA, and MM, respectively). Angora females bred to Angora males (AA) produced fewer (78.4 vs 140.4%) and smaller (36.8 vs 52.2 lb) weaned kids than meat females bred to meat males (MM). The crossbred kids (both AM and MA) weaned at intermediate weights that were different ($P < 0.05$) from AA and MM but not different (NS) between the reciprocal crosses. Feedlot performance data showed differences similar to those for weaning weights. Kids from the AA group gained slower (.15 vs .26 lb/d; $P < .10$) compared with those from the MM group whereas the crossbred groups were intermediate. Other data collected included fleece weights of the Angora females and kids and differences in gain due to sex and diet type. These data will be used to evaluate the use of Angora females to produce crossbred kids for meat during periods of low mohair prices.

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Introduction

Angora goat numbers are declining and meat goat numbers are increasing in Texas as a result of low and variable mohair prices and increasing demand for goat meat in the United States. Mohair is the primary product of Angora goat enterprises and has received the major consideration in selection and management decisions. The mutually beneficial relationship between the goat and its habitat, goat meat and hides (from surplus kids and salvage adults), and the advantage of enterprise diversity (mixed animal species) are also important considerations. However, low demand and volatile mohair prices varying up to 1,000 percent cause periods of unprofitability for producers. Recent trends in Texas toward replacing Angora goats with meat goats raise the concern that the high quality Angora seed stock that has long dominated the Texas goat population may disappear. These current situations are stimuli for an approach for managing the Angora goat as a dual-purpose animal using meat goat sires at opportune times but holding the option of returning to pure-bred Angora sires when mohair prices are favorable. A 2-yr study was conducted at the Texas A&M University Agricultural Research and Extension Center at

San Angelo, comparing the production components of Angora and meat goats and Angora x meat goat crosses. Data from this study are intended for use in developing a decision aid for optimal long range goat management.

Materials and Methods

The study involved breeding Angora and meat female goat flocks with both Angora and meat goat sires to produce full blood Angora (AA) and meat (MM) kids and crossbred kids from either Angora or meat goat does and meat or Angora sires (AM and MA, respectively). The resulting weaned kids were then fed in a growth trial to determine the effects of breed, sex, and diet type on average daily gain (ADG) and feed efficiency (FE). The Angora flock was typical of a mixed-age (2- to 5- yr), medium body size (70.7 lb) Texas flock. The meat goat flock was younger (6 mo to 3 yr) averaging 51.1 and 87.4 lb during yr 1 and 2, respectively. The meat goat females originated from a herd of Spanish goats bred to Boer sires and consisted of first, second, and third generation upgrading (one-half to seven-eighths Boer). Females from each type (Angora and meat goats) were divided equally among either three (yr 1) or two (yr 2) pastures for breeding to both Angora and meat goat sires during a 45-d breeding season beginning October 1 each . The sires (minium of three per 100 females) were typical high-shearing Angora males and meat goat males (five-eighths Boer) produced from the Texas Agricultural Experiment Station flock at the H.D. Winters Ranch lease in McCulloch County. Breeding groups were arranged so that sire effects were equalized for the straight bred and crossbred groups (i.e., the same sires produced MM and AM kids). The flocks received identical but minimal management beyond breeding and supplemental feeding (approximately .5 lb/hd/d of 32% crude protein supplement) during the winter. Predation, primarily from both red and gray foxes, reduced kid crops substantially. The kids were weaned on August 14 and August 5 in yr 1 and 2, respectively, and identified as AA, AM, MA, or MM by the breed of the dam and the appearance of the sires' influence. Mohair fleece weights were recorded for the adult Angora females in February and August and for the weaned kids in August. Weaning dates for all kids corresponded with the August shearing for the Angora goats. Between weaning and beginning of the feedlot trials, the kids were fed a standard diet (Table 1) during a uniformity period.

Feeding trials were conducted each year to determine effects of breeding (AA, AM, MA, and MM), sex (M,F), and diet type (HR, LR; Table 1) on growth rate and feed efficiency of kids. Kids from the breeding study described above and additional similar kids produced from other breeding studies were used in these growth trials. A replicated $4 \times 2 \times 2$ factorial design (32 pens) was used. The kids were assigned to treatment to equalize weight within breed and sex. Feed was weighed into bunk feeders daily and excesses were weighed back two or three times per wk and discarded. Attempts were made (with limited success) to keep goats out of feed troughs and water buckets. Goats that

died or were targets of severe abuse by pen mates were removed from the pens and were not included in the data. Data collected included initial and 28-d weights and feed consumption. Final weights were recorded 80 and 76 d after the beginning of the trials during yr 1 and 2, respectively.

Table 1. Diets fed to weaned kid goats during a 2-year study to determine the effects of breeding, sex, and diet energy level on growth and feed efficiency

Items	Uniformity diet	High roughage (HR)	Low roughage (LR)
Ingredients			
Cottonseed hulls	10	7.5	3
Peanut hulls		7.5	3
Dehydrated alfalfa meal	20	15	6
Sorghum grain	52	52.5	70
Cottonseed meal	5	11	11
Soybean meal	5	---	---
Molasses	5	4	4
Ammonium chloride	0.75	0.75	0.75
Calcium carbonate	1	0.75	1
Salt	0.5	0.5	0.75
Vitamin/mineral premix	0.75	0.5	0.5
Rumensin (10 mg/lb active)	+	+	+
Estimated nutrient contents			
Crude protein	15	15	15
TDN	67	64	70
Calcium	0.77	0.60	0.57
Phosphorus	0.30	0.34	0.37

Results and Discussion

The numbers of kids produced by the breeding groups were below expectations, especially during yr 1 (data not shown). The meat goat females were younger than the Angoras and, possibly as a result, produced fewer kids. Also, predation during yr 1 was very high. Therefore, data on kid production is presented for yr 2 only (Table 2). These data indicate clearly the advantage of the meat goat over the Angora in reproductive rate. The sire effect on kids weaned was unclear. Although statistical analyses were not applied to the reproductive rate data, it appeared that the kid crop was slightly lower in crossbred than in pure-bred goats. In addition to kids produced, the Angora females produced an average annual total of 11.9 lb of mohair (Feb. = 5.5 lb; Aug. = 6.2 lb); the weaned kids produced 2.3 lb/hd (Aug. only) of fine, high quality mohair.

Angora kids weighed less ($P < 0.05$) and meat goat kids weighed more ($P < 0.05$) at weaning than either of the two crosses (Table 3). A breed × sex interaction ($P < 0.05$) suggested that crossbred males had a greater advantage over crossbred females when the dam was Angora and the sire meat goat than the reverse situation. However, the average weaning weights of crossbred kids did not differ, regardless of breeds of parents.

Table 2. Comparative reproductive rates of Angora and meat goats (year 2 only)

	Angora sire		Meat sire	
Item	Angora female	Meat female	Angora female	Meat female
Number of goats (females)	51	48	49	47
Number of kids weaned	40	47	34	66
Kid crop, %	78.4	97.9	69.4	140.4

Table 3. Comparative weaning weights of Angora and meat goats and reciprocal crosses

	Angora sire		Meat sire		
	Angora female	Meat female	Angora female	Meat female	
Item	AA	MA	AM	MM	Total/average
Number of kids weaned	43	28	55	74	200
Average weaning weights, lb					
Male	39.2^{c}	45.6^{b}	54.2^{ab}	58.4^{a}	49.8
Female	34.1^{c}	43.6^{a,b}	41.9^{b}	46.0^{a}	41.4
All kids	36.8^{c}	45.6^{b}	48.0^{b}	52.2^{a}	

^{a,b,c}Within a row, means without a common superscript differ ($P < 0.05$).

Data from the feedlot trial (Table 4) indicated that kids produced by meat goat parents gained faster ($P < 0.10$) than those produced by Angora parents. The average daily gains for crossbred goats were intermediate and did not differ ($P = .34$). Feed conversion ratios ranged from 9.5 to 13.3 and were not statistically different. The Angora kids (AA), which had the lowest gain, also had the lowest feed conversion, indicating a low relative feed intake (data not shown).

Tables 5 and 6 show pooled effects of sex and diet type on growth rate and feed conversion during the feedlot trials. The male kids gained live body weight faster ($P < 0.05$), especially early during the growth period. Later in the trials when kids reached 6 to 7 mo of age (Nov. and Dec.), the male goats displayed rutting activities and gain declined. This decline late in the growth period when feed consumption remained relatively

high apparently reduced feed conversion. Although feed conversion did not differ (P = .72) for the entire period for the kids of different sexes, it is likely the male kids gained more efficiently early and less efficiently late in the trial. Diet type did not affect rate of gain (P = .22) or feed conversion (P = .29).

Table 4. Growth rates and feed efficiencies of Angora and meat goats and reciprocal crosses

	Angora sire		Meat Sire	
	Angora female	Meat female	Angora female	Meat female
Item	AA	MA	AM	MM
Number of kids	102	28	95	71
Average daily gain, lb/d	.15[c]	.21[ab]	.18[bc]	.26[a]
Feed conversion, feed/gain	9.5	13.3	10.8	10.2

[a,b,c]Within a row, means without a common superscript differ (P < 0.10).

Table 5. Growth rates and feed conversions for male and female kid goats[a]

	Sex		
Item	F	M	Pdiff
Number of goats	139	157	
Average daily gain, lb/d	.19	.21	P < 0.05
Feed conversion	10.0 (99)	11.2 (96)	P = .72

[a]Feed conversion was calculated for year 2 data only. The numbers in parentheses represent the numbers of goats used in determining feed conversion.

Table 6. Growth rates and feed conversions for goat kids fed high and low roughage diets[a]

	Diet		
Item	Low roughage	High roughage	Pdiff
Number of goats	149	147	
Average daily gain, lb/d	.21	.20	P = .22
Feed conversion	8.8 (97)	12.4 (98)	P = .29

[a]Feed conversion was calculated for year 2 data only. The numbers in parentheses represent the numbers of goats used in determining feed conversion.

Implications

Reproductive rate was higher in meat goat females than in Angora kids. Meat goat kids exhibited higher weaning weights and growth rates than Angora kids. However, kids out of Angora females that were sired by meat goat males had weaning weights and growth rates higher than Angora kids and similar to those often observed for meat goat kids. Although Angoras cannot successfully compete with meat goats in the production of meat only, the use of meat goat sires on Angora females will increase the likelihood that a combination of meat from crossbred kids and mohair from the Angora females can together return a sum sufficient to justify retention of Angora breeding stock until mohair prices are again favorable.

Nutritional Quality and Intake of Prickly Pear by Goats

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ABSTRACT

Prickly pear is a succulent common throughout the southwestern U.S. Although most efforts focus on control of prickly pear, prickly pear can be used as a reserve forage for livestock during drought. In addition, some ranchers in southern Texas and Mexico have planted a spineless variety of prickly pear for livestock forage. Our objectives were to determine 1) the nutritional quality of both spined (*Opuntia macrorhiza*) and spineless (*Opuntia rufida*) prickly pear, 2) if experiences early in life affect prickly pear intake, and 3) if forage availability affects prickly pear intake. Spineless prickly pear was higher ($P < 0.05$) in dry matter digestibility, organic matter digestibility, crude protein, and tended to promote higher protein retention in goats. Goats at more spined prickly pear on a wet basis, but intake was similar on a dry matter basis. Early life experiences with spineless prickly pear increased ($P < 0.05$) intake of singed prickly pear. Forage availability did not affect prickly pear intake. Collectively, these results suggest that spineless prickly pear would be a more nutritious alternative forage, and that spineless prickly pear can be fed during weaning to increase prickly pear intake after prescribed burning.

Sheep and Goat, Wool and Mohair CPR 2000:65-73

Introduction

Perceptions of prickly pear (*Opuntia* sp.) vary among geographic locations and prevailing climates. Many livestock producers in the southwestern United States attempt to control prickly pear because of its competitive nature with more nutritious forages, livestock health problems caused by prickly pear spines, and interference of prickly pear with livestock handling and forage utilization. In more xeric environments, spineless prickly pear has been introduced as an alternative feed, but little is known about its nutritional qualities. In drought conditions, prickly pear has been used as forage for cattle and other grazing livestock (Griffiths, 1905). Prior to feeding prickly pear as an emergency feed, most ranchers singe pads with a propane burner to improve its acceptance and reduce the health hazards from ingestion of spines (Hanselka et al., 1993).

Throughout most of western and central Texas, prescribed burning is used to manage prickly pear, but mortality rates are typically low following winter fires unless burning is followed with herbicides (Ueckert et al., 1988). The high cost of herbicides lowers the economic feasibility of controlling prickly pear. Given that livestock will consume prickly

pear, particularly once the spines have been removed, it may be feasible to conduct a prescribed burn and then release livestock to consume the singed prickly pear immediately after burning or once the new tender pads sprout.

Recent studies on livestock training have suggested that experiences with certain foods early in life increase intake of those foods later in life (Provenza, 1994). Thus, it may be possible to train livestock to consume more prickly pear, thereby increasing the effectiveness of biological control after prescribed burning.

In Experiment 1, we compared the nutritional quality and intake of spined and spineless prickly pear. Our objective was to determine if either species could meet the nutritional requirements of goats when other forage is limited. In Experiment 2, we determined if goats could be trained to consume prickly pear after prescribed burning. For the third experiment, we assessed how forage availability affected prickly pear intake.

Methods

Nutritional Quality

Experiment 1 began in early summer of 1999 with the use of eight goats (Boer X Spanish Cross) from 15 to 16 mo of age, and weighing approximately 99 lbs. For 5 d, four goats were fed spineless prickly pear (Treatment 1), and four goats (Treatment 2) were fed spined prickly pear with singed thorns. Prickly pear pads were collected on site and chopped into 5 cm strips immediately before feeding each morning. Pad selection was limited to the two outer-most pads that appeared mature. Both species of prickly pear were growing in the same soil type and received the same amount of precipitation. After 5 d of feeding, treatments were reversed and four goats fed spineless prickly pear in Trial 1 were fed singed prickly pear in Trial 2.

Feces and urine were collected daily during each 5-d collection period for each trial. Urine was frozen to maintain nutrient quality until analysis. Feces were dried at 60° C to measure dry matter content and ground to pass through a 1-mm Wylie mill screen. Digestible protein, using nitrogen contents of feces and urine, was determined with standard micro-Kjeldahl procedures. Dry matter digestibility, organic matter digestibility, and digestible organic matter of prickly pear were estimated using standard *in vivo* techniques and compared among the two prickly pear species. Intake was recorded daily for individual goats.

Preliminary evidence suggested that nutrient quality may vary among seasons (Huston et al., 1981). Experiment 1 was repeated in winter (December) to estimate differences in prickly pear quality among summer and winter.

Early Life Experiences

Experiment 2 was conducted at the same time as Experiment 1. Eighteen male and female Boer-cross goats at 4 to 5 mo of age, weighing 44 lbs, were used to determine if experiences early in life affect prickly pear consumption. Treatments consisted of goats

either naive or familiar with prickly pear. All goats were raised in pens to control exposure to prickly pear. The naive goats received only alfalfa pellets (1.5% BW/d) to meet maintenance requirements prior to Experiment 2. Experienced goats were fed spineless prickly pear (two outer pads cut into 2 in strips) ad libitum 1 hr daily until consumption leveled off (8 d). After the initial 8 d, all naive and experienced goats were fed singed prickly pear (two outer-most pads) for 1 hr daily over 4 d with intake recorded daily.

Forage Availability and Prickly Pear Intake

Experiment 3 began 14 d after completion of Experiments 1 and 2. Goats were fed alfalfa pellets at one of the three levels (1.0, 2.0, 3.0% maintenance). Singed prickly pear (two outer-most pads) was fed to all three groups (n = 6/group) for 2 h each morning before feeding their pre-assigned alfalfa ration. Singed prickly pear intake was recorded daily over 5 d. The effects of basal ration feeding level on prickly pear consumption were compared among the three treatments.

Statistical Analysis

A latin square design was used for Experiment 1 and a completely randomized design was used for Experiments 2 and 3. For each experiment, data were analyzed using repeated measures analysis of variance because data were collected over several days. Means were separated using least significant differences (LSD) when $P < 0.05$. Data were analyzed using the statistical computer package JMP.

Results

Nutritional Quality

Goats readily consumed both prickly pear species. Goats consumed more ($P < 0.05$) spineless prickly pear on a wet basis whereas dry matter intake was similar for both species of prickly pear (Table 1). Moisture content during the summer was 95% for spineless, and 90% for singed prickly pear and decreased ($P < 0.05$) in the winter to 90% and 75%, respectively.

Dry matter digestibility varied ($P < 0.05$) among prickly pear species (Table 1). Spineless prickly pear was higher in dry matter digestibility, organic matter digestibility, and digestible organic matter for both summer and winter trials (Table 1).

Digestibility and intake of spined and spineless prickly pear were similar across seasons (Table 2). Crude protein values for both spineless and singed prickly pear were lower in winter than summer (Table 2). Crude protein also differed ($P < 0.05$) among species for the overall experiment (Table 1).

