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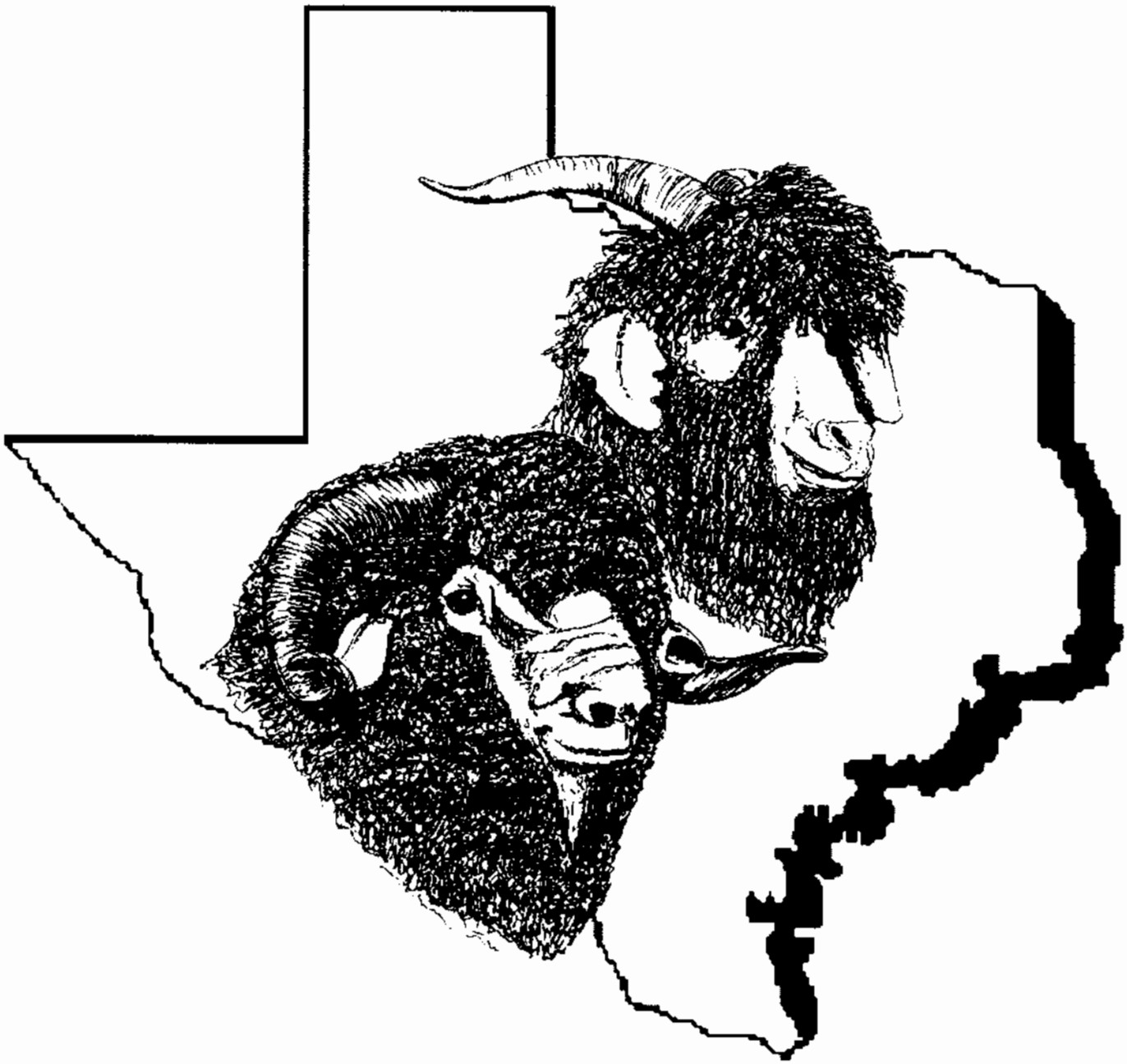

The Agriculture Program
Texas Agriculture Experiment Station
The Texas A&M University System
College Station, Texas
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Foreword

The 2002 Sheep and Goat/Wool and Mohair Consolidated Progress Report has been prepared by Texas Agricultural Experiment Station and Texas Cooperative Extension 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, Stephenville, 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.

At the writing of this report, much of the Texas sheep and goat country has received good summer rains, something we have not seen in quite some time. These recent rains coupled with the nonrecourse marketing assistance loan program for wool and mohair in the Farm Bill should give the Texas sheep and goat industry reason for optimism. Information provided in this and previous progress reports should give producers useful information for increasing the efficiency of their operation and help them take advantage of these recent events.

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Sheep Health

Wool, Mohair, and Cashmere

Effect of the Fec^B allelle on birth weight and post-weaning production traits of Rambouillet-Booroola cross wethers

T.D. Willingham, D.W. Waldron, and P.V. Thompson

ABSTRACT: Rambouillet ewes were single sire mated to rams known to be heterozygous for the Fec^B allele. Birth type, birth weight, dam, rearing type and weight at weaning were recorded. Lambs were identified as B+ or ++ at the Fec^B locus by marker haplotype at weaning. Post weaning weight data were collected while lambs were in feedlot. Estimated differences between B+ and ++ wether genotypes were calculated. Genotype of lamb had no effect on birth weight (BW), adjusted 91d weaning weight (AWW), adjusted 203d final weight (AFW), or post weaning ADG (PADG). Differences in BW, AWW and AFW were due to birth-type (P<.0001). A significant sire effect was also found for BW, AWW and AFW. Rearing type had a significant effect on AWW (P<.0001) and AFW (P<.0001). Genotype within sire, birth type, or rear type were not found to effect PADG. Growth rate of wether lambs that had the Fec^B allele was not significantly different from those that did not.

Key Words: Booroola, Growth, DNA

Sheep and Goat, Wool and Mohair CPR 2002. 1-6

Introduction

The Booroola-Merino, a prolific strain of Merino was imported into the United States in the early 1980's as a potential tool for improving reproductive performance of domestic sheep. The Booroola has a major gene that causes an increase in ovulation rate (Davis et al., 1982; Piper and Bindon, 1982) and litter size (Dodds et al., 1991). The gene has been designated Fec^B (Montgomery et al., 1992). Fec^B will exist in one of three forms within a Booroola cross population of sheep: 1) BB homozygous carrier, 2) B+ heterozygous carrier and 3) ++ homozygous non-carrier. A review of several flocks in different countries, has shown that Booroola-cross ewes (B+) weaned 8.7% additional weight of lamb per ewe mated compared to their ++ contemporaries (Davis et al., 1991). However, some studies have reported no significant difference between B+ and ++ ewes for weight of lambs weaned per ewe lambing (Castonguay et al., 1990) or ewe exposed and present at lambing (Southey, 1996). The B+ ewes had larger litter sizes which resulted in lighter birth weights (Hinch et al., 1985), lower survival rates, and reduced weaning weights (Fogarty and Hall, 1995). Differences between B+ and ++ animals were often confounded with background genotype and/or sire effects because there was no accurate method of prediction of Fec^B genotype prior to reproductive age for females, or reproductive age of daughters for males. The use of DNA markers (Montgomery, et al., 1993; Lord et al., 1998) allows for prediction of Fec^B genotype in animals of any age. There is a need to determine the effect of the Fec^B allele on growth rate independent of indirect effects associated with litter size or reproduction and independent of sire effects. Prediction of genotype at the Fec^B locus allows the estimation of the effect of the Fec^B genotype, within paternal half-sib families, on growth rate in lambs that have no reproductive records. The objective of this

study was to estimate the effect of the Fec^B allele on growth rate in Rambouillet-cross wether lambs within paternal half-sib families.

Materials and Methods

Rambouillet - Booroola rams were selected from progeny of ewes known to be B+ based on ovulation rate records. Rams (N=6) were initially predicted to be B+ based on their genotype at markers available at the time, OarAE101 and BM1329 (Lord et al., 1996). The rams had one or more Booroola-Merino rams in their pedigree. Booroola-Merino ancestry varied from 28% to 5% in the 6 rams. These rams were mated to commercial Rambouillet ewes (++) in order to produce paternal half-sib families of lambs that were either B+ or ++ at the Fec^B locus. Two rams were used each Fall within each of 3 years thus, 6 paternal half-sib families were produced. Within a year, all ewes were the same age. Ewes were bred in single sire pastures at the Winters Ranch in McCulloch county, near Brady, Texas. Ewes lambed in confinement. Dam, birth date, birth weight, and birth type were recorded for each lamb. All lambs were weighed at weaning and were taken to the Texas A&M Agricultural Research and Extension Center at San Angelo and were kept in a (100f x 100f) outdoor pen. Lambs were castrated with elastrator bands, vaccinated for enterotoxemia, and treated with an anthelmintic 1 to 2 d post weaning. Within a year, time on feed was equal for all lambs. Final body weight was recorded at the conclusion of the postweaning feeding period. The number of lambs, age at weaning, and number of days on feed are shown in Table 1. Lambs were given ad libitum access to a 15.82 % CP, 0.70 NE_g (Mcal/kg diet DM) starting diet for approximately 7 d then changed to a 13.76% CP, 1.17 NE_g (Mcal/kg diet DM) finishing diet by 14 d after weaning. Blood samples were collected by venipuncture for extraction of DNA. Blood collection tubes contained sodium heparin as an anticoagulant. Extraction of DNA was done using the procedure described by Montgomery and Sise, (1990). Marker genotype determination was conducted by GenomNZ using three markers linked to the Fec^B allele (Lord et al., 1998). Only lambs identified as B+ or ++ by marker haplotype were present and used in data analysis.

Table 1. Summary statistics

Year	1997	1998	1999
No. of animals	29	31	48
Date of weaning	June 12, 1997	July 13, 1998	June 1, 1999
Age at weaning/d	78.6	106.6	88.8
Days on feed	137	78	118
Age at slaughter/d	215.6	184.6	206.8

Statistical Analysis

The traits analyzed were birth weight (BW), adjusted weaning weight (AWW), postweaning average daily gain (PADG), and final weight per day of age (WDA). There were only 3 lambs that had a triplet birth type so they were combined with twins and classified as multiple birth type. Weaning weights were adjusted to 91 d of age, by the following formula:

$$AWW = \{[(\text{weaning wt} - \text{birth wt})/\text{age at weaning}] \times 91\} + \text{birth weight}$$

Post weaning average daily gain was calculated as:

$$PADG = (\text{final wt} - \text{weaning wt})/\text{days on feed}$$

The linear model used to estimate the difference in birth weight between lambs inheriting the haplotype linked with the Fec^B allelle and the alternative paternal haplotype included fixed effects for type of birth (single or multiple) and predicted Fec^B genotype (B+ or ++) nested within sire family. Proc GLM of SAS (SAS, 1991) was used for these analyses. The Estimate statement of PROC GLM was used to obtain estimates of the difference in performance between lambs receiving the paternal haplotype associated with the B allele and those receiving the paternal haplotype associated with the + allele across sire families.

Results and Discussion

Genotypes were assigned based on segregation of markers flanking the 10 cM region containing the Fec^B locus. Phase information for the alleles at the Fec^B and marker loci were determined for each sire from previous generations.

Effect of Fec^B

Earlier comparisons of performance of Booroola-Merino cross lambs with other breeds (Davis et al., 1991) were a function of Fec^B and Booroola-Merino genetic background. Some studies have estimated the effect of the Fec^B allele by comparing animals from sires known to be either BB or ++, thereby providing an estimate from within a common genetic background (Meyer et al., 1994). Still other studies have estimated the effect of Fec^B by assigning genotype based on ovulation rate. Estimates of the difference between B+ and ++ wether lambs for BW, AWW, AFW, and PADG for this study are shown in table 2. No significant differences were found between genotypes for any of the growth traits examined. In a similar study Visscher et al. (2000) evaluated differences between ram lambs with and without Fec^B when genotypes were assigned by presence of linked DNA markers. Visscher et al. (2000) reported no significant difference in postweaning average daily gain due to the Fec^B genotype of the lamb. Visscher et al. (2000) did report, however, that B+ lambs had greater end weight, greater carcass weight, greater dressing percent, and greater longissumus muscle area. However, their data were not adjusted to a common weight and these differences are in the expected direction, given that B+ lambs were on feed for a greater number of days and had greater live weight at the end of the trial.