Protein balance (below, at, or above maintenance requirements) was similar among species and across seasons even though percent crude protein differed (Tables 1 and 2). Protein balance for spineless prickly pear was well above maintenance requirements in the winter (Table 2). Values were slightly negative for both species in the summer, but were as high as 0.88 oz for spineless prickly pear in the winter (Table 2).

Table 1. Mean nutritional parameters of spine (singed) and spineless prickly pear fed to goats for Experiment 1. Data were pooled across the summer and winter trials because of a lack of a season effect. Crude protein values were measured using the two outermost pads of each species

Parameter	Singed	Spineless
Wet matter intake, oz/lb BW	2.5[a]	1.2[b]
Dry matter intake,oz/lb BW	0.22	0.19
Dry matter digestibility, %	58.0[b]	79.0[a]
Organic matter digestibility, %	70.0[b]	83.0[a]
Digestible Organic Matter, %	53.0[b]	62.0[a]
Protein balance, oz	0.09	0.39
Crude protein, %	4.8[b]	8.1[a]

[a,b]Within a row, means without a common superscript letter differ (Wet matter intake, $P < 0.05$; DMD, $P < 0.05$; OMD, $P < 0.07$; DOM $P < 0.07$; CP, $P < 0.05$).

Table 2. Mean nutritional parameters of spine (singed) and spineless prickly pear fed to goats during summer and winter. Crude protein values were measured using the two outermost pads of each prickly pear species. Species by season interactions were not significant

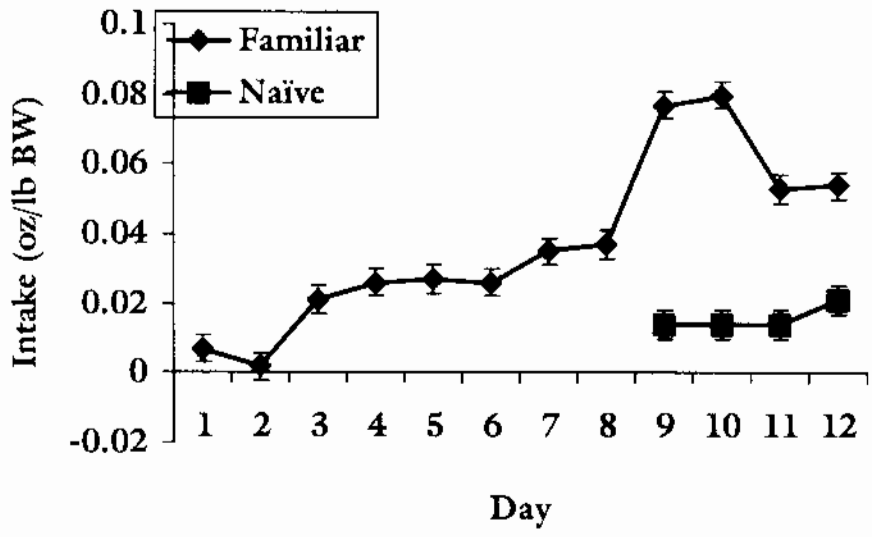
	Summer		Winter	
Parameter	Singed	Spineless	Singed	Spineless
Dry matter intake, oz/lb BW	0.23	0.18	0.21	0.20
Dry matter digestibility, %	63	75	53	83
Organic matter digestibility, %	73	79	67	87
Digestible organic matter, %	54	56	51	69
Protein Balance, oz	-0.04	-0.09	0.23	0.88
Crude protein,	5.1[b]	8.6[a]	4.6[b]	7.6[a]

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).

Early Life Experiences

During the 8-d familiarization period, goats ate an average of 0.02 oz/lb BW (dry weight) of spineless prickly pear during the 1-hr feeding interval. Following initial exposure to spineless prickly pear, goats familiar with spineless prickly pear ate more ($P < 0.05$) singed prickly pear than naive goats (Familiar = 0.05, Naive = 0.02 oz/lb BW, respectively). Intake of prickly pear differed ($P < 0.05$) over the four d of feeding (Figure 1). Nevertheless, familiar goats consistently ate more singed prickly pear than naive goats.

Figure 1. Dry matter intake (lb/oz BW) of singed prickly pear by naive and familiar goats over a 4-d trial period on d 9, 10, 11, and 12 of Experiment 2. The first 8 d involved the familiarization period when experienced goats were fed spineless prickly pear. Goats were fed prickly pear for 1-hr daily for 12 d. Average consumption of spineless prickly pear for the familiarization period was 0.02 oz/lb BW on dry basis.



Forage Availability and Prickly Pear Intake

Varying forage availability levels did not affect singed prickly pear intake for this study (0.05, 0.05, and 0.06 oz/lb BW for below, at, and above maintenance, respectively). Goats familiar with spineless prickly pear in the previous experiment continued to eat more ($P < 0.08$) singed prickly pear than naive goats, regardless of the forage availability (Figure 2).

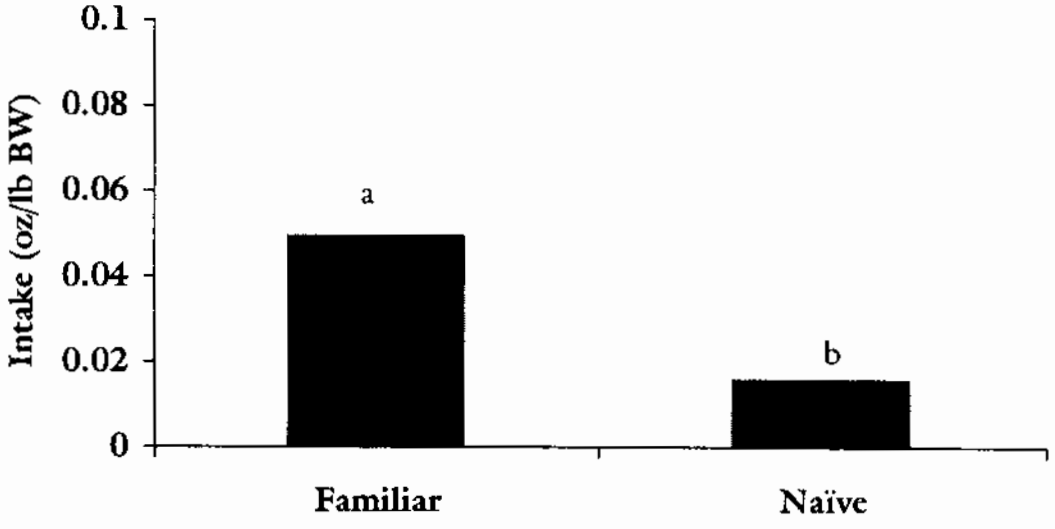
Discussion

Nutritional Quality

Prickly pear is perceived as being of low nutritional value, especially for protein, and a poor feed source for goats (Huston et al., 1981). In this study, spineless prickly pear was higher in nutritional value than spined prickly pear. However, goats readily consumed both species. Given that goats will consume singed prickly pear, and do receive some nutritional benefit from it, ranchers could follow prescribed burning with goating. Grazing singed prickly pear and the new pads that sprout in the spring should increase available forage and reduce regrowth of prickly pear.

Goats were unable to meet maintenance requirements for protein during the summer. Conversely, maintenance requirements for protein were met during the winter when goats were consuming prickly pear. Thus, protein supplementation would be required in the summer when goats were eating prickly pear and alternative forage was limited.

Figure 2. Dry matter intake (oz/lb BW) of singed prickly pear by naive and familiar goats in Experiment 3. Goats were fed a basal ration at 1.0, 2.0, or 3.0% maintenance. Goats were fed prickly pear for 1 h daily for 12 d. Intake of the basal ration did not affect ($P > 0.05$) intake of prickly pear.



The relatively high digestibility and positive protein balance of spineless prickly pear suggest that it may serve as a viable alternative feed source for goats and possibly other ruminant livestock. Establishing spineless prickly pear can be highly successful, but requires at least 4 yr for sufficient biomass to accumulate (Turpin and Gill, 1928). The palatability of spineless prickly pear will likely necessitate fencing around the perimeter to limit herbivory until plants are established. Thereafter, offering spineless prickly pear as a forage would be more cost effective than burning spined prickly pear in droughts because of the high cost of labor and cost of propane.

Spineless prickly pear could also serve as emergency forage for wildlife in the form of food plots when forage is limited. Given the relative palatability of spineless prickly pear, producers may need to limit wildlife access to prevent over-harvesting. Some area ranchers are establishing deer-proof fences around food plots that can be raised or lowered to control deer access to the plot. As forage becomes limited on rangelands, fences could be lowered to allow deer access to spineless prickly pear.

Most forages grown in food plots for deer were developed in areas that receive higher and more consistent precipitation and are not adapted to xeric climates. Because spineless prickly pear evolved in dry conditions, it should remain productive even during drought.

Early Life Experiences

Experiences early in life can improve consumption of undesirable plants later in life as evident from this experiment and others (Provenza, 1994). Weaning is a vulnerable

time for diet selection because of limited maternal influences on dieting habits (Hinch et al., 1987). Following weaning, goat kids could be hand-fed spineless prickly pear to improve its acceptance. Given that spineless is more nutritious than spined, goats should develop a preference for it (Provenza, 1995). Once goat kids acquire a preference for spineless prickly pear, the transition to singed prickly pear is easily attainable. As an alternative to growing and hand-feeding spineless prickly pear, producers could wean goat kids in a pasture after singeing prickly pear spines instead of conditioning with spineless prickly pear.

Forage Availability and Prickly Pear Intake

Forage availability did not affect prickly pear intake in this study. Goats consumed prickly pear at a constant rate regardless of the energy content of the basal ration. Goats may have continued to consume prickly pear because of an innate desire to consume a variety of foods. In another study, when lambs were offered three rations varying in nutrient quality (high, medium, and low), they consistently ate all three even though the high quality ration met all of their dietary requirements (Provenza et al., 1996). Food preferences change within meals often to less nutritious foods (Newman et al., 1992) and ruminants prefer alternatives to forages they have consumed for several days (Ramos and Tennessen, 1993) or even several hours (Parsons et al., 1994). Reasons for why animals consume a variety of foods remains unclear; however, Provenza (1995), argued that preferences change in response to postingestive feedback from nutrients and toxins within a meal. For instance, as energy or protein levels consumed increase, preference of the flavor associated with the nutrient decreases (Villalba and Provenza, 1999). Thus, as levels of energy increase, preferences for foods high in energy decreases and preferences for food high in protein increases (Gietzen, 1993). This results in animals selecting a diet that achieves a ratio of digestible energy intake to digestible protein intake between 47-49 (Egan, 1977). Given the positive protein balance that resulted from consumption of prickly pear in Experiment 1, goats may have consumed prickly pear in this study even though energy requirements were met with the basal ration.

Prickly pear may also provide other essential nutrients such as some minerals and vitamins that may be limited. Preliminary studies have illustrated that livestock and wildlife often consume prickly pear even when forage quantity is not limited (Taylor et al., 1980). In 1999, monthly samples of spineless and spined prickly pear were taken to determine changes in nutrient content throughout the yr. These samples will be analyzed for digestibility, N, P, K, Mg, and several trace minerals to identify correlations among changes in specific nutrient content levels and the selection of prickly pear as a dietary item.

Implications

The concept of eliminating prickly pear is not practical because of economic restraints, its use as emergency feed during droughts, and it's importance for wildlife habitat.

Improved methods of controlling and utilizing it may be feasible. Environmentally sound range improvement methods will be demanded in the future for natural ecosystem sustainability. The capabilities to manipulate goats at weaning are achievable if producers take time to implement a training period by means such as feeding spineless prickly pear. In the near future, producers may have the knowledge and technology available to select goats for both commodity production and as biological control agents.

Spineless prickly pear has the potential as an alternative forage when range conditions are depleted. Nutritionally, it yields enough protein to meet and even exceed a goat's protein requirements. Spineless prickly pear could be used for deer forage in the form of high-fenced food plots, but the cost of implementation is unknown.

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Germination and Subsequent Diet Selection of *Juniperus Ashei* and *Juniperus pinchotii* Seedlings by Angora Goats

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ABSTRACT

Ashe and redberry juniper (*Juniperus Ashei* and *J. pinchotii*, respectively) contain phytochemicals that reduce their palatability. This is part of the reason these plants have extended their geographic range as well as increased in density. The objectives of this project were to determine the germination of redberry and Ashe juniper seeds and then use the seedlings from the germination study along with live oak (*Quercus virginianus*) and ashe juniper with mature foliage to determine preference of Angora goats for these plants in a pen study. Ten thousand seeds of redberry and Ashe juniper were planted in 200, 1-quart pots (50 seeds per pot). Seeds were randomly collected from 40 trees (20 trees per species) in December and January and planted in the spring with the fruit removed. Only about one-tenth of the seeds of redberry and Ashe that emerged germinated in the spring, compared to about one-fifth to one-fourth in the fall, and about two-thirds in the winter. There was no germination of either species during the summer. Preference determined using **Rodgers' Index** for cafeteria-style experiments averaged .87, .53, .34, and .24 for live oak, redberry juniper seedlings, Ashe juniper seedlings, and mature Ashe juniper, respectively. Sixteen and 39% of the redberry and Ashe seedlings were killed by goating, respectively. Distance from mineral soil to cotyledons averaged 0.7 in for redberry and 1.3 in for Ashe juniper. Ashe juniper seedlings are more susceptible to goating than redberry because of greater cotyledon height.

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Introduction

Redberry juniper (*Juniper pinchotii*) and Ashe juniper (*Juniper Ashei*) contain phytochemicals (terpenoids) that reduce their palatability (Riddle et al., 1996; Pritz et al., 1997). This reduced palatability partially explains why these plants have been able to extend their geographic ranges and greatly increase their abundance. Juniper has significantly increased over the past 100 yr (Ansley et al., 1995; Smeins et al., 1997; Ueckert, 1997). This increase in juniper has caused a significant reduction in the carrying capacity of Texas rangelands for livestock (Taylor and Ralphs, 1992; Fuhlendorf and Smeins, 1997), decreased water yield and increased erosion (Thurow and Hester, 1997), increased labor costs associated with problems of livestock management (Scifres, 1980),

decreased wildlife habitat (Rollins and Armstrong, 1997), and a loss in biodiversity (Fuhlendorf et al., 1997).

Management of juniper on rangeland is usually expensive and success can be variable for most techniques. Therefore, preventive measures and management of such lands requires an understanding of the causes of the problem as well as the implementation of cost-effective juniper control methods to meet resource goals and objectives. This requires an understanding of the life history and physiological aspects of the vegetation and how they are related to the grazing behavior and physiology of the livestock to properly utilize grazing techniques to guide succession toward a desired plant community. Previous research at the Texas Agricultural Research Station has shown that immature juniper foliage has lower concentrations of terpenoids than mature juniper foliage (Straka, unpublished data). Also because of different compositions of terpenoids, mature redberry juniper is less palatable than mature Ashe juniper (Riddle et al., 1996; Pritz et al., 1997). The Ashe and redberry juniper seedlings had needle leaves and retained their cotyledons for approximately 4 mo. The mature foliage of the Ashe juniper was represented by scale leaves with fully developed glandular trichomes. Glandular trichomes containing secretory cells in the epidermal layer are the primary sites of terpenoid production and accumulation in most oil producing species (Yamaura et al., 1992; Gershenzon et al., 1992). It is our hypothesis that juniper seedlings are more palatable and therefore more vulnerable to herbivory than Ashe juniper with mature foliage. This knowledge, coupled with when juniper seeds germinate, provide information that would allow the tactical use of goats to remove juniper at its most vulnerable growth stage. The objectives of this study were: 1) to document the seasonal germination of redberry and Ashe juniper seeds over an 18-month period; and 2) to quantify the preference for redberry and Ashe juniper seedlings in the cotyledon stage by Angora goats relative to live oak and Ashe juniper with mature foliage.

Materials and Methods

The study was conducted at the Texas Agricultural Experiment Station (31° N, 100 ° W) between Sonora and Rocksprings, Texas. Detailed site descriptions can be found in Riddle et al. (1996).

For the germination trial over 10,000 seeds of redberry and Ashe juniper were randomly collected from 40 trees (20 trees per species) during December,1993 and January, 1994. Pulp was removed from the juniper berries before planting. Two hundred 1-quart pots were filled with soil collected from a site on the Experiment Station which supported equal numbers of redberry and Ashe juniper. Fifty seeds per pot (200 total pots) of each juniper species were planted approximately 1.5 cm deep in 100 pots in the spring of 1994. The pots were placed in a greenhouse and new seedlings per pot were counted on a seasonal basis. The greenhouse was cooled with an exhaust fan and

evaporative cooler in the summer. It was not uncommon for temperatures within the greenhouse to reach 100° F during the hottest part of the summer. A natural gas heater was used during the winter months; however, freezing temperatures were occasionally measured in the greenhouse. The germination study was concluded when no new seedlings were recorded for two successive seasons.

Live oak acorns were collected in the fall of 1992 and planted in small styrofoam cups filled with soil from the Experiment Station. After these seedlings reached 1 yr of age they were transplanted to 1-quart pots (one seedling per pot). Ashe juniper plants 12 to 18 in tall with mature foliage were randomly located on the Experiment Station and transplanted into 1-quart pots in 1993. Live oak and Ashe juniper with mature foliage were included in the cafeteria trials because these plants are generally abundant where seedling recruitment is taking place and we wanted a better understanding of how goats would use the vegetation complex when browsing. Live oak is more palatable than redberry or Ashe juniper (Taylor, 1992). Although live oak also has phytochemicals (tannins) that affect palatability and intake, it's tannins apparently are less aversive to domesticated herbivores than terpenoids.

In April 1995, eight Angora goats were randomly placed into individual pens (4 - 8 ft) and fed a 16% crude protein pellet (full feed) for 5 d. After a base line intake had been determined for each goat, goats were fed 75% of their average intake of the pelleted ration and were also offered live oak, redberry and Ashe juniper free choice for a 10-d preliminary feeding period.

Four goats that appeared to be the best adjusted, based on feed and forage consumption and temperament, were selected for the cafeteria trials. A total of 16 cafeteria trials were conducted (four trials per goat). The number of pots of each species needed for the cafeteria trials were placed outside of the greenhouse approximately 1 mo prior to the feeding trials to allow plants to "harden". For each trial four 1-quart pots each of redberry juniper seedlings, Ashe juniper seedlings, live oak, and Ashe juniper with mature foliage were placed into a pen. Pots were randomly arranged in a tray and the goats were allowed to browse on the plants for 5 min. Three different methods were used to quantify use on each plant species. One method recorded the bites/plant while another method was a measure of plant disappearance by measuring pre- and post-browsing plant length. Feeding time per plant was also recorded. Calculation of Rodgers' Indices of preference were determined from the bite data. This method of determining preference is recommended for cafeteria trials where forage is not replenished as it is consumed (Krebs, 1989).

Data were analyzed as a one-way analysis of variance ($P < 0.05$) and means were separated by Duncan's Multiple Range test (SAS, 1988).

Results and Discussion

Germination

Total germination of redberry and Ashe juniper averaged 5.7 and 5.3%, respectively, for the 18-mo study. Only one redberry seedling emerged 22 mo after the seeds were planted. This low germination is typical of these two plant species (Smeins and Fuhlendorf, 1997). Based on their results from germination studies conducted at the Texas Agricultural Experiment Station, Smeins and Fuhlendorf concluded that desiccation, bacteria, and other degrading factors seem to destroy the seeds after 18 mo. In another study near Uvalde, Texas, germination of juniper seeds from a seed bank was 0% while germination of freshly collected seeds was 5% (Owens and Schliesing, 1995).

For our study, total germination was not as important as when germination actually occurred. Percent of total germination of redberry seeds averaged 11.9, 0, 26.7, and 61.3% for the spring, summer, fall and winter seasons, respectively. The pots were monitored for another two seasons after the winter period but no new seedlings were observed. Percent of total germination of Ashe juniper averaged 9.4, 0, 18.2 and 72.3% for the spring, summer, fall and winter seasons, respectively. For both species the greatest level of germination occurred approximately 12 mo after the seeds had been collected from the trees ($P < 0.05$).

Since soil moisture was readily available and fairly constant throughout the germination study, temperature must have been a major factor in determining when germination was initiated. Smeins and Fuhlendorf (1997) reported that favorable precipitation during the late spring-early summer period was responsible for germination of juniper seeds. They also reported that cold-stratification of seeds with the fruit removed increased overall germination. Even though results of these germination studies still leave some uncertainty, knowledge of the level of juniper berry production along with seasonal weather conditions should illuminate optimal periods of seedling recruitment.

Cafeteria trial

Number of bites per min averaged 21, 16, 13, 11 and 5 for the first, second, third, fourth, and fifth min of feeding trials, respectively. Biting rate over each 5-min trial was affected mostly by forage disappearance. As the preferred foliage was harvested, goats reduced their biting rate and spent more time searching through the remaining foliage.

Goats averaged 31, 18, 11, and 9 bites from live oak, redberry juniper seedlings, Ashe juniper seedlings and Ashe juniper with mature foliage for the 5-min trials. Because pots with juniper seedlings had less biomass than the live oak or Ashe juniper with mature foliage, total number of potential bites per seedling pot was limited. Number of bites for the first min averaged 15.4, 3.9, 1.4 and .4 for live oak, redberry juniper seedlings, Ashe juniper seedlings, and Ashe juniper with mature foliage, respectively (Table 1). Goats generally selected live oak, removing the easily accessible foliage first and then moved to redberry and Ashe juniper seedlings. Number of bites for the second min of each trial

were similar for live oak, redberry and Ashe juniper seedling but lower for mature Ashe juniper foliage ($P < 0.05$). Once the seedlings had been mostly harvested, the goats would go back to the live oak and harvest the remaining foliage or alternate between live oak and juniper seedlings. Mature Ashe juniper foliage was mostly avoided until the fourth and fifth min when very little live oak or juniper seedlings were left.

Table 1. Average number of bites per minute from live oak, redberry and Ashe juniper seedlings, and Ashe juniper with mature foliage by Angora goats

	Bites per Minute				
Species	1st	2nd	3rd	4th	5th
Live oak	15.4[a]	4.6[a]	4.6[a]	2.6[ab]	0.6
Redberry juniper	3.9[b]	4.6[a]	4.1[a]	4.1[a]	0.6
Ashe juniper	1.4[bc]	4.3[a]	3.0[ab]	0.9[b]	1.3
Mature Ashe Juniper foliage	0.4[c]	1.6[b]	1.3[b]	3.3[ab]	2.0

[a,b,c]Within a column, means without a common superscript letter differ ($P < 0.05$).

Values calculated by using Rodgers' indices of preference were .87, .53, .34 and .24 for live oak, redberry juniper seedling, Ashe juniper seedling, and Ashe juniper with mature foliage, respectively. These values were determined from the entire 5-min cafeteria trial. Live oak was preferred over other species ($P < 0.05$) and redberry and Ashe juniper seedlings were preferred over Ashe juniper with mature foliage ($P < 0.05$). Goats spent 43, 27, 17 and 1.3% of their feeding time on live oak, redberry and Ashe juniper seedlings, and Ashe juniper with mature foliage, respectively.

Percent of plant height removed was 31, 59, 58, and 1% for live oak, redberry and Ashe juniper seedlings, and Ashe juniper with mature foliage, respectively. After the cafeteria trials were completed the plants were monitored and plant deaths were recorded. Sixteen percent of the redberry juniper seedlings were killed by goating compared to 39% for Ashe juniper seedlings. Any seedlings bitten below the cotyledon area died. The average height from mineral soil to the cotyledons was 0.7 in for redberry juniper seedlings which represented 18.5% of total plant height compared to 1.4 in for Ashe juniper seedlings which represented 35.7% of total plant height. Because the cotyledons were more elevated for Ashe juniper seedlings, they were more vulnerable to goating than redberry juniper seedlings. These findings were unexpected but may help explain why redberry and Ashe juniper are not evenly distributed over the research station. For example, two long-term livestock exclosures at the Sonora Research Station (exempt of domestic grazing and browsing since 1948) have an Ashe juniper to redberry juniper ratio of 95:5 (based only on plant numbers). Pastures that have had some level of domestic

herbivory since 1948 have Ashe juniper to redberry juniper ratios that range from 80:20 to 5:95.

Implications

Since the weakest link in the life cycle of juniper is the seedling stage, we recommend frequent browsing with goats to take advantage of the window of palatability that seedlings experience before they cross over the threshold and become less palatable. Concentrate goats on the young seedlings to attack the juniper when it is in its most vulnerable life stage and lowest in terpenoids. Increase grazing pressure (concentration of goats) on target pastures in the winter. Hit the juniper hard when goats will most likely consume it and harm to other plant species can be minimized. Initiate a close monitoring program for early detection of juniper seed germination and seedling emergence. Monitor use on the preferred forage to insure that over browsing does not occur. Goating is a unique management tool in that it can directly generate income in the short term to help pay for other control methods and to extend the effective treatment life of the more expensive, conventional control methods.

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Near Infrared Spectroscopy of Sheep Feces for Predicting Botanical Composition of Diets

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ABSTRACT

The lack of simple and affordable techniques for estimating the dietary composition (both chemical and botanical) of free-grazing ruminants is a major limitation to grazing management. The objectives of this study were to expand the use of near infrared spectroscopy (NIRS) of fecal samples for predicting the percentage of mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb) Beetle) in the diet, investigate the ability of NIRS to simultaneously predict multiple botanical species or categories, and to quantify the limitations of using NIRS of fecal samples to predict diet composition. This research was conducted at the USDA, U.S. Sheep Experiment Station located in Dubois, Ida. Fecal materials from three feeding trials with known levels of sagebrush were used to develop NIRS fecal calibration equations and to validate these equations. The 1996 trial varied both level of sagebrush and levels of alfalfa and grass hay. The 1998 trial compared frozen to air-dried sagebrush. The Wyoming trial was a metabolism study using frozen sagebrush. Trials used different levels of sagebrush varying from 0 to as much as 30% of the diet in increments of 4 to 10 percentage points. All data sets had acceptable calibrations for percentage of sagebrush in the diet. Coefficients of determination ranged from 0.91 to 0.95 with a standard error of calibration (SEC) of about 2 percentage points or about 15% of the mean level of sagebrush in the diets fed. The validation statistics for independent data sets were generally acceptable, with some exceptions. Validation for internal data sets, i.e., when validation data were a subset of samples used for calibration, were excellent with an R^2 exceeding 0.90, slopes of 1.0 and coefficient of variation from 11 to 22%. The average H statistic far exceeded the recommended value of 3 for all external validation data sets (i.e., data sets that were not a subset of the same trial from which the calibration was developed). However, a small average H did not ensure that the bias and slope did not exceed acceptable limits. This use of NIRS of fecal samples to predict botanical composition of diets made research possible that could not have been conducted with other procedures.

Sheep and Goat, Wool and Mohair CPR 2000:81-94

Introduction

The lack of simple and affordable techniques for estimating the dietary composition (both chemical and botanical) of free-grazing ruminants is a major limitation to grazing management. Near infrared spectroscopy (NIRS) of fecal samples to predict the percentage of leafy spurge (*Euphorbia esula* L.) in the diets of sheep and goats is an alternative to more costly procedures such as microhistological analysis (Walker et al., 1998).

The objective of this study was to expand the use of NIRS of fecal samples for predicting the percentage of mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb) Beetle) in the diet and as a methodology for estimating the phenotypic expression of sagebrush consumption for estimation of the heritability of preference for sagebrush (Snowder et al., 2000). We also investigated the ability of NIRS to simultaneously predict multiple botanical species or categories. Finally, we tried to quantify the limitations of using NIRS of fecal samples to predict diet composition in the case typical of free grazing animals where samples are not available for validating suspected spectral outliers.

Methods

This research was conducted at the USDA, U.S. Sheep Experiment Station located in Dubois, Ida. Fecal materials from three feeding trials with sheep fed known levels of sagebrush were used to develop NIRS fecal calibration equations and to validate these equations. A feeding trial was conducted in 1996 to develop a NIRS calibration equation. A feeding trial in 1998 was conducted to validate the 1996 trial and determine if the intake of sagebrush was affected by air-drying compared to storing samples frozen before feeding. Fecal samples from a trial conducted in Wyoming to determine the effect of increasing levels of sagebrush on intake and digestibility were analyzed to validate and compare results from the 1996 and 1998 feeding trials.

1996 Feeding Trial

The 1996 feeding trial consisted of feeding varying levels of mountain big sagebrush, early bloom alfalfa hay (*Medicago sativa* L.) and a grass hay that was composed of smooth brome (*Bromus inermis* Leyss.) and timothy (*Phleum pratense* L.). The sagebrush was collected in late September 1996 and air-dried in the shade (maximum daily temperature 70° to 85° F). Diets were mixed to contain 0, 4, 8, 12, 16 and 24% sagebrush with a base diet of alfalfa/grass hays in the following proportions: 0:100, 20:80, 40:60, 60:40, 80:20 and 100:0 for a total of 36 different diets. Molasses was added to the diets (5% DM) during the mixing process to cause feed to adhere together and reduce sorting when fed.

The diets were fed to 36 mature white-faced western range ewes housed in individual pens. Diets were fed at 0800 and 1600 h and refusals were removed at 0800 h. The trial

consisted of a 6-d adaptation period and 4-d collection period. Fecal samples were collected from the floor of the pens at1600 and 0800 h, and dried in a forced air oven at 140 °F.

1998 Feeding Trial

The 1998 feeding trial consisted of feeding varying levels of mountain big sagebrush that was stored either air-dried or frozen before the study (Fraker 1999). The sagebrush for this trial was current season's growth of vegetative stems (no flowering stalks) collected the last week of August 1997. Half of the sagebrush was air dried (maximum temperature 85° to 90°F) and stored in plastic bags, and half was frozen promptly after collection and stored in a freezer. Diets were mixed to contain 0, 8, 16 and 24% of either dry or frozen sagebrush with a base diet of 1:1 alfalfa/grass (grass was a mixture or smooth brome and timothy hay) for a total of 7 different diets. Molasses was added to the diets (5% DM) during the mixing process to cause feed to adhere together and reduce sorting.

An intake and digestion trial was conducted in January 1998 using 6 to 7-month-old white-faced crossbred lambs. The animals were penned individually and 5 animals were assigned to each diet for a total of 35 animals (34 wethers and 1 ewe). Animals were fitted with fecal bags to determine total fecal production. Feed was offered in excess from 0800 to 1100 h and from 1300 to 1600 h. Every 30 min, while feed was offered, feed bunks were checked and more feed was added if needed. This procedure limited the potential for sorting and minimized the amount of refusal. The trial consisted of a 5-d adaptation period and a 6-d collection period. Fecal bags were emptied twice daily, and a sub-sample of feces was collected. Afternoon samples were composited with collections made the following morning and dried in a forced air oven at 140°F.

Wyoming Feeding Trial

Fecal samples from a feeding trial conducted by Ngugi et al. (1995) and kindly provided by Jeff Powell, University of Wyoming, were used to validate a calibration equation based on the combined 1996 and 1998 trials. This trial used 16 Rambouillet wether lambs (60 to 90 lb body weight) fed diets containing mixtures of hand-harvested current year's growth of mountain big sagebrush leaves and native grass hay. Sagebrush leaves were harvested in September from the western edge of the Medicine Bow Range, Carbon County, Wyo., and stored in sealed plastic bags in a freezer until fed. Four diets in the following proportions of grass hay:sagebrush: 100:0, 90:10, 80:20, and 70:30 were fed. Four animals received each diet. The trial consisted of a 9-d adjustment period followed by a 6-d collection period when all urine and feces were collected. Fecal samples were composited by animal for the 6-d collection period and ground through a 1-mm screen of a Wiley mill. Samples were reground through a cyclone mill before being scanned to collect NIRS reflectance. Details of this trial were presented by Ngugi et al. (1995).

Equation Development

All fecal samples were ground in a cyclone mill to pass a 1-mm screen, packed into sample cells with a near-infrared transparent quartz cover glass, and scanned 32 times using a NIR Systems, Inc. (Silver Spring, Md.) model 6500, scanning reflectance monochromator. Reflected energy (log 1/R) was measured, averaged over the 32 scans and recorded at 2-nm intervals from 400 to 2,500 nm.

Calibration equation development was done using stored NIRS spectra from fecal samples as the independent variables and percent sagebrush, grass or alfalfa fed in the diets as the dependent reference data in the 1996, 1998 and Wyoming trial diets. Before calibration, each spectrum was transformed with a (1,8,8) derivative. The first number in parenthesis is the order of the derivative the second number is the gap (number of data points), and the third number is the smooth (number of data points). Scatter correction was done with the standard normal variance and detrend procedure. Prediction equations were developed using stepwise regression. A maximum of five wavelengths were selected with entry criteria based on maximizing R^2.

Data Analysis

Data from the 1996 and 1998 trials were individually examined to identify and remove outlier samples. Separate calibration equations and outlier eliminations were done for the 1996 and 1998 trials. Samples, which were contained in the calibration data set, that had an H larger than 3 or a residual "t" statistic greater than 3 were eliminated. This resulted in the elimination of 6 and 10 samples from the 1996 and 1998 data sets, respectively, or approximately 5% of the samples from each of the data sets.

Calibration equations were evaluated for usefulness based on validation statistics for unrelated samples. Calibration refers to the development of a multiple regression equation using the reflected energy (log 1/R) of the near infrared spectra as independent variables to predict the botanical component (i.e., dependent variable or reference value). Validation refers to the ability of the calibration equation to predict the reference value of a sample that was not part of the data set used in the development of the calibration equation. Validation samples are referred to as internal if they were a subset of a uniform group of samples used to develop a calibration equation and external if they were from a set of samples from a different trial or treatment. The statistics that were evaluated included standard error of prediction (SEP), coefficient of determination, slope and bias calculated from the predicted and actual values for percent composition of the diet. Six pairs of calibration and validation data sets were evaluated for the ability to predict percentage of sagebrush in the diet.