Table 2. Estimated difference between alleles at the Fec^B locus for birth weight and growth traits

Performance Trait	n	B - (+) Estimate	SE (±)	Pr > T
BW kg	108	-.39	.41	.41
AWW kg	108	-5.33	5.15	.30
AFW kg	108	-5.63	6.12	.36
ADG kg	108	-.003	.05	.96

Studies of crossbred ewe lambs (Meyer, et al., 1994), and ewe lambs from flocks where Fec^B has been introgressed into a local breed (Southey, 1996; Schulze,1999) have failed to show significant differences in growth rate. The reports of lower body weight in Booroola-crosses by several authors appear to be due to either 1) indirect effects of the larger litters produced by carriers of Fec^B or 2) the indirect effect of increased reproduction on body weight of the Fec^B ewes.

Effects of Birth type and Rearing type

Least squares means BW, AWW, AFW and PADG by sire, birth type and rear type are shown in table 3.

Table 3. Least squares means and SEM of BW, AWW, AFW and PADG by sire, birth type and rear type

Sire	n	BW kg	AWW kg	AFW kg	PADG kg
2011	17	3.34 ± .08	23.1 ± 1.2	49.5 ± 1.4	.235 ± .012
2150	15	3.52 ± .09	24.9 ± 1.2	49.1 ± 1.4	.216 ± .012
2191	12	3.28 ± .10	23.5 ± 1.4	48.6 ± 1.7	.228 ± .014
2219	16	3.49 ± .09	24.8 ± 1.2	50.7 ± 1.4	.231 ± .012
2639	27	3.79 ± .07	26.5 ± 0.9	51.8 ± 1.1	.226 ± .009
2670	21	3.77 ± .08	27.6 ± 1.1	53.3 ± 1.3	.229 ± .011
Birth type					
Single	53	3.77 ± .05	27.8 ± .60	52.6 ± .72	.221 ± .006
Multiple	55	3.29 ± .05	22.1 ± .63	47.5 ± .75	.227 ± .006
Birth/Rear type					
Single/Single	53		27.8 ± .60	52.6 ± .70	.221 ± .006
Multiple/Single	6		25.4 ± 1.83	51.8 ± 2.17	.236 ± .018
Multiple/Multiple	49		21.7 ± .65	47.0 ± .77	.226 ± .006

Birth type affected birth weight, AWW, and AFW (P<.001). Single born lambs were significantly heavier (.48 kg) than lambs born as multiples. Multiple birth lambs were lighter (5.7kg) at weaning and at completion of the feeding period (5.1kg). No differences in PADG associated with birth type were observed. Rearing-type of lambs did affect AWW (P<.0001) and AFW(P<.0001). Single and multiple born lambs raised as singles had similar AWW and AFW, but were significantly heavier than lambs born as multiples and reared as multiples. Sire differences were found for BW (P <.0001), AWW (P<.01), and AFW (P<.06) but not PADG (P<.91). However, sire was nested within year thus, preventing accurate interpretation of these estimates. Sire, birth type, or rear type were not found to have an effect on PADG.

Implications

Fec^B can be introgressed into Rambouillet sheep without having a negative effect on growth rate of B+ wether lambs. The results of this study suggest that reported effects of Fec^B on body weight may be due to sire effects, birth type or rearing type. Effects of Fec^B genotype on mature ewe body weights, may result from greater depletion of body condition due to energy costs of producing and/or nursing a greater number of lambs . Further work should be conducted to evaluate Fec^B effects on mature weight of ewes and rams.

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Interrelationships of traits measured on fine-wool rams during a central performance test

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

ABSTRACT: A correlation analysis was conducted to estimate the relationships between all traits measured on fine-wool (n = 505) rams during the past three central performance tests. Imposition of minimum initial weight levels (for certification) appeared to have an effect on previously reported significant correlations. In addition to the reported traits, several other traits (fiber diameter measures of variability, average fiber curvature and variability) that have not previously been reported were included into the analysis. The correlation coefficients calculated are expected to assist breeders to better understand the consequences of their actions when selecting for individual traits. Observed differences between core and side sample average fiber diameters were not highly correlated with any other traits currently measured on the test. Average fiber curvature was not highly correlated with any measure of average fiber diameter but was negatively correlated with several important production traits which may have serious negative consequences for breeders who are selecting for or trying to maintain small crimp.

Key Words: Traits, Rams, Central Performance Test

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Introduction

Since 1947, the Texas Agricultural Experiment Station (TAES) has hosted a central performance test for yearling rams to assist breeders in identifying their most productive animals. Innovations have been incorporated into the test procedure as new improvements in technology became available. One example is the measurement of average fiber diameter (AFD) and its variability (coefficient of variation, CV). Until a few years ago and because of the limitations of the projection microscope method, it was necessary to remove wool samples from the rams 2½ months before the final field day in order to have adequate time to measure the samples. Rather than shear the whole fleece at this early stage of the test, side samples were shorn and measured as indicators of the AFD of the whole fleece. A britch sample was also measured to indicate the AFD of the coarsest wool in the fleece. Some years ago, TAES' acquisition of the Optical Fibre Diameter Analyser 100 (OFDA 100; Baxter et al., 1992) made it possible to subsample and measure the whole fleece shorn at the end of the growing period, just one month before the field day. After careful consideration, the side AFD and britch AFD were replaced by core sample AFD and CV for calculation of the index because the core sample values provide better estimates of the overall fleece AFD and variability. Nevertheless, because the breeders wanted the data, we continue to measure and report side and britch AFD's. We have calculated and reported the average difference between side and core AFD (about 0.7 μm) for the past five yr. However, after noting the wide range in differences among individual rams, we have attempted to explain this variability in terms of all the other traits measured during the test procedure. We have also taken this

opportunity to identify significant correlations between all the traits measured on these test animals in an attempt to identify any changes that have occurred since the last time these relationships were reported.

In addition to AFD and CV, the OFDA instrument is capable of concurrent measurement of average snippet (2 mm length of fiber) curvature (AFC) and CV. The AFC of snippets has been shown to provide a reasonable indication of fiber crimp propensity (Pfeiffer et al., 2001). Because of the general interest among breeders in the appearance of wool and because of the technical textile implications of crimp, we have measured (but not reported) this trait on rams participating in the past three TAES performance tests. Our investigation of this trait and implications for breeders selecting for particular types of crimp are also reported here.

Materials and Methods

Records collected on 505 rams completing the last three TAES Central Ram Performance Tests (Waldron and Lupton, 2000, 2001, and 2002) were used to conduct correlation analysis (CORR procedure of SAS [SAS Inst. Inc., Cary, NC]) among all traits measured and calculated for the test including several (e.g., AFC, along-snippet average fiber diameter (ASAFD) and their variabilities) that were not previously reported. Multiple stepwise linear regression analysis (REG procedure of SAS) was used to identify those traits that best explained the side/core AFD differences (SAFD - CAFD) among rams.

Results and Discussion

Table 1 shows the mean standard deviation minimum and maximum values for all the traits measured for the three ram tests being considered. The phenotypic relationships among many of these traits have been calculated and discussed previously (Shelton and Lewis, 1986; Lupton et al., 1997). The present discussion will consider the previously compared traits, but the main emphasis will be on traits that were not considered previously. One major difference between the tests conducted between 1982 and 1986 and the present time is the current restriction (for certification purposes) on incoming or initial body weights. Minimum initial weights were introduced some years ago to reduce the variability in this trait so that the comparisons among rams would be more meaningful. The more homogeneous (in terms of BW) initial population would be expected to affect some of the previously reported relationships. Correlation coefficients between traits measured and calculated on the 2000 - 2002 ram tests are summarized in Table 2.

Initial weight

The significant correlations with final weight (FW, +), grease fleece weight (GFW, +), folds score (FS, -), and scrotal circumference (SC, +) have been noted previously (Shelton and Lewis, 1986). However, previously reported significant correlations between IW and average daily gain (ADG), clean fleece weight (CFW), and average fiber diameter (AFD) are absent in this data set, possibly in part due to the current restriction on IW for certifiable animals. Significant negative correlations are present between IW and clean yield (CY, -), staple length (SL, -), and some of the measures of variability of side and britch fiber diameter. Generally, as IW increases, variability in side and britch fiber diameter tends to decrease. These correlations were not significant for the core and along-snippet measurements. The only high correlation was between IW and FW (0.76) which was very similar in magnitude to that reported by Shelton and Lewis in 1986 (0.77).

Table 1. Means and variability of ram traits measured and calculated for three central performance tests (2000 to 2002)

Trait	n	Mean	SD	Minimum	Maximum
Initial weight, lb	505	126.0	20.8	66	213
Final weight, lb	505	250.1	25.8	184	334
Average daily gain, lb/d	505	0.89	0.12	0.47	1.22
Average daily gain (body), lb/d	505	0.82	0.12	0.41	1.15
Grease fleece weight, lb	505	25.2	4.4	10.9	40.0
Clean yield, %	505	45.6	5.1	29.7	59.4
Clean fleece weight, lb	505	11.5	2.3	3.9	18.3
Staple length, in	505	5.4	0.6	3.5	7.0
Side sample, AFD, microns	505	22.6	1.4	18.6	27.2
SD, microns	505	3.7	0.5	2.6	7.1
CV, %	505	16.5	1.8	12.6	29.9
Britch sample, AFD, microns	505	25.0	1.9	19.3	32.4
SD, microns	505	4.4	0.8	2.7	8.7
CV, %	505	17.4	2.4	12.6	32.7
Core sample, AFD, microns	505	21.9	1.3	18.1	25.8
SD, microns	505	4.5	0.6	3.2	6.7
CV, %	505	20.5	2.5	15.6	29.7
Along snippet, AFD, microns	348*	22.0	1.3	17.9	26.1
SD, microns	348*	1.0	0.1	0.6	1.2
CV, %	348*	4.5	0.4	3.4	5.5
Prickle factor, % fibers > 30 microns	505	3.9	3.0	0.2	21.4
(Britch AFD-Side AFD), microns	505	2.4	1.1	-1.9	9.6
(Side AFD-Core AFD), microns	505	0.7	0.8	-3.6	4.3
Average fiber curvature, deg/mm	505	91.1	10.4	63.5	124.0
SD, deg/mm	505	58.5	5.8	43.0	76.0
CV, deg/mm	505	64.3	3.1	56.4	73.8
Face cover score, 0-4	505	1.1	0.5	0.3	3.8
Belly wool score, 1-4	505	1.5	0.6	0.9	4.0
Folds score, 1-4	505	1.6	0.6	0.9	4.0
Scrotal circumference, cm	505	34.9	2.5	27.0	42.0

* = 2 years' data

Table 2. Pearson correlation coefficients for traits measured and calculated on ram central performance tests

	FW	ADG	ADGB	GFW	CY	CFW	SL	SAFD	SSDFD	SCVFD	BAFD	BSDFD	BCVFD	CAFD
IW	0.76**	-0.04	-0.05	0.16**	-0.11*	0.08	-0.10*	0.05	-0.08	-0.12**	0.01	-0.10*	-0.14**	0.05
FW		0.62**	0.60**	0.36**	-0.03	0.29**	0.07	-0.01	-0.23**	-0.27**	-0.04	-0.18**	-0.22**	-0.02
ADG			0.99**	0.36**	0.08	0.36**	0.23**	-0.07	-0.26**	-0.26**	-0.07	-0.15**	-0.16**	-0.09*
ADGB				0.26**	0.09*	0.28**	0.19**	-0.09*	-0.28**	-0.28**	-0.09*	-0.18**	-0.19**	-0.11*
GFW					-0.09	0.83**	0.47**	0.12**	0.12**	0.07	0.05	0.17**	0.18**	0.18**
CY						0.47**	0.38**	-0.04	-0.22**	-0.24**	-0.09*	-0.10*	-0.07	0.05
CFW							0.62**	0.08	-0.01	-0.06	-0.01	0.10*	0.12**	0.19**
SL								-0.17**	-0.19**	-0.12**	-0.16**	-0.09*	-0.03	-0.11*
SAFD									0.50**	0.01	0.80**	0.50**	0.20**	0.86**
SSDFD										0.87**	0.38**	0.62**	0.58**	0.39**
SCVFD											-0.01	0.44**	0.57**	-0.03
BAFD												0.64**	0.27**	0.81**
BSDFD													0.91**	0.57**
BCVFD														0.28**

* $P < 0.05$, significant; ** $P < 0.01$, highly significant.