1. The 1996 and 1998 data sets were combined and divided into calibration and validation data sets. Calibrations for the 1996 data were based on samples collected on d 1, 2, and 4 of the 4-d collection period and d 1, 3, and 5 for the 6-d collection period in 1998. Validation data sets were composed of samples collected on the

remaining days so that the calibration data set contained about 72% of the samples and the validation set contained 28% of the samples (96&98 Internal).

2. Combining all of the 1996 and 1998 data for the calibration data set and validating these data with the Wyoming data (96&98 → Wyoming).
3. Using the 1996 samples for calibration and the 1998 samples for validation (1996 → 1998).
4. Using the 1998 samples for calibration and the 1996 samples for validation (1998 → 1996).
5. Using the 1998 diets from dry sagebrush to predict the 1998 frozen sagebrush diets (DRY → FROZEN).
6. Using the 1998 diets from frozen sagebrush to predict the 1998 dry sagebrush diets (FROZEN → DRY).

The only samples that were appropriate to evaluate the ability of NIRS of fecal samples to predict multiple botanical components in the diet were the 1996 samples. For this analysis the samples from d 1, 2 and 4 were used for calibration and d 3 was used for validation.

Results and Discussion

All data sets had acceptable calibrations for percentage of sagebrush in the diet (Table 1). Coefficients of determination ranged from 0.91 to 0.95 with a SEC of about 2 percentage points or about 15% of the mean level of sagebrush in the diets fed. The validation statistics for independent data sets were generally acceptable, with some exceptions. As expected, the validation of combined 1996 and 1998 samples (96&98 Internal) with an equation based on a subset of these samples resulted in one of the best calibrations. The Wyoming validation had a high coefficient of determination, but the slope of 3.1 indicated that the range of the predicted values was about one-third the range of the actual samples and the bias of 11.1 showed that the predicted values averaged 11 percentage points less than the actual values (Fig. 1).

The low coefficient of determination (0.68) for the validation of the 1998 frozen samples with the calibration equation calculated from the 1998 dry samples (DRY → FROZEN) was caused primarily by predicted values for percentage of sagebrush in the diet that were lower in the 24% sagebrush diets (Fig. 2). This may have been caused by a lower intake by animals fed this high level of FROZEN sagebrush (Fraker, 1999). In contrast, the Wyoming data validated well (R^2 = 0.89, SEP = 13.7) even though there was a much greater decrease of intake with increasing levels of sagebrush (Ngugi et al., 1995) compared to the 1998 trial. Validation statistics for the calibration equation developed from the 1998 frozen samples to predict the 1998 dry samples were much improved. Presumably, the stepwise regression procedure of the 1998 frozen samples

identified wavelengths that were not affected by reduced intake when higher percentage levels of dry sagebrush were fed.

The use of calibration equations developed from either of the two different trials to predict the other trial (96 → 98 or 98 → 96) resulted in somewhat similar validation statistics. Both calibrations had coefficients of determination of 0.83, but the slope and bias for the predicted 1998 samples indicated that the range of the predicted values and the mean of these values were less than actual values (Fig. 3). In contrast, the predicted values for 1996 samples had a range and mean that was greater than the actual values (Fig 3). The higher SEP (9.9 percentage points) for the 1998 validation statistics compared to the 1996 samples (4.6 percentage points) was a result of the higher bias in the former set of samples.

Internal validation of the 96&98 data set provided a satisfactory average H statistic (1.0) and a perfect slope (1.0) proving that NIRS can be a highly reliable tool for estimating botanical composition of diets if the predicted samples are from the same population as the calibration samples. However, for all external validation data sets, i.e., data sets that were not a subset of the same trial from which the calibration was developed (Table 1), the average H statistic far exceeded the recommended value of 3. A small average H did not ensure that the bias and slope did not exceed acceptable limits (Shenk et al., 1989) as in the 1998 feeding trial DRY → FROZEN or FROZEN → DRY calibration and validation test. Based on the suggested limits of Shenk et al. (1989), these equations would not be applicable beyond similar samples generated in the same feeding trial from which calibrations were developed as in the 96&98 internal calibration validation data sets.

Calibration and internal validation statistics for the prediction of sagebrush, alfalfa, and grass from fecal samples from the 1996 trial (Table 2) show that NIRS of fecal samples could predict an array of dietary components (Fig. 4). The SEP was greater in the Alfalfa and Grass components, but this was related to the larger mean for these components. The CV for these different components ranged from 11 to 20%. For comparison, Walker et al. (1998) showed a CV of around 10% for NIRS predictions of leafy spurge in the diet, and Coleman et al. (1995) reported a CV of around 16% for percent digestibility of diets.

Conclusions

The results of this study show that NIRS of fecal samples is a useful tool for predicting botanical composition of diets of free-ranging ruminants when the calibration fecal samples are a sub-sample of the population of fecal samples whose near infrared spectra are being used to predict the diet composition. We also believe this is a useful but less accurate procedure when calibration equations are based on fecal samples from a different population than the one being predicted. These results indicate that the use of NIRS of fecal samples to predict botanical composition of diets should be limited to

instances where relative differences between treatments or animals grazing similar pastures are a sufficient level of measurement.

We recently used equations developed from these data sets to estimate the amount of sagebrush in diets of almost 2,000 free-ranging sheep. This was done to estimate the heritability of preference for sagebrush (Snowder et al., 2000a,b). Whereas the accuracy of the predictions is unverifiable, the results were in line with what we anticipated in that animals that consumed more sagebrush in September also consumed more in October. Cook and Harris (1968) also reported that overall sagebrush consumption increased as the season progressed. However, the mean level of sagebrush in the diets was higher than we would have anticipated, indicating a probable bias in the data. Despite this potential shortcoming a study of that magnitude would not have been possible with any other available technology.

Table 1. Calibration and validation statistics for fecal NIRS equations used to predict percentage of sagebrush in the diets of sheep

	Calibration Statistics				Validation Statistics						
Data Sets	n	R^2	Mean[a]	SEC[b]	n	R^2	SEP[c]	Slope[d]	SEP(C)[e]	Bias[f]	Average H[g]
96 & 98 Internal	240	0.92	12	2.3	97	0.90	2.7	1.0	2.7	1.4	1.0
96 & 98 Wyoming	337	0.91	12	2.4	20	0.89	13.7	3.1	8.3*	11.1*	10.2*
1996 → 1998	137	0.95	10	1.8	200	0.83	9.9	1.7	4.4*	8.8*	8.1*
1998 → 1996	200	0.93	13	2.2	137	0.83	4.6	0.7	4.5*	-0.8	5.2*
DRY → FROZEN	106	0.94	13	2.0	94	0.68	7.6	1.2	4.6*	6.0*	1.6
FROZEN → DRY	94	0.95	13	1.8	106	0.89	3.1	1.1	2.9*	1.2*	1.6

[a]Mean = mean percentage of sagebrush in calibration diets.
[b]SEC = standard error of calibration.
[c]SEP = standard error of prediction.
[d]Slope = slope of the line between reference and predicted values.
[e]SEC(C) = standard error of prediction corrected for bias.
[f]Bias = systematic error (i.e., intercept).
[g]Average H = standardized Mahalanobis distance.
*Exceeded value recommend by Shenk et al. 1989.

Table 2. 1996 feeding trial calibration and validation statistics for fecal NIRS equations used to predict sagebrush, alfalfa, and grass in the diets of sheep

	Calibration Samples				Validation Samples							
	n	R^2	Mean[a]	SEC[b]	n	R^2	SEP[c]	Slope[d]	SEC(C)[e]	Bias[f]	Average H[g]	CV[h]
Sagebrush	106	0.95	11	1.8	31	0.93	2.1	1.0	2.1	-0.1	1.1	0.20
Alfalfa	102	0.97	44	5.1	30	0.98	5.1	1.0	4.5	2.4	1.0	0.11
Grass	102	0.96	45	5.9	30	0.96	6.2	1.0	6.2	0.9	1.1	0.14

[a]Mean = mean percentage of sagebrush in calibration diets.
[b]SEC = standard error of calibration.
[c]SEP = standard error of prediction.
[d]Slope = slope of the line between reference and predicted values.
[e]SEC(C) = standard error of prediction corrected for bias.
[f]Bias = systematic error (i.e., intercept).
[g]Average H = standardized Mahalanobis distance.
[h]CV = residual coefficient of variation calculated by dividing SEP by the reference mean × 100.

Figure 1. Actual percent mountain big sagebrush fed vs predicted percent using NIRS prediction equations based on fecal spectra. Data represent an internal validation of the combined 1996 and 1998 feeding trials subset into calibration and validation data sets (•), or an external validation using the entire 1996 and 1998 data to develop an equation to predict samples from a Wyoming feeding trial (+).

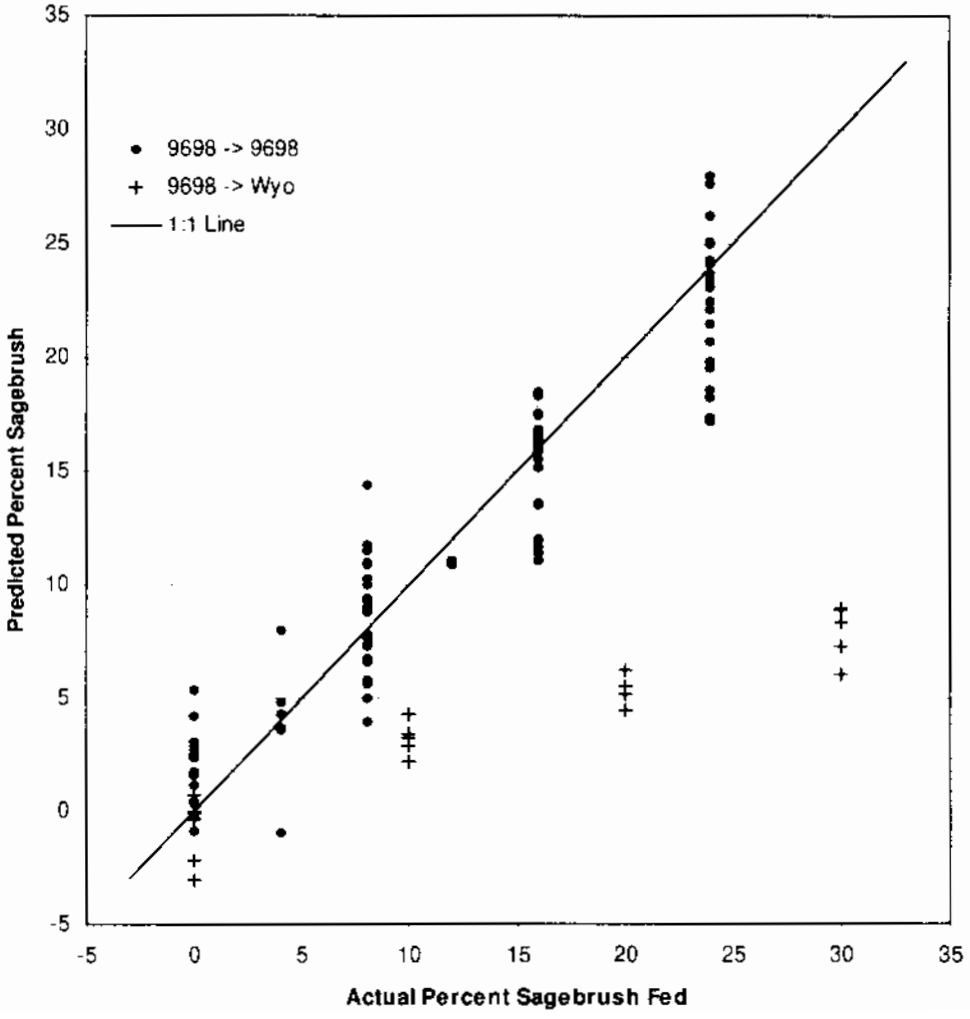


Figure 2. Actual percent mountain big sagebrush fed vs NIRS prediction equations using fecal spectra. Data represent equations developed with the 1998 DRY samples to predict the 1998 FROZEN samples (•), or the 1998 FROZEN samples to predict the 1998 DRY samples (+).

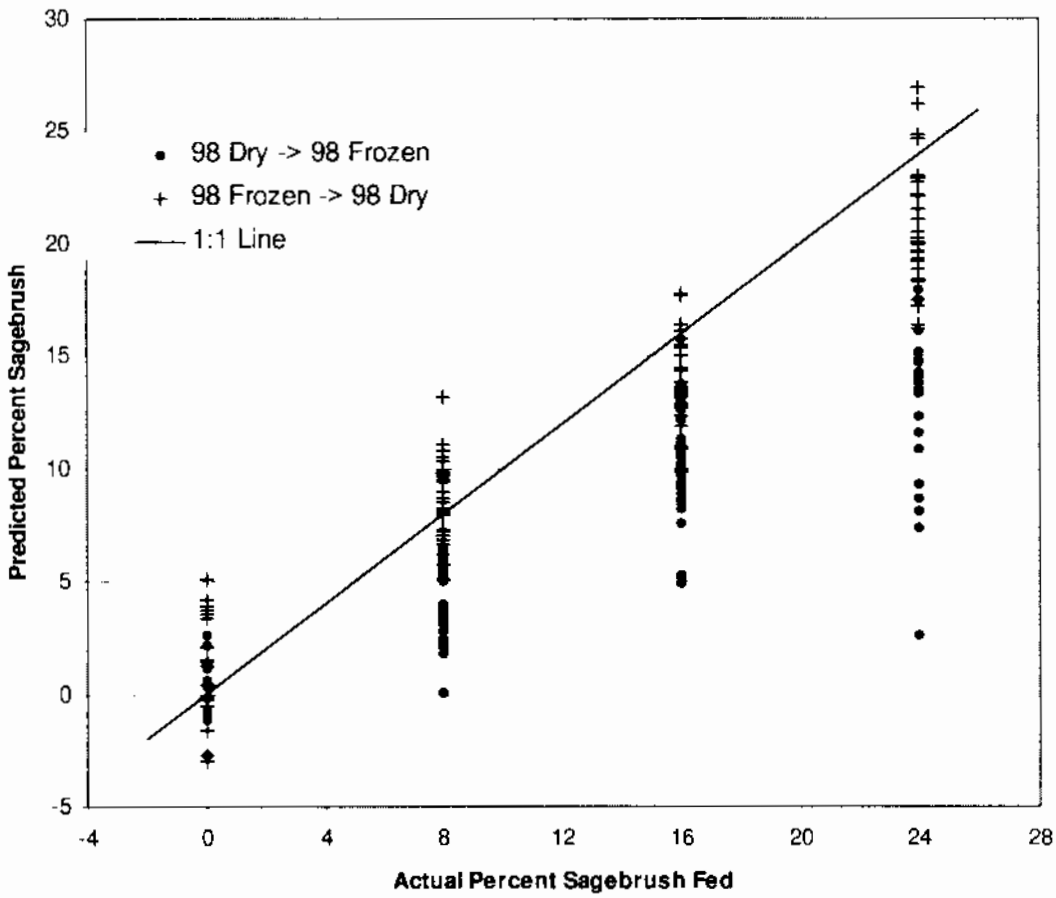


Figure 3. Actual percent mountain big sagebrush fed vs NIRS prediction equations using fecal spectra. Data represent equations developed from the 1998 feeding trial to predict the 1996 feeding trial samples (•), or from the 1998 feeding trial to predict the 1996 feeding trial samples (+).