Table 2. Pearson correlation coefficients for traits measured and calculated on ram central performance tests (continued)

	CSDFD	CCVFD	ASAFD	ASSDFD	ASCVFD	PF	(BAFD-SAFD)	(SAFD-CAFD)	AFC	SDFC	CVFC	FCS	BWS	FS	SC
IW	-0.04	-0.08	0.03	0.03	0.01	0.06	-0.04	0.01	0.06	0.04	-0.07	-0.04	0.14**	-0.28**	0.32**
FW	-0.09*	-0.10*	-0.01	-0.05	-0.05	0.01	-0.05	0.01	-0.11*	-0.09*	0.07	0.01	0.13**	-0.13**	0.41**
ADG	-0.09*	-0.06	-0.05	-0.13*	-0.10	-0.06	-0.03	0.01	-0.24**	-0.19**	0.20**	0.06	0.02	0.13**	0.23**
ADGB	-0.09*	-0.05	-0.08	-0.12*	-0.08	0.08	-0.03	0.02	-0.20**	-0.15**	-0.18**	0.05	0.05	0.10*	0.23**
GFW	0.04	-0.05	0.19**	-0.12*	-0.26**	0.17**	-0.07	-0.09*	-0.51**	-0.46**	0.26**	0.07	-0.21**	0.37**	0.14**
CY	-0.25**	-0.31**	0.05	-0.36**	-0.44**	-0.04	-0.10*	-0.15**	-0.39**	-0.42**	0.04	0.10*	-0.17**	0.11*	0.05
CFW	-0.09*	-0.20**	0.18**	-0.28**	-0.45**	0.13**	-0.12**	-0.16**	-0.66**	-0.64**	0.25**	0.12**	-0.28**	0.39**	0.15**
SL	-0.23**	-0.21**	-0.12*	-0.37**	-0.33**	-0.15**	-0.05	-0.13**	-0.72**	-0.65**	0.35**	-0.02	-0.12**	0.06	0.01
SAFD	0.43**	0.06	0.84**	0.48**	-0.03	0.74**	0.06	0.45**	0.04	-0.00	-0.11*	0.07	-0.25**	0.16**	0.05
SSDFD	0.40**	0.26**	0.36**	0.36**	0.15**	0.49**	-0.00	0.29**	0.09	0.12**	0.01	0.01	-0.08	0.19**	-0.09*
SCVFD	0.22**	0.27**	-0.07	0.12*	0.19**	0.14**	-0.03	0.08	0.08	0.13**	0.08	-0.03	0.06	0.12**	-0.13**
BAFD	0.47**	0.14**	0.80**	0.43**	-0.06	0.73**	0.64**	0.15**	0.04	-0.01	-0.13**	0.05	-0.18**	0.08	0.06
BSDFD	0.50**	0.28**	0.54**	0.27**	-0.06	0.63**	0.43**	-0.02	0.01	-0.01	-0.05	-0.02	-0.17**	-0.20**	0.04
BCVFD	0.37**	0.28**	0.24**	0.11*	-0.04	0.38**	0.20**	-0.10*	-0.01	-0.01	0.00	-0.05	-0.12**	0.20**	0.00
CAFD	0.48**	0.05	0.99**	0.47**	-0.16**	0.84**	0.25**	-0.08	-0.04	-0.11*	-0.16**	0.08	-0.30**	0.20**	0.10*
CSDFD		0.90**	0.46**	0.42**	0.15**	0.59**	0.24**	-0.02	0.13**	0.15**	0.00	0.06	-0.02	0.07	-0.08
CCVFD			0.01	0.22**	0.25**	0.25**	0.15**	0.02	0.17**	0.23**	0.08	0.03	0.13**	-0.02	-0.15**
ASAFD				0.50**	-0.12*	0.85**	0.20**	0.10*	0.00	-0.09	-0.19**	-0.00	-0.30**	0.23**	0.15**
ASSDFD					0.80**	0.48**	0.08	0.10*	0.51**	0.55**	-0.11*	-0.14**	-0.15**	0.16**	-0.07
ASCVFD						-0.04	0.27**	0.20**	0.59**	0.68**	0.00	-0.16**	0.04	0.03	-0.18**
PF							0.27**	-0.04	-0.01	-0.03	-0.05	0.06	-0.21**	0.25**	0.09*
(BAFD-SAFD)								-0.33**	0.02	-0.01	-0.07	-0.01	0.03	-0.08	0.04
(SAFD-CAFD)									0.14**	0.19**	0.06	0.00	0.04	-0.03	-0.08
AFC										0.91**	-0.49**	-0.05	0.03	-0.06	-0.04
SDFC											-0.09	-0.06	0.02	-0.02	-0.08
CVFC												0.01	-0.01	0.09*	-0.07
FCS													0.08	0.03	-0.08
BWS														-0.33**	-0.04
FS															-0.02

* $P < 0.05$, significant; ** $P < 0.01$, highly significant.

Glossary of Terms

IW:	Initial weight
FW:	Final weight
ADG:	Overall average daily gain
ADGB:	Average daily gain of body (grease wool not included)
GFW:	Grease fleece weight;
CY :	Clean yield
CFW:	Clean fleece weight
SL:	Staple length
SAFD:	Average fiber diameter of side sample
SSDFD:	Standard deviation of fiber diameter of side sample
SCVFD:	Coefficient of variation of fiber diameter of side sample
BAFD:	Average fiber diameter of britch sample
BSDFD:	Standard deviation of fiber diameter of britch sample
BCVFD:	Coefficient of variation of fiber diameter of britch sample
CAFD:	Average fiber diameter of core sample from whole fleece
CSDFD:	Standard deviation of fiber diameter of core sample from whole fleece
CCVFD:	Coefficient of variation of fiber diameter of core sample from whole fleece
ASAFD:	Along-snippet average fiber diameter of core sample
ASSDFD:	Along-snippet standard deviation of fiber diameter of core sample
ASCVFD:	Along-snippet coefficient of variation of fiber diameter of core sample
PF:	Prickle factor
(BAFD - SAFD):	Average fiber diameter of britch sample - average fiber diameter of side sample
(SAFD - CAFD):	Average fiber diameter of side sample - average fiber diameter of core sample
AFC:	Average fiber curvature
SDFC:	Standard deviation of fiber curvature
CVFC:	Coefficient of variation of fiber curvature
FCS:	Face cover score

Final weight

The significant correlations with ADG (+), fleece weights (+), and SC (+) are again present. Completely absent are any significant correlations between FW and any of the four measures of AFD. Shelton and Lewis (1986) had reported small but significant correlations with side average fiber diameter (SAFD, 0.19) and britch average fiber diameter (BAFD, 0.16). In the populations of rams tested over the past three yr, AFD appears to be independent of FW. As with IW, FW is significantly and negatively correlated with most of the measures of variability (SD and CV) of AFD (along-snippet being the exception). The fact that larger animals tend to be more uniform in fiber diameter is interpreted to reflect that less change in fiber diameter occurs in these animals during their time on test. There is a small but significant correlation between FW and average fiber

curvature (AFC, -) indicating heavier rams tend to produce wool having bolder crimp. The FW is also significantly correlated with belly wool score (BWS, +) and FS (-), as was IW.

Average daily gain

The significant correlations with FW (+), GFW (+), CFW (+), and SC (+) are present, as previously reported (Shelton and Lewis, 1986). In addition, ADG is significantly correlated with SL (+), and negatively correlated with most of the measures of AFD variability and AFC. Higher gaining rams are positively associated with higher FS. With the fleece weight excluded from calculation of ADG, ADGB is obtained. As expected, these two measures of ADG are very highly correlated (r = 0.99). Correlations of ADGB with the other traits follow the same trend as ADG.

Grease fleece weight

As expected and previously reported, GFW is highly and positively correlated with CFW and SL. Smaller but significant correlations are present with FW, ADG, SAFD, core sample AFD (CAFD), and along-snippet AFD (ASAFD) indicating that larger fleeces tend to be coarser. The GFW is highly and negatively correlated with AFC (heavier fleeces tend to have bolder crimp), negatively correlated with BWS and positively correlated with FS and SC.

Clean yield

Clean yield is positively correlated with CFW (but not GFW) and SL and negatively and consistently correlated with the SD and CV of fiber diameter measurements (higher yielding fleeces tend to be less variable in terms of fiber diameter). The CY is negatively correlated with AFC and SDFC (higher yielding fleeces tend to have bolder crimp), (SAFD-CAFD), and BWS. Small positive correlations are present with ADGB, FCS, and FS.

Clean fleece weight

Clean fleece weight is positively correlated with FW, ADG, GFW, CY, SL, CAFD (but negatively with variability), ASAFD (and negatively with variability), PF, FCS, FS and SC. It is negatively correlated with (BAFD - SAFD) and (CAFD - SAFD), AFC and SDFC, and BWS. The potentially antagonistic correlations are with AFD, PF, FCS and FS. The significant correlation with IW as reported by Shelton and Lewis (1986) is no longer present, no doubt due in part to the relatively new restriction on starting weight.

Staple length

Staple length (SL) is positively and significantly correlated with ADG, GFW, CY and CFW. In contrast, negative correlations are present with IW, all measures of AFD and their SD's and CV's, PF, AFC, SDFC and BWS. Longer staples are associated with finer, less variable fibers having bolder crimp. None of the significant correlations with SL are considered antagonistic. These correlations are similar in direction and magnitude with those reported by Shelton and Lewis (1986). However, the previously reported significant negative correlations with FCS and FS are absent from the current analysis.

Average fiber diameter

All measures of AFD are negatively correlated with SL and positively correlated to each other, their measures of variability (SD and CV), PF, and FS. The correlations with BWS are negative. Core AFD is positively correlated with GFW and CFW. Noteworthy are the absences of significant

correlations with IW, FW, and AFC. Average fiber diameters in these three sets of animals appear to be independent of initial and final bodyweights and fiber curvature. This is quite different from the situation in 1982-1986 (Shelton and Lewis, 1986) when bigger rams tended to produce coarser wool.

For the purpose of evaluating rams, there seems to be no advantage in using multiple AFD measurements made on samples removed from different locations (side, britch) versus a representative sample of the whole fleece (core). This is the basic conclusion of a previous study (Lupton et al., 1997).

Measures of variability in fiber diameter

Because CCVFD is used in the index we calculate for evaluating rams, this will be the focus of discussion. The CCVFD is negatively correlated with FW, CY, CFW, SL, and SC, none of which are considered antagonistic. It is positively correlated with SSDFD, SCVFD, BAFD, BSDFD, BCVFD, CSDFD, ASSDFD, ASCVFD, PF, (BAFD - SAFD), AFC, SDFC, and BWS. Except for the significant correlation with BAFD, correlations with other measures of AFD are not significant.

Prickle factor

By definition, PF is the % fibers greater than 30 μm, so it is no surprise that PF is positively correlated with all measures of AFD and most measures of variability in fiber diameter (ASCVFD being the one exception). The PF is also positively associated with the fleece weights and FS but negatively correlated with SL and BWS.

(Britch average fiber diameter - Side average fiber diameter)

This trait was used for many years as an indicator of variability of fiber diameter in the fleece as a whole. It is significantly correlated with CCVFD (the best estimate of variability of fiber diameter in the fleece) but at a relatively low level, r = 0.15. Re-stated, the variability in (BAFD - SAFD) accounts for only 2% of the observed variability in CCVFD. This is why these measures were replaced by CAFD and CCVFD in the index. The magnitude of this relationship is quite similar to that reported previously for rams participating in the 1994 - 1996 tests (Lupton et al., 1997).

(Side sample - core sample average fiber diameter differences)

We rationalize that CAFD is generally less than SAFD because measurement of the latter does not include the relatively fine staple tip (Lupton and Shelton, 1986). Small but significant negative correlations are present between this calculated variable and GFW, CY, CFW, and SL. As these traits increase, there is a tendency for (SAFD - CAFD) to decrease. A relatively high (r = 0.45) correlation exists with SAFD but not CAFD (r = -0.08). A highly significant correlation (r = -0.33) is present between (BAFD - SAFD) and (SAFD - CAFD).

Stepwise multiple regression analysis was used to establish the relationship between (SAFD - CAFD) and all variables measured and calculated in the three ram tests being considered. When measures of AFD remained in the model, SAFD and CAFD enter the equation first and second (respectively) to produce an $r^2 = 1$. When all measures of AFD, SD, CV, and PF are omitted from the model, the only variable to enter the model for $P < 0.05$ is SDFC ($r^2 = 0.04$). No other variable meets the 0.05 significance level for entry into the model. When the four measures of AFD (only) are removed from the model, the variables entering the model to produce an $r^2 = 0.93$ were

measures of variability of fiber diameter (Table 3) which themselves are significantly correlated with the mean values.

Table 3. Summary of stepwise regression analysis for dependant variables (SAFD - CAFD)

Variable*	Parameter estimate
Intercept	0.77
SSDFD	5.55
SCVFD	-1.25
CSDFD	-4.40
CCVFD	0.96

*No other variables met the 0.05 significance level for entry into the model.

(SAFD - CAFD) is positively correlated with AFC and SDFC. In other words, this variable tends to increase as the AFC (and its variability) increases, i.e. as the staple crimp becomes smaller.

In summary, these analyses do not shed much light on why (SAFD - CAFD) is so variable among rams. In the absence of a better explanation, we conclude the observed variability is likely due to differences in genetics, pre-test conditioning, and/or other things that we do not measure during the test (e.g., weight per day of age). Suffice it to say, the differences exist and they are real.

Average fiber curvature and variability

These traits have been measured concurrently with CAFD for the past three yr. Negative correlations exist with ADG, GFW, CY, CFW, SL, and CVFC. Thus, selecting for increases in any of these traits will result in wool having bolder crimp. Positive correlations exist with CSDFD, CCVFD, ASSDFD, ASCVFD, (SAFD - CAFD) , and SDFC. In other words, selection for smaller crimp (higher AFC) will tend to increase variability in fiber diameter. Obviously, these results provide a serious warning to any breeder who is trying to produce wool having a small crimp while selecting for increases in wool production or rate of gain.

No significant correlations exist between AFC and any of the measures of AFD. In these populations of rams, fiber crimp (measured as AFC) is not a good indicator of AFD.

Face cover score

Face cover score is only significantly correlated with four traits, CY (+), CFW (+), ASSDFD (-) and ASCVFD (-). Intuitively, the relationship with CFW seems reasonable. We have no rationale for the other relationships. These relationships were not observed by Shelton and Lewis (1986). Conversely, we did not observe the significant negative correlation between FCS and SL reported earlier.

Belly wool score

Belly wool score is positively correlated with body weights and CCVFD and negatively correlated with fleece weights, CY, SL, average fiber diameter and measures of variability, PF, and

FS. Thus, selecting for lower BWS will tend to result in heavier fleeces containing longer, cleaner and coarser wool produced by sheep having lower body weights and more folds.

Folds score

Fold score is positively correlated with ADG, GFW, CY, CFW, SAFD, CAFD, ASAFD and PF and negataively correlated with IW, FW, and BWS.

Folds were bred off the Rambouillets during an era when a small cut inflicted during shearing would often result in death due to screw worm invasion. Screw worms no longer are present in Texas. More productive sheep have folds which appear to be quite acceptable in other countries. However, in Texas the demand has evolved for smooth-bodied rams. To change this perception of a "desirable ram" would be difficult. Shearers have learned to shear on smooth sheep and may now have difficulty shearing more productive sheep with excessive folds or wrinkles.

Scrotal circumference

Scrotal circumference is positively correlated with body weights, ADG, and fleece weights. Some significant, negative correlations exist with some of the measures of variability of fiber diameter.

Implications

Numerous breeders use the TAES performance test to evaluate their rams. Many commercial sheep producers purchase performance-tested rams, their offspring and/or related sheep from the breeders. Often individuals are attempting to improve one or a few individual traits in their flock while maintaining or improving other traits. This report will assist them in understanding the consequences of selecting for a single trait.

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Relationship of lifetime fleece weight of ewes to sire's yearling fleece weight on performance test

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ABSTRACT: A progeny test of 24 centrally tested Rambouillet rams obtained from the Sonora Central Performance Test in 1994, 1995 and 1996 was conducted. The postweaning central performance test was 140 d long. Objective traits evaluated on the central test included average daily gain, fleece weight, fleece fiber diameter and staple length. Rams were also given subjective scores for face cover and belly wool. Female progeny records included objective measures of fleece weight, fiber diameter, and staple length and subjective scores of face cover and belly wool. Only analysis of 365d adjusted grease fleece weight (AFW) data from yearling to five years of age has been completed and is reported here. Daughter's AFW was regressed on sire's central test performance in order to estimate the accuracy of central test records for predicting genetic merit for this trait. The estimated regression coefficient of daughter's AFW on sire's CFW on central performance test was .14 ± .05 (P = .01). This indicates an increase of .14 lbs grease fleece weight per daughter per year for every lb increase in sire's clean fleece weight on central test. Fleece weights decreased as age of ewe increased from 1 to 5 yr. Open ewes produced .61 lbs more AFW (P<.0001) than ewes that gave birth to a single lamb and weaned it. Ewes that gave birth to multiples and weaned all of them produced .91 lb AFW less (P<.0001) than open ewes. Central performance test evaluations of fleece weight are useful for predicting genetic merit for wool production in daughters under commercial conditions.

Key Words: Wool, Sheep, Central Test, Genetic Improvement

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Introduction

Differences in animal performance can be attributed to differences in genetics of the animal or the environment in which performance is measured. If animal performance is to be improved, separation of genetic from environmental differences in performance is essential, because only genetic differences will be passed on to progeny. This is particularly true when comparing performance of animals raised on different ranches. A central performance test of Rambouillet rams has been conducted annually at the Sonora Station since 1948 (Shelton, 1979). A purpose of such a central performance test is to provide a common environment to allow for valid comparisons of performance of animals from different ranches. However, it must be assumed that pretest environment has no effect on rams' performance on central test. Research work conducted during the early years of the Sonora test (Shelton, 1959) showed a positive relationship between central test performance and progeny performance. However, central test practices have changed since the 1950s and the population of rams tested has changed. Test length was shortened to decrease the cost of testing and to reduce the incidence of overfat rams (Shelton and Lewis, 1986). Central performance tests in the Midwestern United States which are 63 d long have shown no significant relationship between central test performance and post weaning growth rate of progeny (Waldron et al., 1990). The objective of this report is to estimate the relationship between sires' clean fleece weight from the central performance test and daughters' lifetime wool production.

Material and Methods

Twenty-four unrelated rams that completed the Sonora Central Performance Test in either February 1994, February 1995 or February 1996 were selected for a progeny test. Nine rams were

chosen in each of the first two years, but one ram chosen in 1995 failed to produce any offspring. An additional ram selected in 1995 was removed from the analysis because of having only one daughter. Eight rams were selected in 1996. The rams were chosen so that a wide range of performance was represented for average daily gain (ADG), clean fleece weight (CFW) and fiber diameter (FD). Measures of performance among all rams completing the performance test in 1994, 1995, and 1996 and the 24 progeny tested rams are shown in Table 1.

Table 1. Mean, minimum and maximum of wool traits on central test by year for all rams and for progeny tested rams

	1993-1994 Ram Test			1994-1995 Ram Test			1995-1996 Ram Test		
	No.*	Mean	Range	No.*	Mean	Range	No.*	Mean	Range
Clean fleece	N=203	11.5	6.3- 19.2	N=169	11.6	6.2 - 19.5	N=161	12.1	7.1 - 19.2
wt., lb/yr	n=9	12.2	9.2 - 15.3	n=7	12.0	8.8- 14.1	n=8	12.5	8.5 - 16.6
Staple length,	N=203	4.7	2.9 - 6.1	N=169	5.1	3.6 - 6.6	N=161	5.0	3.5 - 6.4
in/yr	n=9	4.9	4.5 - 5.6	n=7	5.1	4.1 – 6.2	n=8	5.0	3.9 - 5.5
Fiber	N=203	23.7	17.8 - 29.6	N=169	23.3	19.2 - 27.5	N=161	23.9	19.4 - 29.2
diameter, mm	n=9	23.8	20.2 - 27.0	n=7	23.7	20.7 - 27.5	n=8	23.7	21.3 - 26.1
Face cover	N=203	1.1	.4 - 3.5	N=169	1.1	.5 – 3.9	N=161	1.1	.5 - 2.8
Score	n=9	.9	.8 - 1.1	n=7	1.2	1.0 - 1.7	n=8	1.3	.9 - 2.0
Belly wool	N=203	2.2	1.1 -3.5	N=169	1.8	1.1 - 3.5	N=161	1.7	1.0 - 3.5
Score	n=9	2.1	1.9 - 2.6	n=7	2.2	1.3 - 3.5	n=8	1.7	1.0 - 3.5

*N is the number of rams finishing the central performance test within that year, n is the number of rams producing progeny for test each year.

Commercial Rambouillet ewes maintained on the Winters Ranch near Brady, Texas were randomly assigned to sires. Ewes were mated in single sire pastures in September 1994, September 1995 and August 1996. All lambs were weighed at birth and at weaning.

Ewe lambs were weaned at approximately 4 mo of age. At weaning, ewe lambs were maintained on native pastures and given limited supplemental feed. Ewe lambs were shorn at approximately 6 mo of age so that the fleeces obtained at 1 yr of age would have the same growth period. No analysis was done on the lamb fleece shorn at approximately 6 mo of age. Ewe lambs entered the breeding flock at approximately 18 mo of age. Once in the breeding flock they were maintained on native pastures at one of three experimental ranches within the Edwards Plateau. All ewes born within a year were managed as a single contemporary group except for the breeding season. Ewes were lambed through a barn in order to obtain data on reproductive performance. At shearing, fleeces were individually bagged, identified and transported to Texas A&M Wool and Mohair Research Lab for weighing and analysis. Data collected included grease fleece weight, lab scoured yield, clean fleece weight and mean fiber diameter.

Grease fleece weights were adjusted to 365-d growth period prior to analysis. Six fleece weights were removed from the data set because the ewe had shed a significant portion of the fleece prior to shearing. Grease fleece weights were analyzed with PROC MIXED (SAS, 1992). The model used for analysis included fixed effects for year of production, age of ewe and number of lambs weaned, random effects for sire and ewe nested within sire, and a covariate for sire's clean fleece weight on central performance test.

Results and Discussion

Sires' performance on central test for CFW affected (P<. 01) daughter average grease fleece weight (AFW). The regression estimate indicated that for each 1 lb difference in sires' central test CFW, a .14 lb difference is expected in daughters AFW. A producer can expect to shear an average of 5 fleeces from each daughter over her lifetime. Therefore, a 1 lb increase in CFW is expected to result in .70 lb (5 fleeces x .14 lb/fleece) greater AFW per daughter. If a superior sire is used to produce 100 daughters, the result will be 70 lbs of AFW for each lb of increase in sire's central test CFW. This projection ignores benefits from all other traits and ignores the expected benefits in the next generation of replacement ewes.

The influence of age of ewe (P<. 01) on her AFW is shown in table 2. The estimates of AFW decrease with increasing age. The most noticeable difference in AFW when comparing age groups is at 1 yr of age. Yearling ewes produced 2.75 lb greater AFW than 5yr olds. The advantage of yearling ewes for AFW when compared to other ages is due largely to the absence of reproductive demand for nutrients within 1 yr old ewes. After breeding, a greater share of the nutrients are utilized for maintenance of pregnancy, and lactation. The smallest decrease (.18 lb) in AFW occurred between 2 yr and 3 yr old ewes. After 2 yr of age, subsequent years' AFW will decline at an increasing rate through 5 yrs of age. This may indicate a cumulative effect of previous years reproductive performance on proceeding wool production.