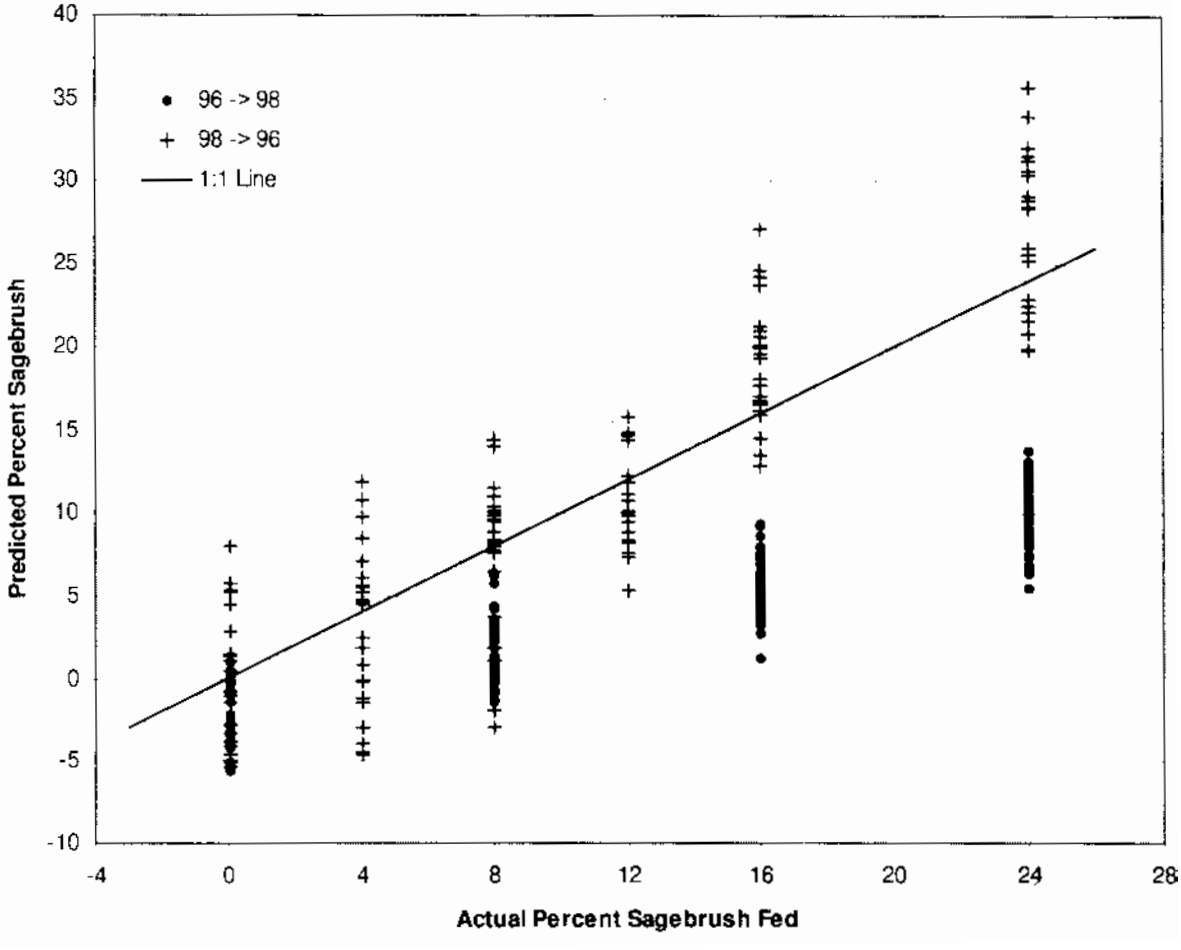
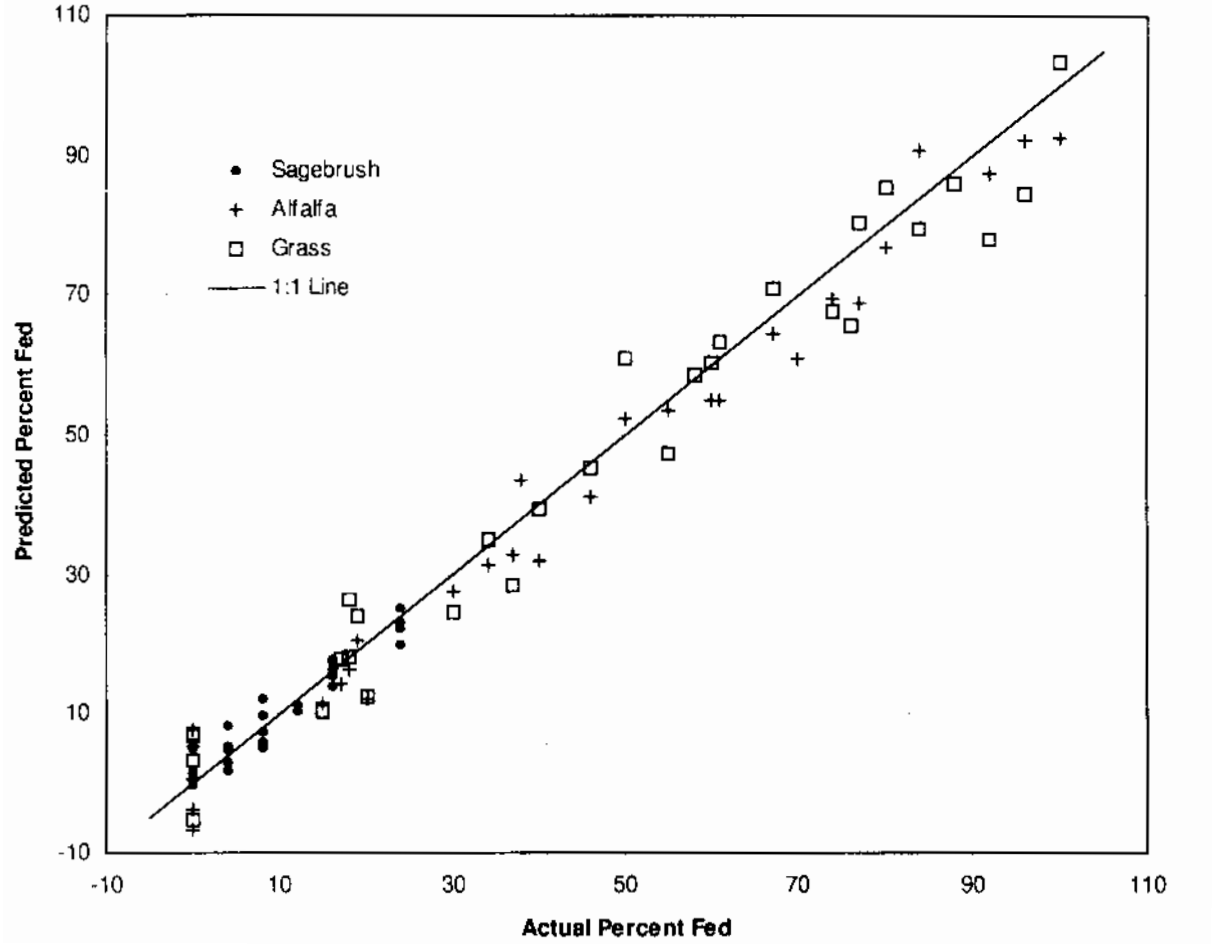


Figure 4. Internal validation of composition of diets for three botanical components (sagebrush, alfalfa and grass) using NIRS prediction equations based on spectra of feces from animals fed the diets.



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The Effects of Location on Fiber Production by Cashmere Goats: The Latitude/Climate Study - Two Years In

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ABSTRACT

Goats of two genotypes [Cashmere (C), higher producing; and Spanish (S), lower producing] were maintained for two years at three diverse sites in the USA to study the effects of latitude and climate on cashmere production and quality. After one and two years on location, goat body weights in TX > MT > AK for both breeds. Raw fleece weights tended to be lower in AK than in MT and TX whereas cashmere yields (%) tended to be higher in AK and MT than in TX. Cashmere production (g/animal) tended to be higher in MT than in AK and TX. However, after adjustment for body weight, cashmere production (g/lb live weight) was similar in AK and MT and invariably > TX. Cashmere down tended to be coarser and shorter in TX than in AK and MT.

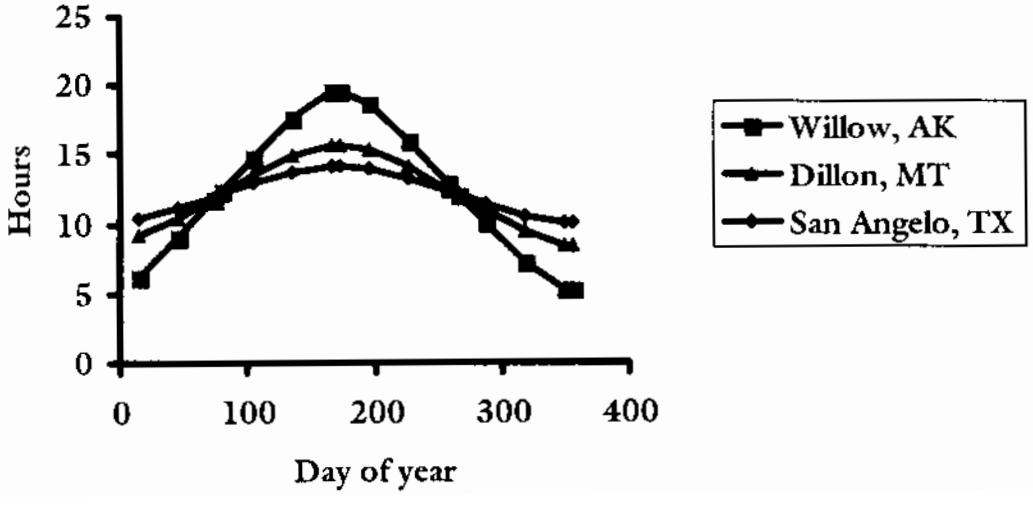
Sheep and Goat, Wool and Mohair CPR 2000:95-102

Introduction

Development of the cashmere-producing industry in the USA has been described by Dooling and Dooling (1996) and corresponded with partial disruption of supplies of raw material from traditional sources such as China, Iran, and Afghanistan in the mid to late 1980's. A desire to create a new fiber production industry in the USA led potential producers to seek information concerning all aspects of cashmere production. Much of this information was available from scientists (e.g., as referenced by McGregor, 1996; Walkden-Brown and Restall, 1996; Pattie and Restall, 1996) and breeders in Australia and New Zealand who were actively attempting to establish cashmere production in their countries. More recently, excellent information has been made available from China (many Chinese authors, 1996). Between 1988 and the present, some useful cashmere information has also been generated by U.S. scientists (e.g., Teh, 1990; Lupton, 1999). Despite the initial optimism of new breeders and some scientists, cashmere production has not grown at the anticipated rate. In fact, in 1997 the fledgling industry produced only about 1000 lb of down. One possible factor contributing to the slow growth of cashmere production in the U.S. may be that potential producers were exposed to the "conventional wisdom" that cashmere can only be successfully produced in high, and/or cold, dry locations. The

effects of latitude and possibly altitude on initiation of cashmere fiber growth and onset of shedding are known in general terms. In many cashmere producing goats, down production is initiated close to the time of the longest summer day, whatever the location (Figure 1). However, shedding begins in mid-winter in southern USA (i.e., late January in Texas) but not until March in northern parts of the country (e.g., in Montana). If the rate of fiber production were constant at these two locations, it follows that more fiber would be produced in a northern location because of the longer growing season. In fact, this claim has been made by *inter alia*, cashmere breeders based in the northern USA. Since numerous authors (as cited by McGregor, 1996; Litherland, 1996) have reported that cashmere follicle activity ceases altogether in late fall or early winter, this hypothesis seems highly unlikely. However, the reported data were usually generated in the southern hemisphere in relatively warm climates. It is possible that goats maintained in much colder climates grow more cashmere by either producing it at a faster rate during the 'traditional' growing period, by growing down for a longer period, or by activating a higher proportion of secondary follicles. To the best of our knowledge, an experiment has not been conducted to substantiate any such possibility either in the USA or elsewhere. Consequently, the current experiment was conceived and designed to partially fill this void in our knowledge. The results will be of national and international interest.

Figure 1. Annual changes in day length (sunrise to sunset) at the three research sites (1999).



Unfortunately in an experiment like this, it is virtually impossible to control all the variables that contribute to fiber quality and quantity of production while attempting to generate the data on a fairly restricted budget. Thus, in the planned experiment numerous effects are confounded (e.g., latitude, altitude, longitude, nutrition, animal health, year and age of goat). Nevertheless, some major variables will be fixed (e.g., genetics, health program, and fleece testing procedures) so that ultimately the major effects on cashmere production and quality will be latitude and climate which conceptually includes customary local management.

Materials and Methods

Approximately 60 each of Cashmere (C) and selected Spanish (S) yearling castrate goats were selected from populations of contemporary animals in flocks being maintained in Montana (MT) and Texas (TX), respectively. The flocks belonged to Tom and Ann Dooling, Pioneer Mountain Farm, Dillon, MT and Tom Syfan, Three Mill Ranch, Mountain Home, TX. Criteria for original selection were subjectively assessed body size, fiber production, and fiber quality (fineness and style). We attempted to select animals that appeared uniform in size, appearance, and fiber production. Genetics in the Dooling cashmere flock originated from the Karakan stud in Australia and selection pressure for the past 10 yr had been for increased cashmere production and quality. In contrast, the Syfan Spanish goats resulted from a 15-yr selection program for increased cashmere and meat production in a closed flock of black Spanish meat goats.

Following acquisition, all goats were shorn (prior to initiation of shedding) and subsequently weighed. Raw fleeces were packaged individually and sent to the Wool and Mohair Research Lab, Texas Agricultural Experiment Station for weighing and analysis. The following data were obtained for each fleece: grease fleece weight; lab scoured yield (ASTM, 1998a); guard hair and down staple lengths (ASTM, 1998b); theoretical cashmere down yield using the Optical Fibre Diameter Analyser (Lupton et al., 1995); and average fiber diameter of down, also using the Optical Fibre Diameter Analyser (IWTO, 1995).

Twenty goats of each type were then assigned and subsequently transported to the three research sites (Table 1) in June, 1998. Within type, the animals were "blocked" on yearling live weight and raw fleece weight, cashmere yield, down fiber diameter and guard hair and down staple lengths of their first fleeces. In this way, the mean values of all measured variables of each group of goats at each location (within type) were not different at the beginning of the experiment.

Table 1. Geographical and climate data for the three research sites

	Research Sites		
	Susitna Ranch Willow, Alaska	Pioneer Mountain Farm Dillon, Montana	Texas Agricultural Experiment Station San Angelo, Texas
	(Talkeetna weather station)	(Helena weather station)	(San Angelo weather station)
Latitude, °	61° 44'N	45° 13'N	31° 26'N
Longitude, °	150° 03'W	112° 38'W	100° 27'W
Elevation, ft	350	5096	1848
Average annual temperature, °F	33	44	64
Average summer temperature, °F (J, J, A)	56	66	81
Average winter temperature, °F (D, J, F)	12	22	46
Annual extremes of temperature, °F	– 48 to 91	– 42 to 105	– 4 to 111
Average annual rainfall, in	29	12	20
Average annual snowfall, in	115	47	3
Average annual wind speed, mph	4	7	10

Sources: The National Climatic Data Center, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and http://www.indo.com/distance/.

Since maintenance requirements and available feed resources were expected to be substantially different among locations, the goats were fed according to local customs with locally common types of hay (and other supplements) to achieve and subsequently maintain the target weights listed in Table 2.

Table 2. Target weights for growing goats

Age, mo.	Date	Live weight, lb		
		Cashmere	Spanish	
12	5/98	36	47	(actual)
18	8/98	85		
24	2/99	100		
30	8/99	115		
36	2/00	135		
42	8/00	135		
48	2/01	135		
54	8/01	135		
60	2/02	135		

Goats were weighed twice a year, immediately after shearing and approximately six months later. In this way, recommendations were made to increase or decrease feed levels to better approach the target weights. A comprehensive drenching and health maintenance program was installed at each location to attempt to ensure good health in the goats. Since year effects are expected to be substantial, the experiment will be continued for at least three years.

Results & Discussion

At one year of age, S goats (n = 64) were heavier than the C goats (n = 63; 46.7 vs 36.0 lb, $P < 0.05$) but produced less grease fleece (145 vs 228 g, $P < 0.05$) and less cashmere down both in terms of actual grams of cashmere/animal and when expressed as fiber production per unit of live weight (.5 g vs 1.1 g/lb live weight). Actual cashmere yields from the raw fleeces were comparable (15.6%), as were cashmere average fiber diameters (AFD, 15.7 μm), standard deviations (SD, 3.7 μm) and coefficients of variation (CV, 23.6%). Guard hair and cashmere from the C goats were longer ($P < 0.05$) than from the S goats (3.6 vs 2.5 in and 1.7 vs 1.3 in, respectively). Variability among staples (CV, %) was not different between the two breeds.

Based on these yearling live weights, fleece and fiber properties, the goats were assigned and transported to the three research sites. One cashmere goat died en route to AK from MT. Because of a potential health problem, we were not allowed to transport S goats from TX through Canada to AK in 1998. The S goats that were originally destined for AK were instead transported to MT where they were maintained for 1 yr prior to going to AK in June, 1999. During the 2 yr of this experiment, seven C goats and 10 S goats died due to accidents, internal parasites, and/or exposure to excessively cold weather. Loss of this many goats from the original groups necessitated statistical analyses in which initial values were used as covariates in all of the models considered. Throughout the year, goats were fed somewhat differently at each location to attain the indicated target weights. During the first yr in TX, goats were maintained either in dry lot, in a small trap, or on native range. Rations fed in dry lot contained 15% CP and 65% TDN (4 mo) and 13½% CP and 58% TDN (approximately 6 mo). Thereafter, the goats were fed large round bales of sorghum hay (approximately 8% CP and 52% TDN) in a small trap with a limited amount of native forage, then finally, were moved to native rangeland having ample forage of medium quality. Salt and clean water were available free choice. The goats remained on native range with minimal supplementation during yr 2 of the study. In MT, the goats were maintained on irrigated pastures and supplemented with native grass hay. In AK, native pasture was supplemented with Timothy/wild grass hay plus some corn and alfalfa through the winter.