Table 2. Least Squares Means and Standard Errors for 365 d Adjusted Grease Fleece Weight by Ewe Age

Age / yr	LSMean ± SE
1	11.5 ± .36
2	9.79 ± .23
3	9.61 ± .15
4	9.36 ± .20
5	8.79 ± .32

The number of lambs born and/or weaned had a negative affect on a ewes' grease fleece weight production when compared to open ewes. The reduction in grease fleece weight is not a negative genetic relationship but results from competition within a ewe for nutrients required to produce wool, reproduce and lactate (Snowder and Shelton, 1988). No attempt was made to separate the effect of pregnancy or lactation on fleece production because, there is a confounding of these two effects. A ewe that has a single lamb but fails to raise it has a different nutritive demand than an open ewe or a ewe that rears her lamb. This is also true for a ewe having twins yet raising both, one or none. The estimated effects of pregnancy and lactation are shown in table 3. Open ewes sheared .61 lb more AFW than ewes that gave birth to a single lamb and weaned it. Ewes having twin lambs and weaning both sheared .91 lb less AFW than open ewes. The reduction in AFW due to pregnancy and lactation found in this trial, closely agrees with the 5% and 9% reduction in fleece weight of single and twin bearing ewes reported by Snowder and Shelton (1988).

Central test performance is a useful tool to select for increased AFW in Rambouillet ewes managed under range conditions. The genetic superiority will be expressed in each fleece over a ewe's lifetime. Therefore, the investment in superior genetics will be realized over the lifetime of the ewe.

Table 3. Least Square Means and Standard Errors for 365 d Adjusted Grease Fleece Weight for Selected Birth-Wean Combinations.

Number lambs born-number lambs weaned	LSMeans ± SE
0-0	10.66 ± .18
1-1	10.05 ± .15
2-2	9.75 ± .17

Implications

The central performance test has been widely used in helping sheep producers identify genetically superior rams. The results of this analysis indicate that the test is effective in identifying genetic superiority for fleece weight in finewool sheep. Genetic improvement in a flock that produces its own replacement ewes is permanent, because the daughters of Sire A, will produce daughters, which will be granddaughters of Sire A. Therefore, differences in genetic merit of sires used this year will have an additive effect on the flock's production for many years.

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Selection practices for meat goats: Estimation of the relationship between sire's performance on central test and the performance of his progeny

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ABSTRACT: A progeny test, of selected bucks from central performance tests, was conducted in order to establish the relationship between central test performance and progeny performance for meat goats. Progeny (N=285) from 14 different sires over a two yr period were analyzed using a mixed model. Regressions of offspring performance (birth weight, weaning weight, postweaning gain) on sire's central performance were positive but not significantly different from zero. These results suggest that performance records collected during a central performance test were not as accurate for predicting progeny performance as within-herd records.

Key Words: Goats, Growth, Central Test

Sheep and Goat, Wool and Mohair CPR 2002. 21-25

Introduction

The goat industry is changing focus with an increased emphasis on meat production. Growth rate of the slaughter animals is one of the most important factors determining the amount of meat produced. Producers that want to increase the growth rate of kids by using breeding stock which are genetically superior for growth rate are in need of objective information on how to select breeding stock. Within-herd selection is straightforward because all animals are raised in a common environment. Therefore, all animals are subject to the same environmental effects and observed differences in performance are largely genetic. The heritability of six- and nine-mo wt averaged .50 in a Boer herd in South Africa (Schoeman et al., 1997). However, many goat producers are acquiring breeding stock, especially males, from other herds. Therefore, environmental differences can affect performance. One method, used in other meat producing species, to partition genetic effects from environmental effects is the central performance test. A central performance test measures performance of animals from several different ranches in one common, central environment.

In the summer of 1995 an annual central performance test for meat goats was reinstated at San Angelo. The groups that were involved in the planning and/or conduct of this test were representatives from the American Meat Goat Association (AMGA), American Boer Goat Association (ABGA), Angelo State University (ASU) and Texas Agricultural Experiment Station (TAES) at San Angelo. The rationale for a central performance test is to try to accurately measure performance of animals from different ranches in a common environment so that performance is not influenced by different environments. If there are no pretest environmental effects that influence performance, the observed differences in performance are assumed to be predictors of genetic differences. There is evidence from 63-d central performance tests of Suffolk ram lambs in the Midwestern U.S. that indicates that pretest environment affects test performance and therefore central test performance is not a reliable predictor of progeny growth rate (Waldron et al., 1990). The objective of this project was to determine the relationship between central test performance and progeny performance in typical environments.

Materials and Methods

Central Performance Test

This study used data from the central tests conducted from 1995 through 1997. There have been management changes across years, but in all years the test was conducted in an environment where the growth of the bucks was not limited by nutrient availability. The participation, in terms of number of goats and number of herds, increased each year (Table 1). This increased participation is evidence of goat breeders' interest in performance recording and genetic improvement. The increase in the mean central test performance over the three-yr period was concurrent with an increase in the proportion of Boer genetic influence.

Table 1. Number of bucks finishing central performance test by year

Year	Number of Goats	Increase	Number of Herds	Mean ADG,lb	Length of test, days
1995	49		7	.43*	112
1996	78	59 %	12	.58	84
1997	121	55 %	19	.63	84

* Gain for the first 84 days of the 112-day test.

Progeny Test

At the conclusion of each of the central tests (1995 - 1997) bucks were selected for a progeny test. Bucks were selected to represent a broad range of performance on the central test. A total of 14 bucks were mated in the progeny test in the three years. The central test performance of selected sires is shown in Table 2. Each buck was mated with approximately 20 Spanish does on the Winters Ranch lease near Brady, Texas. Does were assigned to sires so that the average age and weight of does was similar for each sire. Kids were born in the spring of 1996, 1997 and 1998.

Table 2. Central test performance of progeny tested sires

Year	ADG, lbs/day
1995	.58, .58, .42, .38, .36
1996	.87, .73, .55, .45, .40
1997	.85, .74, .51, .48

The kids were weighed at birth, at weaning (approximately 120 d of age) and during a postweaning gain period up to approximately 6 months of age. The numbers of kids with records are listed in Table 3. There was an average of 20 kids/sire for birth weight. In order to obtain information from two different environments, kids were randomly assigned, within sire group, to either a feedlot or pasture group for the postweaning gain period. The average weights and rates of gain are shown in Table 4.

Table 3. Number of birth, weaning, and postweaning records by year.

Year	Birth	Weaning	Postweaning	Number of sires
1996	142	129	129	5
1997	83	80	66	5
1998	60	53	53	4

Table 4. Progeny performance means by year.

Year	Birth wt	Weaning wt	Feedlot ADG	Pasture ADG	Feedlot final wt	Pasture final wt
			(lbs)			
1996	5.7	37.2	.41	-.01	59.6	43.2
1997	6.3	38.1	.45	.11	64.8	47.9
1998	5.9	59.5	.47	.09	86.7	63.0

Data were analyzed to estimate the extent to which central test performance is a predictor of progeny performance. The statistical model included fixed effects for year, sex and type of birth, (single vs. multiple) linear covariates for age within year and sire's central test performance, and a random effect for sire. The sire's central test performance was expressed as a deviation from the test average for that year.

Results

The estimated regression coefficients are shown in Table 5. A plot of sire means for central test performance and progeny performance is shown in Figure 1. The variability in sire groups and the deviations about the regression are evident in Figure 1. The ADG of the sires is expressed as a deviation from the mean of all bucks on test in that year.

Table 5. Regression of progeny performance on sire's ADG as measured on central test

Trait	Regression coefficient ± s.e.	P
Birth weight	.47 ± .35	.18
Weaning weight	.56 ± 4.30	.89
Postweaning gain		
Feedlot	.066 ± .092	.48
Pasture	.013 ± .052	.80
Final weight		
Feedlot	-.3 ± 8.4	.97
Pasture	9.1 ± 5.3	.09

* 42 day postweaning growth period

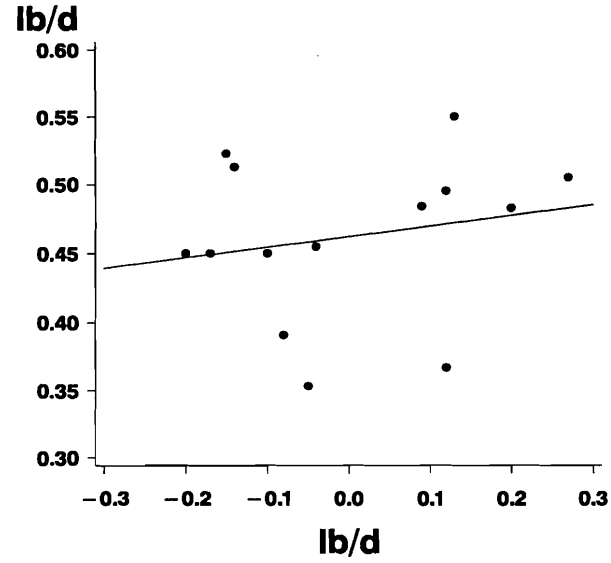

Figure 1. Progeny postweaning ADG versus Sire's central test ADG deviation.

The regression results indicate there was not a significant relationship between central test performance of the sire and birth or weaning weights of the progeny. Progeny postweaning gain in the feedlot environment is the trait that is the most similar to central test performance. There was not a significant relationship between sire's central test performance and progeny postweaning gain in either the feedlot or pasture environments, even though the estimates were positive. The final weight recorded on the progeny was at approximately 6 mo of age. The regression results for final weight indicate no significant relationship between sire's central test performance and progeny performance in the feedlot and only a weak relationship (P = .09) with progeny performance on pasture.

The data suggest that the central performance tests did not accurately identify genetic superiority for growth rate. These results are based on data from progeny of 14 sires over a three-yr period. It would have been desirable to evaluate progeny from a larger number of bucks. The lack of a strong relationship between sire and progeny performance may have been due to the pre-test environmental differences among the goats tested. Louca and Hancock (1977) found no significant genotype by environment interactions when growing goats on different levels of protein and suggested that genotype by environmental interactions may not hinder selection programs.

The range of birth dates of bucks that were on the central performance test was approximately three mo. When older bucks were compared to younger bucks within this three-mo range, the period of growth being measured may have been at different stages of maturity and therefore the central test evaluation may have been biased. Presently, there is not enough data available to adequately evaluate the effect of starting age on central test performance. Possible changes for the test to improve accuracy are 1) lengthen the test period, and 2) restrict range of birthdates of kids on test. The expected negative consequences of these changes would be an increased cost of testing and lower participation because of the restriction on kidding dates.

Central performance test data did not accurately identify genetic differences among goats from different herds for growth rate. Variation in performance among half-sibs on the central performance test indicates that breeders should be encouraged to test several sons from a sire rather than only one or two sons from each sire. This will result in a more accurate genetic evaluation of the sires. Perhaps the central test should be considered as a progeny performance test. Because most goats are raised in extensive management systems, little performance data is

collected on ranches. Therefore, the central performance test concept has appeal for many breeders. While the results of the current trial do not indicate a significant relationship between central test performance and progeny performance, a stronger relationship may exist when animals are compared within a group of bucks from a single herd. The bucks used in the progeny test came from different herds. A breeder may use the central test to obtain growth data on kids and use that data in selection decisions, because pre-test management will be the same for all kids from one flock. Breeders should also be encouraged to record performance at their own ranch on a greater proportion of kids so that performance information can be combined with pedigree information to more accurately identify genetically superior animals.

Acknowledgement

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Development of a cutability equation for carcasses of show goats

L.A. Rakowitz, T.E. Tschirhart, D.R. McKenna, D.B. Griffin, and J.W. Savell

ABSTRACT: Goats (n = 22) from two livestock shows in the state of Texas were slaughtered at Texas A&M University. Standard carcass assessments were recorded and then carcasses were fabricated into semi-boneless closely trimmed (0.1 in) primals (SBTP). Data were analyzed to develop the best one-, two-, three-, four-, and five-variable equations, respectively, for predicting the percent SBTP. The three-variable equation, which had hot carcass weight, ribeye area, and body wall thickness as variables, was selected as the best overall equation with an $R^2 = 0.73$. The three-variable equation was tested against the existing Houston Livestock Show and Rodeo (HLSR) equation. Analysis revealed an $R^2 = 0.83$ for the three-variable equation and an $R^2 = 0.74$ for the HLSR. This indicates that the three-variable equation was a better predictor of goat carcass cutability than the equation currently used.