The target weight for all the goats was set at 100 lb for two years of age. In their "native" environment of MT, the C goats averaged 61.1 lb suggesting that the growth

potential of these goats was overestimated. In Texas, the C goats averaged 84.7 lb, while in Alaska, growth was much slower and the goats averaged only 48.5 lb. Herein lies a potentially very serious problem that will affect the outcome and validity of the experiment. We are still attempting to remedy this by further adjusting nutrition so that body weights at each location will become more similar. In contrast, we appear to have underestimated the growth potential of the S goats. In Texas, average shorn body weight of 2-yr-olds was 118.6 lb while in MT the goats weighed 81.8 lb. Again, we are attempting to rectify this situation.

With a few possible exceptions, goats were shorn prior to the onset of shedding. Shearing in TX occurred on 1/26/99 and 1/18/2000; in MT on 3/29/99 and 3/13/2000; and in AK, the goats were shorn from 4/19/99 to 5/3/99 and on 4/11/2000. Live weight, fleece and cashmere fiber data for the first two years of the experiment are summarized in Table 3.

Table 3. Live weights, fleece, and fiber properties for Cashmere and Spanish goats at three locations in the U.S.A. (two years data)

	Cashmere			Spanish		
	AK	MT	TX	AK	MT	TX
Number of observations	35	40	41	16	57	41
Live weight, lb	55.1^{c}	74.8^{b}	92.9^{a}	73.3^{c}	87.1^{b}	117.4^{a}
Raw fleece weight, g	429^{b}	527^{a}	516^{a}	351^{b}	421^{a}	419^{a}
Scoured yield, %	90.4^{b}	91.3^{b}	93.4^{a}	93.6^{b}	92.5^{c}	97.1^{a}
Cashmere yield, %	29.7^{a}	24.8^{b}	19.8^{c}	16.0^{b}	19.7^{a}	14.4^{b}
Cashmere, g/animal	122^{a,b}	135^{a}	99^{b}	56^{b}	79^{a}	59^{b}
Cashmere, g/lb live weight	2.29^{a}	1.90^{a}	1.09^{b}	.77^{a}	.94^{a}	.52^{b}
Down fiber diameter, μm	16.8^{b}	17.1^{b}	17.9^{a}	16.8^{b}	17.0^{b}	18.1^{a}
Guard hair staple length, in	3.8	3.6	3.5	2.4^{b}	2.8^{a}	2.4^{b}
Down staple length, in	3.3	3.1	2.9	2.2^{b}	2.5^{a}	2.2^{b}

^{a,b,c}Within a breed and row, means having different superscript letters differ ($P < 0.05$).

Live weights in TX > MT > AK for both C and S goats. Raw fleece weights were lower in AK than in MT and TX. Scoured yields were higher in TX than in AK and MT. For the C goats, cashmere yields (%) in AK > MT > TX. However, the S goats showed a different trend with MT > AK = TX. In terms of cashmere production (g/animal), C goats in MT produced more cashmere than those in TX with AK goats being intermediate. However, for S goats, cashmere production in MT > AK = TX. Since these values are confounded by (*inter alia*) live weight, we calculated cashmere production/unit of live weight, g/lb. For this trait, cashmere production in AK and MT > TX for both breeds. Cashmere produced in TX was coarser than that produced in the other two locations. For

the C goats, latitude and climate did not appear to effect guard hair or down staple length. For S goats, staple lengths in MT > AK = TX. This experiment will continue for at least one more year.

Implications

Our (still) tentative conclusion based on two years of data is that cashmere goats maintained at higher latitudes (AK and MT) produce more and finer cashmere than comparable animals in TX. Data are also being collected that will enable us to calculate cost of cashmere production at the three locations. These data should assist cashmere producers in making rational decisions on where to produce this commodity most efficiently.

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Prickle Factor in Fleeces of Performance-tested Fine-wool Rams

C.J. Lupton, D.F. Waldron, and F.A. Pfeiffer

ABSTRACT

Prickle factor (PF, % of fibers > than 30 μm) is an indicator of the relative comfort of wool fabrics worn next to the skin. Fiber diameter distributions were measured (with an Optical Fibre Diameter Analyser) in three consecutive years on core samples of unskirted fleeces from 524 fine-wool rams completing a central performance test. These measurements were used to establish PF, average fiber diameter (AFD), SD, and CV in fleeces produced under the unfavorable (from a wool fineness and uniformity perspective) test conditions and to determine relationships among PF and fiber fineness and variability. As part of the normal performance test routine, AFD, SD, and CV were measured on side and britch samples for each fleece. The AFD of side samples was used in the index of overall merit and AFD of side and britch samples constituted an independent rejection criteria for ram certification. Core sample PF, AFD, SD, and CV averaged 5.5%, 22.3 μm, 4.4 μm, and 20.0% and ranged from 0.4 to 25.3%, 17.3 to 26.8 μm, 3.1 to 6.4 μm, and 15.2 to 28.6%, respectively. The PF, SD, and CV did not differ among years ($P > 0.05$). It has been suggested that only wools having low PF (< 2%) be used in apparel worn next to the skin. Eighteen percent of the fleeces were in this category. Stepwise multiple regression analysis for PF vs all measured variables plus AFD^2 and differences between side and britch AFD resulted in core AFD^2, core AFD, britch SD, core SD, side CV, and core CV entering the equation. No other variable met the 0.01 significance level for entry into the model. Partial r^2 values for the first three variables were 0.82, 0.10, and 0.03, respectively. This result was essentially unchanged when fleeces (349) having core, side, and britch AFD > 23.6, 24.9, and 27.8 μm, respectively (i.e., from coarse, uncertifiable rams) were excluded from the analysis. Most of the variability in PF can be accounted for by core data alone, i.e., $PF = 199.57 + 0.46*AFD^2 - 19.33*AFD + 6.01*SD - 1.01*CV$, $r^2 = 0.94$.

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Introduction

In a survey conducted in the U.S. several years ago (Margerum, 1984), 30% of consumers polled claimed to be allergic to wool while 70% considered wool to be too "scratchy" for apparel intended to be worn next to the skin. These types of perceptions caused CSIRO researchers in Australia to focus on the causes of fabric prickle and attempt to quantify the effects and relative importance of fiber, yarn, and fabric properties on skin

comfort. Because lightweight apparel is a potentially substantial and lucrative market for wool, numerous studies were initiated over the past 15 yr to try and understand this problem. Garnsworthy et al. (1985; 1988a and b) concluded that the prickle sensation (also referred to as "itchy" and "scratchy") experienced by some people when wearing some fabrics next to the skin is caused by a mechanical triggering of pain nerve sensors which are situated close to the surface of the skin. The nerves are triggered when stiff fiber ends exert a force > 0.00017lbf (75 mgf) on soft skin. When the mechanical stimuli are removed or reduced, the prickle problem disappears. Meticulous studies have shown that skin temperature and moisture, length of fiber protruding above the fabric surface, and fiber diameter (but not fiber type; Naylor, 1992a and b) are key factors in causing prickle sensations (Mayfield, 1987; Kenins, 1992). Although the critical fiber diameter (26 to 32 μm) associated with skin discomfort is dependant to some degree on fabric type, percentage of fibers > 30 μm, but not the distribution of these coarse fibers, is a reasonable indicator of the relative skin comfort of different wools (Naylor and Hansford, 1999).

Reducing the percentage of wool fibers > 30 μm (the coarse edge) in the diameter distribution will improve skin comfort. In principle, this can be achieved by reducing the average fiber diameter or by decreasing the distribution (coefficient of variation of fiber diameter) both options being possible in sheep selection programs. In some areas, time of shearing might also be adjusted to achieve a reduction in coarse fiber ends (Naylor and Hansford, 1999). Theoretically, zero fibers > 30 μm would be required for "absolute" skin comfort in fabrics worn next to the skin. In practice, < 5% of fibers > 30 μm in single jersey knit fabrics has been found to reduce prickle intensity to a level that will not be perceived as skin discomfort by most (80 - 90%) people under normal conditions (Garnsworthy et al., 1988a; Naylor, 1992b). Some experienced fabric judges can consistently distinguish between fabrics containing 1 and 2% fibers > 30 μm (Naylor, 2000). Consequently, a lower level (2%) has also been suggested for ram selection (Lupton et al., 1999).

Because prickle factor has become so important to manufacturers of wool apparel, we have started to report it in our annual central ram performance test (Waldron and Lupton, 2000). We began to study and measure prickle factor in ram fleeces in 1994 with the following objectives: 1) to determine PF in rams completing the test; 2) to establish mathematical relationships among PF and other fiber traits currently being measured; and 3) to determine if PF should be added to the index equation currently used to assess the overall merit of these fine-wool rams.

Materials and Methods

Side (S), britch (B), and 32 x ½-in core samples (C) removed from the whole, unskirted fleeces of 524 rams completing the 1994 (201), 1995 (169), and 1996 (154) Texas Agricultural Experiment Station central performance tests were measured for average

fiber diameter (AFD, μm), standard deviation of fiber diameter (SD, μm), coefficient of variation of fiber diameter (CV, %) and PF (core samples only; %) using an Optical Fibre Diameter Analyser (OFDA; Baxter et al., 1992). The GLM procedure of SAS (SAS, 1996) was used to identify differences in traits among years. Simple linear regression and stepwise multiple regression analyses were used to establish relationships among PF and the measured variables plus AFD^2 and differences between britch AFD and side AFD.

Results and Discussion

Core sample PF, CAFD, CSD, and CCV averaged 5.5%, 22.3 μm, 4.4 μm, and 20.0% and ranged from .4 to 25.3%, 17.3 to 26.8 μm, 3.1 to 6.4 μm, and 15.2 to 28.6%, respectively (Table 1). The PF, CSD, and CCV did not differ among years ($P > 0.05$), though all other traits did (Table 2). Fifty eight percent of all fleeces tested contained PF < 5%. Eighteen percent of the fleeces were in the (highly desirable) low (< 2%) PF category. These relatively small proportions can be partially attributed to the fleeces not being skirted and to the composition and quantity of the ram's test feed not being conducive to fine fiber production. Though this ram test was designed to measure the maximum genetic potentials of the rams (in terms of weight gain, wool production, fiber fineness, staple length, etc.), it is important to remember that yearling female offspring of these rams are typically 4 μm finer under range conditions (Waldron et al., 1998). Prickle factor is significantly correlated with all 3 measures of AFD (core > side > britch) and with both measures of variability (SD > CV, Table 3). Stepwise multiple regression analysis for PF versus all measured variables plus $CAFD^2$ and differences between side and britch AFD resulted in $CAFD^2$, CAFD, BSD, CSD, SCV, and CCV entering the equation (Table 4). No other variable met the 0.01 significance level for entry into the model. Partial r^2 values for the first three variables were 0.82, 0.10, and 0.03, respectively. Figure 1 shows the relationship between PF and $CAFD^2$. This result was essentially unchanged when fleeces (349) having core, side, and britch AFD > 23.6, 24.9, and 27.8 μm, respectively (i.e., from coarse, uncertifiable Rambouillet rams) were excluded from the analysis. Most of the variability in PF can be accounted for by core data alone (Table 5).

$$\text{i.e., } PF = 199.57 + 0.46*AFD^2 - 19.33*AFD + 6.01*SD - 1.01*CV,\ r^2 = 0.94$$

Table 1. Means, variabilities, and ranges of measured traits (N=524)

Trait	MEAN	SD	MIN	MAX
Average fiber diameter, side, μm	23.6	1.9	17.8	29.6
SD of fiber diameter, side, μm	4.0	0.6	2.8	6.7
CV of fiber diameter, side, %	17.1	2.0	13.1	24.0
Average fiber diameter, britch, μm	26.6	2.4	19.4	36.3
SD of fiber diameter, britch, μm	5.0	1.1	3.1	9.9
CV of fiber diameter, britch, %	18.8	3.2	12.9	33.0
Average fiber diameter, core, μm[a]	22.3	1.5	17.3	26.8
SD of fiber diameter, core, μm	4.4	0.5	3.1	6.4
CV of fiber diameter, core, %	20.0	2.0	15.2	28.6
Prickle factor, %	5.5	4.3	0.4	25.3

[a]Core sample of unskirted whole fleece.

Table 2. Variation among years for several measures of fiber fineness and variability and prickle factor

Trait	1994	1995	1996
Average fiber diameter, side, μm	23.7[a]	23.3[b]	23.9[a]
SD of fiber diameter, side, μm	4.3[a]	3.8[c]	4.0[b]
CV of fiber diameter, side, %	18.3[a]	16.2[c]	16.6[b]
Average fiber diameter, britch, μm	27.0[a]	26.2[b]	26.6[a,b]
SD of fiber diameter, britch, μm	5.7[a]	4.5[b]	4.7[b]
CV of fiber diameter, britch, %	20.9[a]	17.3[b]	17.8[b]
Average fiber diameter, core, μm	22.1[b]	22.4[a]	22.5[a]
SD of fiber diameter, core, μm	4.4	4.5	4.4
CV of fiber diameter, core, %	20.0	20.0	19.8
Prickle factor, %	5.3	5.5	5.7
Britch - Side average fiber diameter, μm	3.3[a]	3.0[b]	2.6[c]

[a,b,c]Within a row, means without a common superscript differ ($P < 0.05$).

Table 3. Correlation coefficients and probability values for prickle factor versus other trait

Trait	r	P
Average fiber diameter, side, μm	0.80	0.0001
SD of fiber diameter, side, μm	0.56	0.0001
CV of fiber diameter, side, %	0.10	0.0183
Average fiber diameter, britch, μm	0.78	0.0001
SD of fiber diameter, britch, μm	0.55	0.0001
CV of fiber diameter, britch, %	0.25	0.0001
Average fiber diameter, core, μm	0.89	0.0001
SD of fiber diameter, core, μm	0.67	0.0001
CV of fiber diameter, core, %	0.19	0.0001
Britch - side average fiber diameter, μm	0.25	0.0001

Table 4. Stepwise multiple regression analysis for prickle factor (all variables in model)

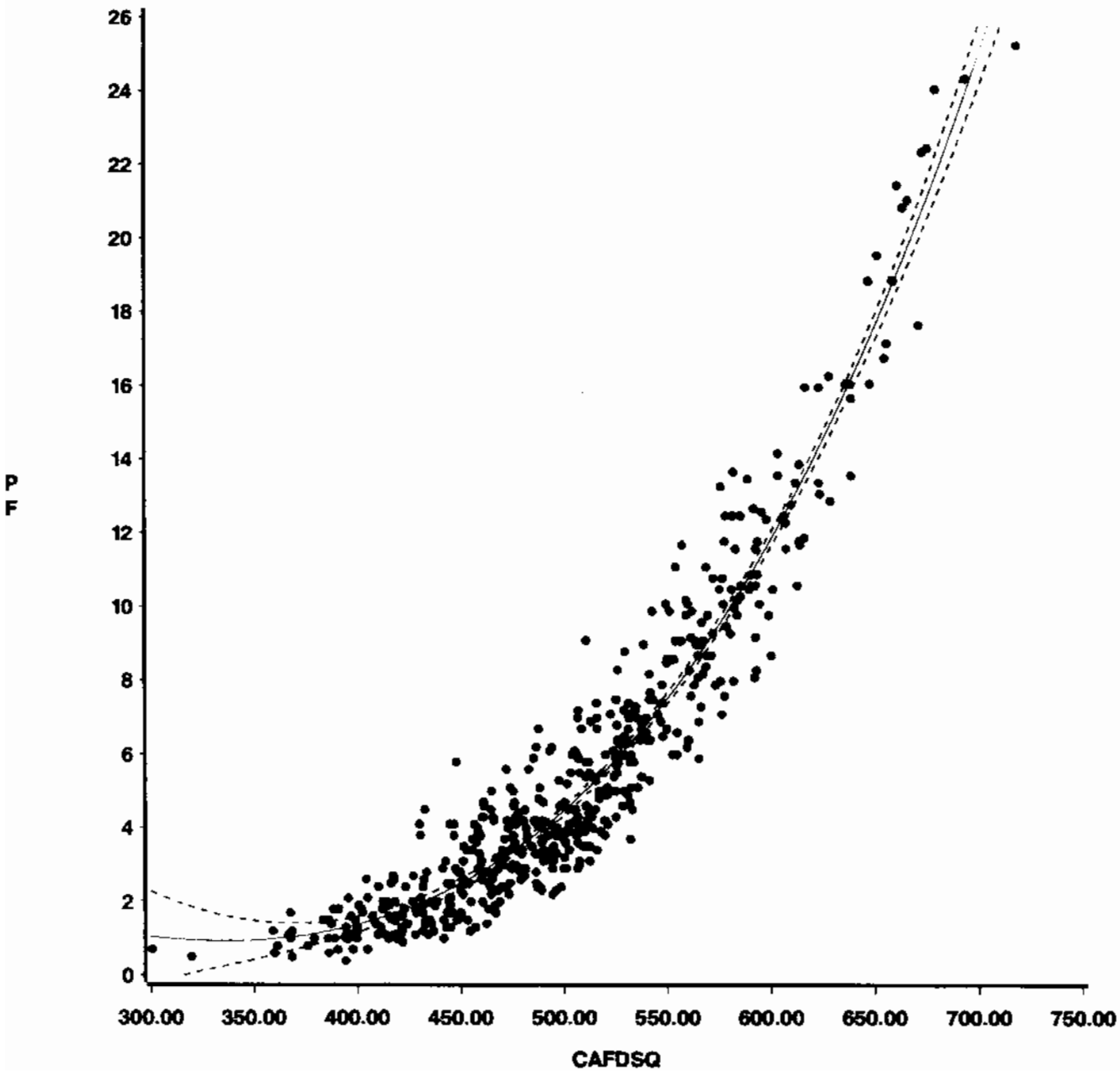
Trait	PARTIAL r^2	P
Average fiber diameter, core, μm^2	0.8184	0.0001
Average fiber diameter, core, μm	0.1021	0.0001
SD of fiber diameter, britch, μm	0.0249	0.0001
SD of fiber diameter, core, μm	0.0121	0.0001
CV of fiber diameter, side, %	0.0023	0.0001
CV of fiber diameter, core, %	0.0007	0.0023
TOTAL	0.9605	

Note: no other variable met the 0.01 significance level for entry into the model.

Table 5. Stepwise multiple regression analysis for prickle factor (core traits only in model)

Trait	PARTIAL r^2	MODEL r^2	P
Average fiber diameter, core, μm^2	0.8184	0.8184	0.0001
Average fiber diameter, core, μm	0.1021	0.9205	0.0001
SD of fiber diameter, core, μm	0.0233	0.9438	0.0001
CV of fiber diameter, core, %	0.0012	0.9445	0.0009

Figure 1. Prickle factor (PF, %) versus the squared average fiber diameter of core samples (CAFDSQ, square microns).



Conclusions

1. About 92 % of the variability in PF can be accounted for by CAFD and CCV.
2. Because CAFD and CCV are currently used in the index equation for overall merit and since adding another trait would dilute the contributions of the existing traits, we concluded that PF should not be included into the index equation at this time.

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Comparison of Three Measuring Techniques for Staple Length and Strength in U.S. Wools

F.A. Pfeiffer and C.J. Lupton

ABSTRACT

Twenty-nine consignments of greasy wool in Texas warehouses were used to compare three measuring techniques for staple length (SL) and strength (SS) and to assist the U.S. wool industry in deciding which techniques to adopt for commercial testing. Samples (~10 lb/lot) were obtained using a bale grab sampler and were subsampled at the Texas Agricultural Experiment Station (TAES) Wool and Mohair Research Laboratory (WMRL) to provide three sets of comparable staples. One complete set of staples (29 lots x 65 staples/lot = 1,885 staples) was sent to the Australian Wool Testing Authority (AWTA) for measurement using the Automatic Tester for Length and Strength (ATLAS) while another set was sent to SGS Wool Testing Services (SGS) in New Zealand for testing with the Agritest Staple Breaker Model 2. A third set was measured at WMRL using the American Society for Testing and Materials (ASTM) manual method for SL and an Agritest Staple Breaker (manual model) for SS. Each testing lab used the same wool base and vegetable matter base values to convert "greasy" to "clean" SS. Paired t tests and linear regression analyses were conducted to test for differences and calculate r^2 values between test methods. Warehouse personnel provided visual estimates of SL. Mean values of SL determined by AWTA and the visual assessments were not different (3.20 and 3.21 in, respectively, $P > 0.05$; $r^2 = 0.63$). Measurements of SL made by SGS and WMRL were not different (3.07 and 3.12 in, respectively, $P > 0.05$; $r^2 = 0.74$) but were smaller ($P < 0.05$) than the AWTA and visual results. Mean values of variability in staple length (CV) were not different ($P > 0.05$) among the three measuring techniques. The AWTA and SGS means of SS were not different (32.1 and 31.8 N/ktex, respectively, $P > 0.05$; $r^2 = 0.41$). The WMRL mean value, 41.7 N/ktex, for SS was greater ($P < 0.05$) than the other two labs, which strongly suggests that either the manual instrument and/or the WMRL technique produced excessively high values. Further testing incorporating a broader cross-section of U.S. wools is required before an authoritative recommendation can be made to the U.S. wool trade.

Sheep and Goat, Wool and Mohair CPR 2000:111-116

Introduction

The U.S. wool industry has expressed an interest in having some of its staple wools objectively measured for SL and SS before the time of sale of greasy wool to further describe the wool being sold and to achieve optimum price discovery. According to Adams (1997), SS is second only to fiber diameter in determining the value of raw wool because it is an important contributor to Hauteur, i.e., average fiber length in the wool top after early stage processing. Qi et al. (1994), reported that SL is the third most important characteristic of wool after scoured yield and fiber diameter. Australian methodology and machinery are currently available for obtaining staple samples for measuring SL and SS but as yet are not easily adapted for most U.S. wool packages (i.e., 6 and 8 ft wool bags). The ATLAS instrument used in Australia for measuring SL and SS is very expensive and, even if it were available, may not be cost-effective in the U.S. commercial testing lab. Fortunately, less expensive instrumentation is available from Agritest for measuring SL, SS, and position of break but it requires further evaluation to establish its equivalency with both the now accepted ATLAS technique and the established ASTM and manual Agritest methods.

Materials and Methods

Twenty-nine commercial lots of sound, staple length wool were identified in member warehouses of the Producers Marketing Coop, Inc. (San Angelo). An Australian bale grab sampler was used to obtain approximately 10 lb of sample from each lot. These samples were transported to the WMRL and subsampled to provide three sets of comparable staples for each of the 29 lots. One set of staples consisted of 65 individual staples each being suitable for measurement of SL and SS. This number (65) of staples per lot has been established as the minimum necessary to produce the desired degree of accuracy when measuring SS and SL.

One complete set of staples (29 lots x 65 staples = 1,885 staples) was sent to the Australian Wool Testing Authority (AWTA) in Guildford, New South Wales for measurement using the ATLAS instrument. Another set was sent to SGS Wool Testing Services (SGS) in Wellington, New Zealand for testing with the Agritest Staple Breaker Model 2. A third set was measured at the WMRL using a manual method (ASTM, 1999b) to measure SL and an Agritest Staple Breaker (manual model) for measuring SS. Wool and vegetable matter bases were determined for each lot (ASTM, 1999a) by Yocom-McColl Testing Labs, Inc. in Denver. Each testing lab used the same wool base and vegetable matter base values to convert "greasy" to "clean" SS. Paired t tests and linear regression analyses were used to test for differences and calculate r^2 values between test methods (SAS, 1996).

Results and Discussion

The results of testing at the three locations using the different methods are summarized in Table 1. We have assumed that 65 staples/lot were measured by AWTA, as they were by TAES technicians. The SGS lab measured 57-59 staples per lot. Table 2 indicates that overall mean values of staple length determined by AWTA and visual assessments made by warehouse personnel were not different ($P > 0.05$). Similarly, measurements of staple length made by SGS and TAES were not different ($P > 0.05$) but were slightly smaller (~ 0.1 in) than the AWTA and visual results. Mean values of variability in staple length as measured by coefficients of variation were not different among locations. Overall means of SS were not different between AWTA and SGS. The TAES values for SS were considerably higher than the other two labs strongly suggesting that the instrument and/or our technique is producing excessively high values.

Conducting t tests using mean values of each of the 29 lots is only one method of comparing results from the three instruments. Regression analyses were also conducted and our results are summarized in Table 3. Somewhat surprisingly considering the general acceptance of these test procedures by the testing community and elsewhere in the past few yr, SL and SS values obtained using the three different sets of methods were not highly correlated. The r^2 values between labs for SL range from 0.74 to 0.81 ($P = 0.0001$) for the three objectively measured sets of data. Values for visually appraised vs objectively measured SL are lower (0.48 to 0.63, $P = 0.0001$). Coefficients of determination for the SS data are even lower (0.41 to 0.61, $P = 0.0001$ to 0.0002) while those for CV of SL are still smaller (0.11 to 0.39, $P = 0.0003$ to 0.0849). These r^2 values would probably have been higher if unsound, very strong, very short, and very long wools had been included in the study. We chose to use typical, sound, staple-length West Texas wools only. In fact, the AWTA and SGS strength data are remarkably similar for 21 of the 29 lots measured (0 or 1 N/ktex difference between labs). The differences for the other eight lots range from 2-5 N/ktex with no apparent bias.

The relative costs of conducting these tests and the time required to get results from overseas are documented in Table 4. Currency conversion rates effective on 10/21/99 were used in the calculations.

Conclusions

This study indicates that results of testing sound U.S. wool for SS and SL were not highly correlated among the three testing locations (methods). The visual appraisals of SL and measurements using the ATLAS instrument were not different but were greater than (~ 0.1 in) the SL results, obtained using the ASTM standard method and SGS measurements. Mean values of SS were not different between the SGS and AWTA labs but were significantly higher at the TAES lab.

Table 1. Individual, mean, minimum, maximum, and standard deviation values for the 29 wool lots used in this study

Lot number	Visually assessed staple length, in	AWTA			SGS			TAES		
		Staple length, in	CV of staple length, %	Staple strength, N/ktex	Staple length, in	CV of staple length, %	Staple strength, N/ktex	Staple length, in	CV of staple length, %	Staple strength, N/ktex
1	3.1	3.0	22	29	3.0	17	29	3.1	16	37
2	3.1	3.4	13	31	3.1	11	32	3.3	10	45
3	3.2	3.3	14	31	3.1	13	30	3.3	16	44
4	3.3	3.4	13	32	2.8	15	30	3.3	9	39
5	3.2	3.0	18	31	2.8	15	30	3.0	17	42
6	3.0	2.8	15	29	2.7	12	28	2.7	12	37
7	3.1	2.7	12	28	2.6	15	29	2.2	14	32
8	3.3	3.4	12	31	3.2	13	30	3.2	15	40
9	3.3	3.3	11	29	3.1	11	30	2.8	15	35
10	3.4	3.3	12	33	3.3	13	29	3.3	13	40
11	3.6	3.7	16	30	3.5	17	31	3.5	15	37
12	3.2	3.3	13	36	3.2	15	35	3.3	11	46
13	3.2	3.3	12	34	3.1	11	32	3.2	11	37
14	2.8	2.7	11	32	2.8	14	32	2.6	15	37
15	3.3	3.3	11	33	3.3	12	33	3.1	15	42
16	3.2	3.1	18	29	3.0	24	29	2.8	19	36
17	3.2	3.0	17	35	2.9	15	30	3.0	12	42
18	3.0	3.0	13	31	3.0	11	34	2.9	12	47
19	3.1	2.7	13	34	2.6	11	33	2.5	13	45
20	3.3	3.2	17	33	3.1	14	32	3.1	13	47
21	3.4	3.6	12	37	3.5	14	37	3.6	14	50
22	3.3	3.1	12	35	3.1	11	36	3.1	15	44
23	3.3	3.5	16	32	3.4	16	32	3.7	15	41
24	3.4	3.4	11	36	3.3	13	36	3.4	13	48
25	3.3	3.3	17	30	3.1	16	29	3.2	14	41
26	3.2	3.5	13	33	3.3	13	30	3.3	19	40
27	3.3	3.3	18	34	3.2	16	39	3.5	16	53
28	3.4	3.3	14	35	3.3	11	31	3.5	12	44
29	3.0	2.8	16	28	2.7	14	33	2.7	16	40
Mean	3.21	3.20	14.2	32.1	3.07	13.9	31.8	3.12	14.0	41.7
SD	0.16	0.26	2.7	2.5	0.25	2.7	2.7	0.35	2.4	4.7
Min	2.8	2.7	11	28	2.6	11	28	2.2	9	32
Max	3.6	3.7	22	37	3.5	24	39	3.7	19	53

Table 2. Mean values for the 29 wool lots

	AWTA	SGS	TAES	(Visual)
Staple length, in	3.20[a]	3.07[b]	3.12[b]	3.21[a]
CV of staple length, %	14.2	13.9	14.0	–
Staple strength, N/ktex	32.1[b]	31.8[b]	41.7[a]	–

[a,b]Within a row, means without a common superscript differ ($P < 0.05$).

Table 3. Coefficients of determination (r^2 values with P in parenthesis) for the indicated relationships

Staple length			
	AWTA	SGS	TAES
Visual	.63 (0.0001)	.53 (0.0001)	.48 (0.0001)
	–	.81 (0.0001)	.81 (0.0001)
AWTA	–	–	.74 (0.0001)
SGS			

Coefficient of variation of staple length		
	SGS	TAES
AWTA	.39 (0.0003)	.11 (0.0849)
SGS	–	.21 (0.0128)

Staple strength		
	SGS	TAES
AWTA	.41 (0.0002)	.46 (0.0001)
SGS	–	.61 (0.0001)

Table 4. Financial and time considerations

	AWTA	SGS
Samples sent via Federal Express	5/17/99	5/17/99
Cost of Fed-Ex shipping, US $ (~ 20 lb)	223.25	213.05
Results received by airmail	6/3/99	6/8/99
Cost of length/strength test, US $ / sample	25.15	22.24
MAF clearance and fumigation (29 samples)	–	30.17

Implications

The U.S. wool industry had anticipated that results from this study would have been close to identical from each of the three labs participating using different methods and instruments. Further investigations and analyses will be required to help us identify reasons for these disagreements.

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Soremouth: The Return of an Old Enemy

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ABSTRACT

Soremouth, also known as contagious ecthyma, contagious pustular dermatitis, infectious labial dermatitis, orf, or scabby mouth, is a contagious disease of sheep, goats, wild ruminants and humans that is caused by a Parapoxvirus (de la Concha-Bermejillo, 1993,1995; Fenner, 1999). Soremouth was a major problem for the livestock industry in the US before screw worm flies (*Cochliomyia hominivorax*) were eradicated because their larvae invaded soremouth lesions, leading to severe complications and high mortality among sheep and goats. Since the eradication of the screw worm fly, mortality due to soremouth has been reduced dramatically. Nevertheless, soremouth continues to be a nuisance, and outbreaks of the disease continue to occur on a yearly basis. Recent outbreaks of soremouth among soremouth-vaccinated goats in Texas, and the presentation of some severe clinical cases of soremouth have renewed some old concerns about this disease (de la Concha-Bermejillo et al., 1999).

Because, in the majority of cases, soremouth vaccines seem to help control soremouth disease and because of a lesser impact of the disease after screw worm eradication from the US, relatively little research was done on this viral infection for a period of time. Consequently, many voids in the knowledge of this disease still exist. Several reports in the literature indicate that vaccine failures or reinfections in previously exposed animals are common (Buddle et al., 1984; McKeever et al., 1988; Haig et al., 1997). In addition, recent findings that soremouth virus has genes that promote epithelial growth and genes that modify the immune response of the host have prompted a renewed research interest in this disease. The objective of this paper is to review current literature on soremouth virus classification, morphology and genomic organization, epidemiology and transmission, clinical signs and lesions, immune response, treatment, and prevention.

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Introduction

Soremouth virus belongs to a genera of viruses called Parapoxviruses, which in turn, are part of the subfamily *Chordopoxvirinae* in the *Poxviridae* family. Several other Parapoxviruses are of importance to livestock producers and include bovine papular

stomatitis virus, pseudocowpox virus, parapox of deer, and scalpox. Some of the properties of the viruses of the Poxviridae family are that they are among the largest viruses known and their genetic information is in the form of double stranded DNA. Viruses that have a DNA genome tend to be more stable (mutate less frequently) than viruses having their genetic information contained in RNA (Moss, 1999).

All members of the *Parapoxvirus* genera (bovine papular stomatitis virus, pseudocowpox virus, parapox of deer, and sealpox) are genetically and antigenically related and have similar morphology, genomic organization, and virulence mechanisms (Fleming et al., 1993). The virions (virus particles) of poxviruses are larger than those of other animal viruses and are barely visible by light microscopy. Parapoxvirus virions are ovoid; and therefore, distinct from the typical brick-shaped virions of other mammalian poxviruses (Moss, 1999). Specifically, soremouth virions are about 260 nm long by 160 nm wide, and have an outer membrane that consists of a single, long tubule that appears to be whirled around a homogeneous core. The envelope (the outer coat of the virus) is usually closely applied to the surface of the outer membrane (Fenner, 1999). The relevance of this characteristic shape and the large size of the soremouth virions is that the virus can be recognized by electron microscopy (EM). Therefore, observation of soremouth scab material by EM is the most commonly used method to diagnose parapoxvirus infections. However, it is important to note that soremouth virions cannot be distinguised from virions of other parapoxviruses by this method. An important research need is to develop diagnostic methods that differentiate among different parapoxviruses.