Key Words: Goat, Meat, Carcass Evaluation, Carcass Composition

Sheep and Goat, Wool and Mohair CPR 2002. 26-30

Introduction

Goat meat has been an important part of diets of people throughout the world. It is estimated that 70% of the worldwide population consume goat regularly (Bowman, 1999). In the United States, goat has not been the traditional source for red meat in the diet. However, the demand for goat meat is at an all time high and continually increasing making it the most rapidly growing sector of the U.S. livestock industry. Domestically, producers have a difficult time keeping up with the growing demand, resulting in about 1.5 million pounds of goat being imported to the United States weekly (Bowman, 1999). Due to this increasing need for goat production, producers in Texas are beginning to take an interest in raising goats as a part of their livestock operations. Over the past five yr goat production has become a major part of Texas agriculture. Major livestock shows such as Houston, Ft. Worth, San Antonio and San Angelo have even included a goat show as a part of their event. Showing goats has become so popular that in 2001 there were a greater number of goats than lambs validated statewide for the purpose of showing at major livestock shows as 4-H and FFA projects. With this growing interest in showing goats, the carcass contests have become an important part of the shows. Carcass contests are designed to rank animals based on the cutability and palatability merits of their carcasses. This is an important educational part of the livestock shows because it gives producers and exhibitors valuable feedback on the type of product they are producing and showing.

Cutability is the primary determinant used in ranking goat carcasses. Because of this, it is important to have an equation that accurately determines the highest cutability goat carcasses. Smith and Carpenter (1973) reported that the predictive accuracy of cutability equations was reduced when applied to lamb carcasses with narrow ranges in fat thicknesses. Because carcasses

exhibited in contests typically have similar fat thicknesses, the development of an accurate prediction equation is necessary. Currently, the equation that is being used for the goat carcass contest is the lamb cutability equation. The current equation contains the following variables and coefficients:

Percent boneless, closely trimmed retail cuts = 49.936
-0.0848 (Hot carcass weight, lbs.)
-4.376 (Adjusted fat thickness, 12th rib, in)
-3.530 (Body wall thickness, in)
+2.456 (Ribeye area, in^2)

This equation, developed for the Houston Livestock Show and Rodeo (Houston Livestock Show and Rodeo, 2002), pertains to commercial, market-type lambs, which tend to be lighter muscled and fatter than show animals. Due to cutability differences between commercial lambs and the lean, muscular show goats and lambs, there has been concern that this equation is inaccurate when determining the cutability of show lambs and goats. Given the increasing popularity of show goats, it is essential that a cutability equation suitable for goat carcass contests be developed. The objective of this project was to determine the cutability characteristics of show goats and develop a new cutability prediction equation that could be used in future goat carcass contests.

Materials and Methods

Twenty-two goats were selected randomly from the Houston and San Angelo goat show class winners. They were slaughtered using typical industry practices at the Rosenthal Meat Science and Technology Center at Texas A&M University. After carcasses were chilled for 24 h, yield and quality grade data were collected by trained Texas A&M University personnel. Carcasses were split between the 12^{th} and 13^{th} ribs and the following measurements were collected on the cut lean surface: actual fat thickness, body wall thickness, and ribeye area.

Fabrication

Initial carcass weights were recorded before fabrication. Carcasses were split into fore- and hind-saddles and weights were recorded. Foresaddles were fabricated into boneless, square cut shoulders, and 8-rib racks (1 in X 1 in). Shoulders were separated from racks between the 4^{th} and 5^{th} ribs. Breast and foreshank were removed by a cut across the cartilaginous juncture of the first rib that was perpendicular to the shoulder-rack separation. All bones were removed, and 1 in of neck was left on. Racks were chined, and the blade bone, feather bones, and *ligamentum nuchae* were removed. Hindsaddles were fabricated into 1-rib loins (1 in X 1 in), bone-in sirloins, and semi-boneless, short-cut, shank-off legs. Loins were removed from sirloins between the last two lumbar vertebrae. Sirloins were separated from legs by a cut 0.5 in cranial to the lobe of the aitch bone. Flank muscles were removed from sirloins. Legs had the aitch and caudal bones removed, and the shank was removed at the stifle joint. All primal were trimmed to 0.1 in and weights were recorded.

Statistical analysis

Data were analyzed using the Statistical Analysis System (SAS Institute, Cary, NC). Percent semi-boneless cuts from the leg, sirloin, loin, rack, and shoulder was used as the dependent variable. Simple statistics and correlation coefficients were calculated using the CORR procedure. The RSQUARE procedure was used to determine the best 1-variable, 2-variable, 3-variable, 4-variable, and 5-variable equations (n = 22) from the following independent variables: hot carcass weight, fat thickness, body wall thickness, ribeye area, dressing percentage. The best equation was selected and the REG procedure was run to determine the intercept and coefficients for each of the variables (n = 22). The selected equation and the existing equation (i.e., Houston Livestock Show and Rodeo, 2002) were validated using the REG procedure and a random selection of half of the goats (n = 11) in the original data set, with percent semi-boneless, closely trimmed primals (leg, sirloin, loin, rack, and shoulder) as the independent variable.

Results and Discussion

Table 1 shows the means, standard deviations, minimum, and maximum values for goat carcass characteristics. Table 2 shows the simple correlation coefficients of goat carcass traits. Percent semi-boneless, closely trimmed primals from the leg, sirloin, loin, rack, and shoulder (SBTP) was highly correlated to all of the weight measurement (live weight, hot carcass weight, total lean weight, foresaddle weight, and hindsaddle weight). SBTP also was highly correlated to fat thickness and body wall thickness. Ribeye area and dressing percentage were moderately correlated to percent SBTP. Table 3 shows the best one-, two-, three-, four-, and five-variable equations, respectively. We selected the three-variable equation because it had an equally high R^2 value as the other multi-variable equations and it reflected the traits we expect have the greatest impact on cutability. Although there was no additional increase in the R^2 from the two-variable equation, we felt it was important to include some measure of fatness in the equation. Linear regression of these variables resulted in the following equation:

$$\begin{aligned} \%\ \text{SBTP} = {} & 0.69330 \\ & -0.23174\ (\text{Hot carcass weight, lb}) \\ & +1.96202\ (\text{Ribeye area, in}^2) \\ & -1.57832\ (\text{Body wall thickness, in}) \end{aligned}$$

This equation was validated against the HLSR equation using a subset of goats (n = 11) from the original data set. Regression analysis using percent SBTP as the independent variable and the three-variable equation as the dependent variable resulted in an R^2 value of 0.83. In comparison, the HLSR equation had an R^2 value of 0.74.

Implications

While the current equation used to predict cutability of goat carcasses appears to be acceptable, the proposed three-variable equation using hot carcass weight, ribeye area, and body wall thickness should be incorporated into carcass shows as soon as possible.

Table 1. Means, standard deviations, minimum and maximum values for goat carcass characteristics

Variable	Mean	SD	Minimum	Maximum
Live weight, lb	101.8	16.03	73	133
Hot carcass weight, lb	50.0	9.2	34.2	67.4
Foresaddle weight, lb	27.2	5.36	18.7	37.4
Hindsaddle weight, lb	22.8	3.92	15.5	30
Dressing percentage, %	49.0	2.59	44.4	54.0
Total lean weight, lb	26.0	3.87	19.2	32.7
Fat thickness, in	0.15	0.04	0.08	0.22
Ribeye area, in^2	2.35	0.29	1.75	2.9
Yield grade	1.9	0.43	1.2	2.6
Body wall thickness, in	0.83	0.14	0.6	1.1
%SBTP[a]	52.41	2.29	46.59	56.14

[a]SBTP is the percentage of semi-boneless, closely trimmed primals (leg, sirloin, loin, rack and shoulder).

Table 2. Simple correlation coefficients of goat carcass traits

Trait[a]	HCW	FS	HS	DP	TL	FT	REA	YG	BW	SBTP
LW	0.96	0.95	0.94	0.36	0.93	0.77	0.66	0.77	0.79	-0.82
HCW	—	0.99	0.99	0.60	0.98	0.77	0.72	0.77	0.85	-0.83
FS		—	0.97	0.59	0.96	0.79	0.72	0.79	0.83	-0.84
HS			—	0.60	0.98	0.74	0.70	0.74	0.86	-0.80
DP				--	0.61	0.40	0.54	0.40	0.57	-0.41
TL					—	0.74	0.74	0.74	0.81	-0.71
FT						—	0.43	1.00	0.83	-0.71
REA							—	0.43	0.49	-0.47
YG								—	0.83	-0.71
BW									—	-0.76
SBTP										—

[a]HCW = Hot carcass weight, FS = Foresaddle, HS = Hindsaddle, DP = Dressing percentage, TL = Total lean, FT = Fat thickness, REA = Ribeye area, YG = Yield grade, BW = Body wall thickness, SBTP = Percentage of semi-boneless, closely trimmed primals (leg, sirloin, loin, rack and shoulder).

Table 3. Best models for prediction of percentage semi-boneless, closely trimmed primals from goat carcasses

Number of variables in model	R-Square	C(p)	RMSE[b]	Variables in model[a]
1	0.69	0.73	1.31	HCW
2	0.73	0.54	1.26	HCW, REA
3	0.73	2.40	1.29	HCW, REA, BW
4	0.73	4.01	1.31	HCW, REA, BW, DP
5	0.73	6.00	1.35	HCW, REA, BW, DP, FT

[a]HCW = Hot carcass weight, REA = Ribeye area, BW = Body wall thickness, DP = Dressing percentage, FT = Fat thickness
[b]RMSE = Root mean square error

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Development of a cutability equation for carcasses of show lambs

T.E. Tschirhart, L.A. Rakowitz, D.R. McKenna, D.B. Griffin, and J.W. Savell

ABSTRACT: Lambs (n = 20) were selected from various livestock shows throughout the state of Texas and slaughtered at Texas A&M University. Standard carcass data were collected, and then carcasses were fabricated into semi-boneless, closely trimmed (0.1 in) primals (SBTP). Data were analyzed to develop the best one-, two-, three-, four-, five-, and six-variable equations, respectively, for predicting percent SBTP. The two-variable equation, which contained ribeye area and body wall thickness as variables, was selected as the best overall equation with an $R^2 = 0.13$. The two-variable equation was tested against the existing Houston Livestock Show and Rodeo (HLSR) equation. Analysis revealed an $R^2 = 0.50$ for the two-variable equation and an $R^2 = 0.20$ for the HLSR equation. This indicates that the two-variable equation did a better job of predicting lamb carcass cutability than the equation currently being used.

Key Words: Lamb, Meat, Carcass Evaluation, Carcass Composition

Sheep and Goat, Wool and Mohair CPR 2002. 31-35

Introduction

Every year thousands of lambs are validated and shown by 4-H and FFA exhibitors in major regional and local livestock shows across the state of Texas. An important part of these shows are the carcass contests. Carcass contests are designed to rank animals based on the cutability and palatability merits of their carcasses. The carcass contests are a fundamental educational tool of the livestock shows because they give producers and exhibitors valuable feed back on the type of product they are producing and showing. Minimum levels of quality are required to retain eligibility in carcass contests, however, quality assessments are not sufficient to stratify all of the carcasses. Therefore, cutability plays a vital role in determining the final rankings of lamb carcass contests. Because of this, it is important to have an equation that accurately predicts the highest cutability lamb carcasses.

In 1992, USDA yield grade standards were revised to reflect a need for the lamb industry to produce a leaner product (USDA, 1992). The revision required the removal of kidney and pelvic fat before grading and the elimination of leg conformation as a yield grade factor. These changes left adjusted fat thickness as the only determinant of yield grade in the USDA (1992) yield grade equation:

$$\text{USDA Yield Grade} = (10 \times \text{Adjusted Fat Thickness}) + (0.4)$$

The new, simpler equation made it difficult to sort homogeneous groups of lamb carcasses, such as those found in carcass shows, on cutability differences. Research conducted by Smith and

Carpenter (1973) showed that when groups of lambs have little variation in fat thickness other muscling or fatness measures are required to accurately predict cutability differences.