Genetic mapping and sequencing of the soremouth virus genome have revealed that soremouth virus has a typical poxvirus distribution of genes, with those essential for viral DNA synthesis, replication, and packaging located in the central region. These genes are highly conserved (similar) among different poxviruses. Genes located near the genomic termini usually encode viral functions nonessential for replication, but play a role in pathogenesis, host and tissue tropism and virulence (induction of disease) (Mackett and Archard, 1979; Haig and Mercer, 1998). Considerable heterogeneity has been observed between different field isolates when restriction endonuclease digests of soremouth virus DNA were compared by gel electrophoresis (Robinson et al., 1982). Variation in soremouth virus strains can be demonstrated also by cross protection experiments, serum neutralization tests, restriction enzyme analysis of viral DNA, and gene sequencing (Moss, 1999).

The soremouth virus genome contains a gene that is homologous to a mammalian vascular endothelial growth factor that may enhance virulence. The role of the product of this gene is to promote growth of skin cells to ensure that there is a constant source of susceptible cells where more virus can be produced. Soremouth also has a gene, called a vaccinia virus E3L-like gene, which inhibits the effect of the interferons (Meyer et al., 1999; Wise et al., 1999). Interferons are proteins produced by cells of animals that have antiviral and immunoregulatory activities. By blocking these cellular proteins, soremouth

virus escapes from being attacked by the host immune system. Although nonessential for virus replication in vitro and in vivo, the E2L gene of soremouth virus, comprises an important viral gene in determining virulence and pathogenesis of soremouth virus (Cottone et al., 1998). In infected animals, the active site of viral replication is the newly proliferative keratinocyte (skin cell) population growing up under the superficial necrotic layer of affected skin.

Epidemiology and Transmission

Soremouth virus induces proliferative lesions in the skin of sheep, goats, wild ruminants, humans (Haig and Mercer, 1998), and very rarely dogs (Bassioukas et al., 1993; Haig and Mercer, 1998). Other domestic and wild ruminants in which the infection has been described include camel, musk, oxen, alpacas, bighorn sheep, mule deer, white-tail deer, pronghorn, wapiti, and reindeer (Kummeneje and Krogsrud., 1979; Dieterich et al., 1981; Lance et al., 1981, 1983; Dashtseren et al., 1984; Ali et al., 1991; Gitao, 1994; L'Heureux et al., 1996). The virus occasionally infects humans, particularly sheep and goat farm workers, veterinarians and those in the meat industry (Arnaud et al., 1986; Bassioukas et al., 1993). The virus replicates in the skin and sometimes in the mucosa of the digestive tract.

Direct contact between infected and non-infected animals is the main way the infection is spread. It is believed that the virus can be disseminated on pastures indirectly through contact with infected dry scabs in which the virus remains infective and alive. The virus is resistant to environmental conditions and persists from year to year on infected premises (McKeever and Reid, 1986). Dried scabs allow the persistence of the virus for years. Chronically infected, reinfected or possibly, latently infected carrier animals may also allow the virus to persist in a flock. During a border disease vaccine experiment, transmission of soremouth virus from clinically normal ewes to susceptible sheep has been observed, suggesting that clinically normal animals may be carriers of the virus (Nettleton et al., 1996b). Although difficult to prove, it is thought that some damage of the skin is necessary for soremouth infection to be established (McKeever et al., 1988).

An exact geographic distribution of soremouth is not known; however, the disease been reported in most parts of the world where sheep and goats are raised. Outbreaks of soremouth in soremouth-vaccinated animals have been reported (Buddle et al., 1984; Pye, 1990; de la Concha-Bermejillo et al., 1999). In one study, the restriction enzyme DNA patterns of soremouth virus isolates from 43 outbreaks that occurred in vaccinated flocks were described (Gilray et al., 1998). Isolates from twenty-one outbreaks yielded wild-type virus, 10 yielded vaccine viruses, three produced both vaccine and wild-type viruses and no clear results were obtained from nine of the outbreaks. From the 21 outbreaks yielding wild-type viruses, 28 soremouth virus isolates had clear restriction enzyme (RE) patterns and 15 distinct RE patterns were recorded. Usually only one virus type was associated

with each outbreak, but from two farms two different wild-type viruses were recovered. No predominant genotype was identified, with four restriction enzyme profile types being recovered for more than one outbreak. From the more severe form of soremouth involving the buccal cavities of lambs, only wild-type viruses were recovered, with at least four different genotypes being represented. In another study, a region of approximately 20 kbp, some 12 kbp in from the left end, showed the greatest cleavage site variability although there was no evidence of large deletions in this region (Robinson et al., 1987). Furthermore, RE analysis of the DNA from soremouth virus strain NZ2, which had been serially passaged in bovine testis cells, showed that at least three distinct mutant forms in which the right end of the genome had been duplicated and translocated to the left end developed during passage (Fleming et al., 1995).

Clinical Signs and Pathology

Clinically, soremouth disease is characterized by the appearance of vesicles, papules and crusty, rapidly growing scabs on the lips and nose of affected animals. Cauliflower-like growths, resulting from continued epidermal proliferation do occur. The gross lesions usually start at the commissures of the lips and spread around the lip margins to the muzzle. In more severe cases, the skin of other areas, such as the eyes, feet, vulva, abdomen, or udder, may be affected. The latter location occurs particularly in does and ewes that are nursing affected kids/lambs. Occasionally, lesions may develop in the gums, dental pad, palate, and tongue. Very randomly the lesions extend to the esophagus, rumen, omasum and have been reported in the lungs, heart, and lower intestinal tract (Yager and Scott, 1993). The lesions are painful, and depending on the location of the lesions, affected animals may be reluctant to suckle, eat, or walk. The disease usually runs its course in 3 to 4 weeks. However, infections can persist for several months, and secondary bacterial infections or maggot infestation of affected areas may occur (Greig et al., 1984; Ndikuwera et al., 1992; Zamri-Saad et al., 1993; Abu and Housawi, 1997). Occasionally, mortalities as high as 10% have been reported, and may be much higher in countries where screw worm still exists or in places where unsanitary conditions exist (Gumbrell and McGregor, 1997). Extension of lesions into deeper parts of the respiratory or gastrointestinal tracts is rare. Soremouth infection has also been implicated as a contributing factor in an outbreak of clinical mastitis caused by *Pasteurella haemolytica* (Burriel, 1997).

Clinical and epidemiological evidence indicate that, in the majority of cases, animals that have been vaccinated against or that have suffered from soremouth are resistant to natural reinfection for several years, but in unvaccinated flocks often 80% of the animals show signs and lesions of the disease during an outbreak. Yearly vaccination is recommended by some (Tanya, 1992). However, a precise estimate of the duration of protective immunity after vaccination or infection is still not well determined. More recent

reports indicate that continuous reinfection with soremouth virus is possible, not only as a result of antigenic variation of field strains, but also as a result of evolutionary genetic mechanisms that poxviruses have developed to evade the immune response of the host (Haig et al., 1997).

In humans, the disease is most commonly manifested by one or several localized pustules and scabby lesions on the hands and sometimes face or ears (Groves et al., 1991). The lesions progress to form large painful nodules that eventually regress and disappear in 4 to 6 weeks (Lo and Mathisen, 1996; Bodnar et al., 1999). Generalized infection in humans has also been reported (Erickson et al., 1975). Humans affected with the acquired immunodeficiency virus (AIDS) or that are under immunosuppressive therapy (after organ transplantation or cancer) are particularly susceptible to the disease (de la Concha-Bermejillo, 1995).

Microscopically, soremouth lesions are characterized by vacuolation and swelling of keratinocytes in the stratum spinosum of the skin, reticular degeneration, marked epidermal proliferation, intradermal microabscesses, and accumulation of flake-crust. Keratinocyte vacuolation is accompanied by cytoplasmic basophilia. Basophilic intracytoplasmic inclusion bodies are reported as early as 31 hr post-infection. By 72 hr post-infection, the keratinocytes show nuclear pyknosis and marked hidropic change. Intracytoplasmic eosinophilic inclusion bodies can be first seen at about this time and persist for 3 to 4 days. The epithelium becomes 3 to 4 times the normal thickness, mitotic figures are prominent and the rete ridges become markedly elongated. Pseudocarcinomatous hyperplasia is common. Changes in the dermis include superficial edema, capillary proliferation and inflammation characterized by perivascular infiltration of lymphocytes and monocytes (Yager and Scott, 1993). The extensive vascular proliferation characteristic of soremouth lesions may be the result of vascular endothelial growth factors produced by the virus during replication (Meyer et al., 1999; Wise et al., 1999). Neutrophils migrate into the areas of reticular degeneration and form microabscesses (Kluge et al., 1972). Viral antigen in experimentally induced primary infection lesions in sheep has been detected between 3 and 25 days post-infection (Haig et al., 1997).

Immune Response

There is a general belief that animals and humans that recover from soremouth infections are solidly immune. For this reason, vaccination of lambs and kids with live non-attenuated vaccine is practiced in many countries. Recent reports indicate that protection against reinfection is not long lasting. Although the clinical response to a secondary infection is both milder and shorter, soremouth virus can repeatedly reinfect sheep and goats (Haig et al., 1997). This fact has provoked a renewed interest in

soremouth virus research to try to understand the underlying cellular, virological, and molecular mechanisms for its apparent escape from the host protective immune response.

Mechanisms of immunity to soremouth virus are not well understood, and viral proteins responsible for the induction of protective immunity have not been recognized. After inoculation of specific pathogen free (SPF) lambs with soremouth virus, experimental lambs developed an antibody response against the virus (Yirrell et al., 1989). In convalescent sera from infected sheep, up to 16 immunogenic viral proteins have been detected by Western blot (McKeever et al., 1987). Ewes vaccinated 3 to 4 weeks prior to parturition transferred soremouth virus antibodies to their lambs via colostrum. Although these lambs had higher antibody titers at challenge than lambs vaccinated when 1 to 4 days old, only the vaccinated lambs were protected against challenge with soremouth virus at 1 month of age, suggesting that the presence of colostrum-derived maternal antibody in lambs impairs the antibody response to vaccination or virus challenge (Buddle and Pulford, 1984). Furthermore, antibodies able to neutralize poxviruses have been reported, but it is believed that although they may restrict the spread of infection and may assist in limiting reinfections, antibody-mediated mechanisms are generally insufficient to protect against infection by poxviruses (Buller and Palumbo, 1991).

Analysis of the local skin inflammatory reaction under the light microscope shows an early neutrophil influx within the first 48 hr after infection that is followed by an accumulation of γδ T-cell receptor cells, CD4+ T cells, CD8+ T cells, B- cells and MHC class II+ dendritic cells that peak between 9 to 15 days post-infection and return to pre-infection levels around day 30 (Haig et al., 1997). CD4+ T-cells predominate in afferent lymph draining from the site of the infection. The expression of the cytolytic cell-associated serine protease, BLT-esterase, in a proportion of the CD8+ T cells indicate that these cells are activated, particularly in the skin (Haig et al., 1996b). Subsequently, CD45R cells predominate, becoming the main cellular source of lymphokines in the efferent lymph (Haig et al., 1996a).

Viral antigen can only be detected up to day 9 post-infection and the inflammatory response usually resolves within 15 days. Analysis of cytokine mRNAs from lesions has detected the presence of interleukin-2 (IL-2), and interferon-γ mRNAs on days 3 and/or 9 after reinfection. Other cytokines that have been detected in CE skin lesions include IL-1β, TNF-α, IL-3 and GM-CSF. This spectrum of cytokines is what might be expected in a Th1 anti-viral immune response. Furthermore, cyclosporin-A treatment abrogates this partial immunity by targeting T-cell lymphokine production (Haig et al., 1996c; Haig et al., 1996d).

A major reason for soremouth virus' ability to continually reinfect sheep and goats could lay within the evolutionary mechanisms the virus has developed to suppress host immune responses. A gene at the left end of the soremouth virus genome has been identified and shown to have homology to the vaccinia virus E3L gene. This vaccinia virus gene product is an inhibitor of interferon-induced double-stranded RNA-dependent

protein kinase (DIA-Kinase). By inhibiting DIA Kinase, poxviruses create an environment that favors virus replication. Therefore, soremouth virus may temporarily avoid host immunity by a combination of acute, rapid infection, and replication in the epidermis and by producing virulence factors that inhibit protective proteins of the host immune and inflammatory responses (Haig and Mercer, 1998).

Diagnosis

In the majority of cases, the diagnosis of soremouth is generally made by the observation of the typical signs and lesions. Samples (scabs) should be sent to a veterinary diagnostic laboratory for confirmation of the diagnosis (Tanya, 1992). Negative-stain electron microscopy from scabs of affected animals will reveal characteristic ovoid-shaped virions similar to pseudopox virus (Harkness et al., 1977). Scabs for diagnosis should be collected during the earlier, more active phase of the disease and not from animals that are close to recovery. However, it is important to remember that this diagnostic method does not allow the differentiation between soremouth virus infection and other parapoxvirus infections of veterinary importance.

Serum neutralization, agar gel immunodiffussion (AGID), complement fixation, or agglutination, are serological tests that are occasionally used for the detection of anti-soremouth virus antibodies. Agar gel immunodiffusion test using sera from sheep naturally or experimentally infected with soremouth virus or inoculated with capripoxviruses showed cross reactions. However, these two infections could be readily differentiated by Western blot analysis (Chand et al., 1994). ELISA tests to detect antibodies against soremouth have also been developed but are used rarely for diagnostic purposes (McKeever et al., 1987; Chin and Petersen, 1995).

Virus isolation has been performed using a variety of primary cell cultures, including ovine and bovine kidney cells, ovine and bovine testis cells and others. However, results are often unsuccessful. Typical cytopathic effect consists of cell rounding, clumping and detachment. Intracytoplasmic eosinophilic inclusion bodies can be observed in stained cell culture. The virus can also be propagated on the chorioallantoid membrane of embryonated chicken eggs (Tanya, 1992). A recent study indicates that semi-nested polymerase chain reaction (PCR), a new molecular method to copy specific DNA sequences of the virus genome, can be used to detect low copy numbers of soremouth viral DNA (Inoshima et al., 2000). In this case, the technique was adapted to detect all viruses belonging to the genus *Parapoxvirus*. Further developments in this technique are necessary to differentiate between soremouth and other parapoxviruses.

Soremouth cases need to be differentiated from similar diseases, such as infections by other poxviruses and papilloma viruses. Infection by goat poxvirus can be clinically similar to soremouth, but infection by the former tends to result in lesions, particularly around the udder and scrotum and inside the thighs and infrequently around the mouth. Infection by

sheep poxvirus causes lesions throughout the body and internal organs. Soremouth has to be differentiated from other vesicular diseases (Larsen, 1985), and from peste de petits ruminants (Diallo et al., 1995).

Treatment and Prevention

Although not economically feasible in most cases, cryosurgery and diathermy have been used to treat soremouth intra-oral lesions in lambs (Meynink et al., 1987). Secondary infections may be treated with topical disinfectants, antibiotics, or insecticides, the latter if maggot infestation occurs. Young individuals may need to be tube fed if the lesions are severe enough to preclude suckling. Removal of the scabs causes bleeding and delays healing; therefore, they should not be removed.

Soremouth vaccines are live virus vaccines prepared from dried scabs of affected animals, or less frequently propagated in tissue culture (Nettleton et al., 1996a). As a result, the virus present in these vaccines is contagious, can be transmitted to other animals and eventually could produce disease. For these reasons, vaccination should only be undertaken if the infection has already occurred previously on the premises. Recently vaccinated animals should not be allowed to be in contact with unvaccinated soremouth naive animals.

Although there is a general belief that sheep or goats that have been previously vaccinated or have been exposed to the virus are protected for life (Fenner, 1999), some recent reports indicate that this may not be true in all cases (Pye, 1990). A study that investigated the control options for soremouth in Australian sheep exported live to the Middle East showed that vaccination programs reduced the prevalence of disease during live export, but did not guarantee shipments of sheep completely free of soremouth (Higgs et al., 1996). In Texas, the majority of sheep and goat producers vaccinate all animals when they vaccinate for the first time. Thereafter, they vaccinate on an annual basis, but only the lambs or kids born that year and newly purchased animals. This practice seems to be effective in the majority of cases, but complaints about vaccine failure are reported occasionally. It is known that clinical disease can occur in previously vaccinated animals (Buddle et al., 1984; Meynink et al., 1987). However, it is not clear if this is the result of virus strain variation, the result of host immune suppression by viral proteins or a combination of both.

Conclusions

It is clear that soremouth research has fallen behind partially because the use of live non-attenuated virus vaccines helps in the control of the disease. Recent studies indicate that soremouth virus can reinfect sheep in spite of the build-up of a specific immune response (Haig et al., 1997). As a result of this, a growing interest has surfaced to develop soremouth virus vectors for expressing foreign genes in the skin of susceptible animals.

New research is also focusing on the virulence factors of soremouth virus that inhibit the host immune response, and on the development of an effective vaccine that does not preserve the infection in the environment. Because soremouth infection can be confused with other exotic diseases of sheep and goats, it is important to implement research programs on the areas of rapid and accurate diagnostic methods, identification of viral genes that are responsible for virulence, and in the development of safe and efficacious vaccines.

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