To enable more effective and accurate rankings of lambs in carcass contests, an unofficial inquiry by the Houston Livestock Show and Rodeo (HLSR) was addressed to Texas A&M University to develop a prediction equation for lamb carcass cutability on a kidney-fat-out basis. The following equation, called the HLSR equation (Houston Livestock Show and Rodeo, 2002), was developed using cut-out data from 216 lambs from range producers and auction barns:

Percent boneless, closely trimmed retails cuts = 49.936
-0.0848 (Hot carcass weight, lb)
-4.376 (Adjusted fat thickness, 12th Rib, in)
-3.530 (Body wall thickness, in)
+2.456 (Ribeye area, in^2)

The HLSR equation has been used as the cutability equation for lamb carcass contests in every major livestock show in Texas since its development in 1992.

One of the limitations of the HLSR equation is that it was developed from the cut-out data of commercial, market type lambs, which tend to be fatter, lighter muscled, and contain a greater range of variation than what is found in show lambs. The wide range of variation that exists in the commercial lamb population is not representative of the narrow range of variation that is found in the show lamb population. Because of the cutability differences between commercial lambs and the lean muscular show lambs, there has been concern that the HLSR equation is less precise when determining the cutabilty of show lambs.

Given the popularity of show lambs and their importance to livestock shows, it is essential that the HLSR equation be verified as accurate or a new lamb cutability prediction equation be developed for use in lamb carcass contests. The objectives of this study were to test the accuracy of the HLSR cutability equation on carcasses of show lambs and to develop a new prediction equation better suited to evaluate narrow range differences seen in the show lamb population.

Materials and Methods

Twenty lambs were selected randomly from various livestock shows in the state of Texas. Lambs were slaughtered using typical industry practices at the Rosenthal Meat Science and Technology Center at Texas A&M University. After carcasses were chilled for 24 hr, yield and quality grade data were collected by trained Texas A&M University personnel. Carcasses were ribbed between the 12th and 13th ribs and the following measurements were collected on the cut surface: actual and adjusted fat thickness, body wall thickness, and ribeye area. Other factors recorded on each carcass were leg and overall conformation scores, maturity scores, flank streakings, and lean color.

Fabrication

Initial carcass weights were recorded before fabrication. Carcasses were split into fore- and hind-saddles and weights were recorded. Foresaddles were fabricated into boneless, square cut shoulders, and 8-rib racks (1 in X 1 in). Shoulders were separated from racks between the 4th and 5th ribs. Breast and foreshank were removed by a cut across the cartilaginous juncture of the first rib that was perpendicular to the shoulder-rack separation. All bones were removed, and 1 in of

neck was left on. Racks were chined, and the blade bone, feather bones, and *ligamentum nuchae* were removed. Hindsaddles were fabricated into 1-rib loins (1 in X 1 in), bone-in sirloins, and semi-boneless, short-cut, shank-off legs. Loins were removed from sirloins between the last two lumbar vertebrae. Sirloins were separated from legs by a cut 0.5 in cranial to the lobe of the aitch bone. Flank muscles were removed from sirloins. Legs had the aitch and caudal bones removed, and the shank was removed at the stifle joint. All primals were trimmed to 0.1 in and weights were recorded.

Statistical analysis

Data were analyzed using the Statistical Analysis System (SAS Institute, Cary, NC). Percent semi-boneless, closely trimmed primals was used as the dependent variable. Simple statistics and correlation coefficients were calculated using the CORR procedure. The RSQUARE procedure was used to determine the best one-, two-, three-, four-, five-, and six-variable equations (n = 20) from the following independent variables: hot carcass weight, fat thickness, body wall thickness, ribeye area, dressing percentage, quality grade. The best equation was selected and the REG procedure was run to determine the intercept and coefficients for each of the variables (n = 20). The selected equation and the existing equation (Houston Livestock Show and Rodeo, 2002) were validated using the REG procedure and a random selection of half of the lambs (n = 10) in the original data set, with percent semi-boneless, closely trimmed primals as the independent variable.

Results and Discussion

Table 1 shows the means, standard deviations, minimum, and maximum values for lamb carcass characteristics. As expected, there was a narrow range in variation in characteristics for adjusted fat thickness (0.03 - 0.25 in), body wall thickness (0.30 - 0.85 in), and ribeye area (2.2 - 3.9 in^2). Simple correlation coefficients for lamb carcass traits are shown in Table 2. Total lean, and body wall thickness were moderately correlated to percent SBTP. Table 3 shows the best one-, two-, three-, four-, five-, and six-variable equations, respectively. We selected the two-variable equation for further analysis because it had one of the highest R^2 values and low RMSE. Additionally, we did not feel the minuscule increase in R^2 values justified the inclusion of the other variables. Linear regression of these variables resulted in the following equation:

$$\% \text{ SBTP} = 49.729 + 5.473(\text{Body wall thickness, in}) + 0.972(\text{Ribeye area, in}^2)$$

This equation was validated against the HLSR equation using a subset of lambs (n = 10) from the original data set. Regression analysis using percent SBTP as the independent variable and the two-variable equation as the dependent variable resulted in an R^2 value of 0.50. In comparison, the HLSR equation had an R^2 value of 0.20.

Table 1. Means, standard deviations, minimum and maximum values for lamb carcass characteristics

Variable	Mean	SD	Minimum	Maximum
Live weight, lb	122.6	10.6	103.0	143.0
Carcass weight, lb	68.2	6.0	56.8	79.2
Foresaddle weight, lb	35.0	3.3	29.5	41.0
Hindsaddle weight, lb	33.2	2.9	27.2	38.2
Dressing percentage, %	55.7	1.88	52.1	58.6
Quality grade[b]	11.4	0.88	10.0	13.0
Adjusted fat thickness, in	0.13	0.06	0.03	0.25
Ribeye area, in^2	3.28	0.36	2.2	3.9
Body wall thickness, in	0.62	0.12	0.30	0.85
USDA yield grade	1.77	0.59	0.70	2.9
Total lean, lb	38.42	3.79	31.45	44.65
%SBTP[a]	56.28	1.91	52.86	59.34

[a]SBTP is the percentage of semi-boneless, closely trimmed primals (leg, sirloin, loin, rack, and shoulder).
[b]USDA quality grade: 10 = Choice$^-$, 11 = Choice°, 12 = Choice$^+$, 13 = Prime$^-$

Table 2. Simple correlation coefficients of lamb carcass traits

Trait[a]	HCW	FS	HS	DP	TL	AFT	REA	YG	BW	SBTP
LW	0.92	0.92	0.88	-0.12	0.87	-0.31	0.66	-0.31	0.22	0.15
HCW	—	0.98	0.98	0.28	0.94	-0.43	0.69	-0.43	0.11	0.13
FS		—	0.93	0.23	0.91	-0.39	0.65	-0.39	0.09	0.08
HS			—	0.32	0.94	-0.47	0.70	-0.47	0.12	0.19
DP				—	0.23	-0.33	0.11	-0.33	0.26	-0.05
TL					—	-0.36	0.64	-0.36	0.21	0.46
AFT						—	-0.59	1.00	0.51	0.09
REA							—	-0.59	-0.22	0.11
YG								—	0.51	0.09
BW									—	0.31
SBTP										—

[a]HCW = Hot carcass weight, FS = Foresaddle weight, HS = Hindsaddle weight, DP = Dressing percentage, TL = Total lean, AFT = Adjusted fat thickness, REA = Ribeye area, YG = Yield grade, BW = Body wall thickness, SBTP = Percentage of semi-boneless, closely trimmed primals (leg, sirloin, loin, rack, and shoulder).

Table 3. Best models for prediction of percentage semi-boneless, closely trimmed cuts from lamb carcasses

Number of variables in model	R-Square	C (p)	RMSE[b]	Variables in model[a]
1	0.10	-2.37	1.86	BW
2	0.13	-0.86	1.88	BW, REA
3	0.13	1.10	1.94	BW, REA, QG
4	0.14	3.03	2.00	BW, REA, QG, HCW
5	0.14	5.00	2.06	BW, REA, QG, HCW, DP
6	0.14	7.00	2.14	BW, REA, QG, HCW, DP, AFT

[a]BW = Body wall thickness, REA = Ribeye area, QG = USDA quality grade, Hot carcass weight, DP = Dressing percentage, AFT = Adjusted fat thickness.
[b]RMSE = Root mean square error.

Implications

The results indicate that the HLSR equation was less accurate in determining lamb cutability when used on carcasses of show lambs. This equation should be adopted as a better predictor of the composition of carcasses that are both lean and muscular. However, further research needs to be conducted to strengthen our understanding of the cutability determinants of show lambs.

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Oxidative storage stability of Rambouillet lamb leg-meat patties as affected by animal production system

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ABSTRACT: Rambouillet lambs were assigned to three production systems varying in physical environment and diet: RF (an open-sided barn with raised/slatted floor designed to produce high-value wool, with animals fed an oat hay (85%)-barley-molasses mixture); FL (a feedlot, with animals fed typical step-up/high-concentrate rations); and P (a pasture, with animals given access to the pasture and a high-concentrate supplement). Times-on-feed were aimed at attaining similar final shorn weights and carcass weights for the three systems. Ground meat patties were made with knife-separable lean from hind legs and aerobically refrigerated as raw or cooked patties. Raw meat fat content was not significantly different between RF and FL or P, while total saturated fatty acid percentage was slightly higher ($P < 0.05$) with RF. The color of refrigerated raw patties was most stable with RF. Similarly, lipid oxidation (as measured by 2-thiobarbituric acid-reactive substances) in raw patties was lower with RF than FL, but oxidation in cooked patties was greater with RF.

Key Words: Lambs, Production Treatments, Fatty Acids, Color, Lipid Oxidation, Storage Stability

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Introduction

The fatty acid composition of meat is one of the major factors that determine product storage stability. Fatty acid profiles of ruminant tissues are less influenced by animal diet composition when compared to non-ruminant tissues, because rumen microbes can hydrogenate dietary unsaturated fatty acids. However, such ruminal hydrogenation apparently is not complete, as many studies have shown that diet composition can influence fatty acid profiles of ruminant tissues to various degrees (Marmer et al., 1984; Rhee et al., 1997, 2000; Rhee, 2000).

Lambs traditionally have been produced in a feedlot or on the pasture/range. As discussed in a companion paper (Rhee et al, 2002), a new indoor production management system was developed at Texas A&M University Agricultural Research and Extension Center at San Angelo to produce distinctly high-value wool. Animals were housed in an open-sided barn with raised/slatted floor and fed an oat hay-based ration that was lower in energy density than typical grain-based rations. What effect such indoor production management system may have on lamb meat storage traits has not been known. In the aforementioned companion paper, we reported on carcass traits and fatty acid profiles of intramuscular (*semimembranosus* muscle) fat and subcutaneous fat from Rambouillet and Merino x Rambouillet lambs produced with the new system vs. traditional production systems (feedlot and pasture). With diet composition modified for the new indoor production system, the current study has focused on evaluation of the production system effects on storage stability of ground leg-meat patties from Rambouillet lambs, in conjunction with fatty acid profiles.

Materials and Methods

Lamb Production

Lambs were raised in San Angelo. Rambouillet wethers at ~5 mo of age were assigned to three production systems which varied in physical environment and diet: an open-sided barn with raised/slatted floor designed to produce high-value wool, with animals fed a pelleted mixture of oat hay (85%), barley (7.5%) and molasses (7.5%) (production system designated as RF); a feedlot, with animals fed typical step-up/high-concentrate rations (production system designated as FL); and a pasture, with animals given access to the pasture and a supplement (production system designated as P). The compositions of the diets for FL lambs and the supplements given to the P lambs are shown in Table 1. The composition of the diet for the RF lambs in this study differed from that in the previous study (Rhee et al., 2002) – 7.5% barley and 7.5% molasses, rather than 10% wheat and 5% molasses. Changes were made to slow the rate of weight gain (compared to the previous study) so that wool longer than 3.75 inches could be produced before the RF lambs attained the target slaughter (final shorn) weight (130 lb).

Table 1. Percentages of ingredients in the feedlot diets and pasture supplements

Production treatment	**Diet (time fed, wk)**		
FL	Diet #1 (1)	Diet #2 (14)	
P	Diet #1 (1)	Diet #2 (3)	Diet #3 (15.5)
Diet ingredient	**Ingredient percentage**		
Sorghum grain (milo)	65.50	67.75	60.00
Dehydrated alfalfa meal, 17%	10.00	5.00	10.00
Cottonseed hulls	10.00	10.00	0
Cottonseed meal, 41%	10.00	12.00	10.00
Soybean meal, 47.5%	0	0	10.00
Molasses	3.00	3.00	4.00
Urea	0	0.50	0.50
Ammonium chloride	0.50	0.50	0
Calcium carbonate	0.50	1.00	0
Monodicalcium phosphate	0	0	1.00
Vitamin-mineral-antibiotic pre-mix	0.50	0.50	0.25
Salt, mixing	0	0	4.00

As with the previous study, days to slaughter (or treatment duration) were aimed at 130 lb (58.97 kg) shorn final weight with 65 lb (29.48 kg) carcass weight for each production treatment. Lambs were slaughtered in San Angelo. *Semimembranosus* muscle samples and hind legs were removed (~24 h postmortem) from 9 carcasses per production treatment, double-bagged in Ziploc® freezer bags (for muscle samples) or large heavy-duty plastic bags (for legs), and frozen. The muscle samples and legs were transported frozen to College Station. Upon receiving, they were individually vacuum-packaged, and kept at -20°C until analysis or processing.

Processing and Storage of Leg-Meat Patties

Three batches of ground meat were prepared with the legs (3 legs/batch) to conduct the study in three replications. The vacuum-packaged frozen legs were thawed for 2 d at 4°C without breaking the vacuum seal before dissection. Bones and all knife-separable fat and connective tissue were removed. Then, the lean pieces were combined according to the replication/treatment group, ground twice (through a 1.27-cm plate, followed by a 0.32-cm plate), and formed into 115-g patties. One-half of the patties from each group were cooked in a preheated electric skillet set at 164°C (two patties at a time; 5 min on one side and 9 min on the other side) to an internal temperature of ~74°C and cooled on stainless steel racks for 15 min before weighing or packaging. Raw and cooked patties were placed on polyfoam trays (two patties/tray), over-wrapped with oxygen-permeable polyvinyl chloride film [O_2 transmission rate = 2,325 $cm^3/mil/m^2/24$ h at 25°C; film thickness in the British unit (mil) as provided by the supplier = 0.5 mil (=12.7 μm)], and stored at 4°C for 0, 3 or 6 d.

Analytical Methods

Moisture was analyzed by the AOAC (1990) oven-drying procedure. Total lipids were extracted by the procedure of Folch et al. (1957). Total fat content was determined on aliquots of lipid extracts after solvent removal. To determine fatty acid composition, aliquots of lipid extracts were freed of solvent under a nitrogen stream and transmethylated using tetramethylammonium hydroxide in methanol (Metcalfe and Wang, 1981). Fatty acid methyl esters were analyzed by gas chromatography (Rhee et al., 1988). Results for each fatty acid were expressed as a percentage of the sum of the peak areas of all identified fatty acids.

Red color (a*) values of raw meat patties were measured using a Minolta Chroma Meter CR-300 equipped with a DP-301 data processor (Minolta, Inc., Japan). The chromameter was standardized with a white tile (a*=-0.23). Measurement was made perpendicular to the patty surface, on four different locations per patty.

Lipid oxidation in raw or cooked meat patties was assessed by measuring 2-thiobarbituric acid-reactive substances (TBARS). A modified distillation TBARS procedure (Rhee, 1978) was used; a propyl gallate-EDTA solution was added at the sample blending step to minimize potential further lipid oxidation during analysis and the TBA reagent was prepared with no acid. Each patty was analyzed in duplicate (2 distillations/patty). Results were expressed as mg malonaldehyde equivalents/kg meat sample.

Statistical Analysis

The Statistical Analysis System software (SAS 1997) was used to perform data analysis. A mixed model (PROC MIXED) was used, with the following treated as a random effect: animal for carcass data and fatty acid data on *semimembranosus* muscle from each animal, and raw meat batch

for data on ground leg-meat patties. Means were computed by LSMEANS, with pairwise comparisons obtained by the PDIFF option. PROC CORR was used to determine correlations between variables. Significance was established at $P < 0.05$ unless otherwise indicated.

Results and Discussion

Animal and carcass data are shown in Table 2. Initial weights of lambs averaged ~82 lb [vs. ~76 lb in the previous study (Rhee et al., 2002)], with no significant difference among treatments. Likewise, final shorn weights of lambs and carcass weights were similar ($P > 0.05$) for the three treatments as planned; to attain the targets, the RF lambs had to be fed for the longest period and FL lambs for the shortest. The length of time RF lambs were fed reflects changes in the RF-lamb diet previously discussed. The reason for a shorter time for the P lambs (compared to >200 d in the previous study) to reach the targets could be that a very high proportion of the diet consumed by the P lambs consisted of the high-concentrate "supplement" supplied to them because even less vegetation was produced in the pasture during the treatment period in this study due to a worse drought. The RF lambs were lower in dressing percentage than the P and FL lambs, indicating that the RF lambs might have had greater gut fill than the lambs of the other two treatments. This confirmed our previous observation (Rhee et al., 2002). Backfat thickness and body wall thickness were less with RF than P and FL treatments, but USDA yield grade was similar for all treatments.

Table 2. Production treatment effects on carcass traits for lambs used in this study

	Initial weight (lb)	Shorn final weight (lb)	Days to slaughter	Hot carcass weight (lb)	Dressing percentage	Backfat thickness (in)	Body wall thickness (in)	USDA yield grade
Treatment								
P	81.8[a]	129.6[a]	137[b]	68.04[a]	52.52[a]	0.23[a]	1.24[a]	2.4[a]
FL	80.8[a]	128.1[a]	108[c]	67.66[a]	52.82[a]	0.29[a]	1.31[a]	2.2[a]
RF	82.1[a]	133.1[a]	167[a]	61.93[a]	46.52[b]	0.17[b]	1.03[b]	2.0[a]

[a,b,c]Means in the same column which are not followed by a common superscript letter are different ($P < 0.05$).

Fatty acid compositions of lamb diets are shown in Table 3. The changes made in this study for RF-lamb diet (85% oat hay-7.5% barley-7.5% molasses vs. 85% oat hay-10% wheat-5% molasses in the previous study) apparently decreased the total PUFA percentage (~44% vs. ~61%) and increased the total MUFA percentage (~30% vs. ~11%). The ingredients/compositions of the principal FL-lamb diet and P-lamb supplement were not notably different between the two studies. Accordingly, fatty acid profiles of the FL diet and P supplement in this study were similar to those of the previous study.

Table 3. Fatty acid compositions (%) of the supplement for P lambs and diet for FL and RF lambs

Fatty acids	P supplement (Diet #3, Table 1)	FL diet (Diet #2, Table 1)	RF diet
12:0	0.04	0.02	0.34
14:0	0.17	0.22	0.54
15:0	0.05	0.02	0.18
16:0	16.00	16.83	21.00
16:1	0.59	0.56	0.30
17:0	0.10	0.10	0.18
17:1	0	0	0.04
18:0	1.93	1.84	2.62
18:1	27.84	29.38	28.96
18:2	49.53	48.22	36.10
18:3	2.31	2.13	7.64
20:0	0.19	0.22	0.44
20:1	0.27	0.14	0.25
22:0	0	0.08	0.52
22:1	0.34	0.04	0.62
23:0	0.63	0.15	0.04
24:0	0	0.06	0.24
Total SFA	19.11	19.53	26.09
Total UFA	80.89	80.47	73.91
Total MUFA	29.05	30.12	30.18
Total PUFA	51.84	50.35	43.74
UFA/SFA	4.23	4.12	2.86
MUFA/SFA	1.52	1.54	1.17
PUFA/SFA	2.71	2.58	1.69

The total (extracted) fat content of the leg-meat patties was higher for FL than for P, with no significant difference found between RF and P and between RF and FL (Table 4). Cooking yields were higher for RF and P patties than for FL patties.

Fatty acid profiles of the intramuscular (IM) fat, the fat extracted from *semimembranosus* muscle, are presented in Table 5. IM fat from the RF lambs was higher in total saturated fatty acids (SFA) and lower in total polyunsaturated fatty acids (PUFA) than that from the P or FL lambs, as was in our previous study (Rhee et al., 2002). However, there were some notable differences between the two studies. Percentages of total monounsaturated acids (MUFA) and the 18:1 acid (the predominant monounsaturated fatty acid) were not significantly different among the treatments in the current study, while they were lower with P than FL and RF treatments in the previous

Table 4. Fat percentages of raw patties and cooking yields

	Treatment					
	P		FL		RF	
	Mean	SD*	Mean	SD	Mean	SD
Raw patty fat (%)	3.41[bc]	0.59	4.14[a]	0.65	3.85[ab]	0.36
Cooking yield (%)	73.97[a]	2.13	72.46[b]	2.47	74.06[a]	2.03

*SD = Standard deviation.
[a,b]Means within the same row which are not followed by a common superscript letter are different ($P < 0.05$).

Table 5. Production treatment effects on fatty acid compositions (%) of intramuscular fat

Fatty acid	Production treatment					
	P		FL		RF	
	Mean	SD*	Mean	SD	Mean	SD
14:0	2.01[a]	0.25	1.99[a]	0.29	1.85[a]	0.34
15:0	0.36[b]	0.05	0.47[a]	0.08	0.31[b]	0.05
16:0	23.34[b]	1.26	23.89[b]	1.18	24.69[a]	1.73
16:1	1.97[a]	0.25	1.92[a]	0.31	1.35[b]	0.11
17:0	1.38[b]	0.18	1.92[a]	0.50	1.10[b]	0.19
17:1	1.12[b]	0.14	1.49[a]	0.38	0.54[c]	0.26
18:0	12.45[b]	1.43	11.89[b]	0.79	15.91[a]	0.91
18:1	44.59[a]	2.31	44.43[a]	1.47	44.70[a]	1.87
18:2	8.52[a]	1.59	8.37[a]	1.34	6.30[b]	0.35
18:3	0.41[b]	0.10	0.30[c]	0.11	0.76[a]	0.15
20:3	0.21[a]	0.03	0.20[a]	0.05	0.17[b]	0.02
20:4	3.34[a]	0.71	2.91[a]	0.50	2.00[b]	0.25
24:0	0.30[a]	0.09	0.22[b]	0.09	0.32[a]	0.05
Total SFA	39.84[b]	1.53	40.38[b]	1.55	44.18[a]	1.96
Total UFA	60.16[a]	1.53	59.63[a]	1.55	55.82[b]	1.96
Total MUFA	47.68[a]	2.34	47.85[a]	1.32	46.59[a]	1.73
Total PUFA	12.48[a]	2.31	11.77[a]	1.84	9.23[b]	0.56
UFA/SFA	1.51[a]	0.10	1.48[a]	0.09	1.27[b]	0.10
MUFA/SFA	1.20[a]	0.09	1.19[a]	0.06	1.05[b]	0.09
PUFA/SFA	0.31[a]	0.06	0.29[a]	0.05	0.21[b]	0.02

*SD = Standard deviation.
[a,b,c]Means within the row which are not followed by a common superscript letter are different ($P < 0.05$).

study. Additionally, the PUFA percentage differences between RF and P or FL in this study (at least 26% less in RF samples than in P and FL samples) were not as large as those observed in the previous study (more than 45% less in RF samples).

The production treatment effects on fatty acid composition of raw leg-meat patties are shown in Table 6. The trends, or relative differences among treatments, in total SFA (and UFA) percentages - thus UFA/SFA ratio - for leg-meat patties were similar to those of IM fat, i.e., a higher fatty acid saturation with RF than the other treatments. However, there were minor differences in MUFA and PUFA percentages between IM fat and the fat extracted from leg-meat patties (Table 6 vs. Table 5): FL > RF in patties vs. no significant treatment effect in IM fat for the

Table 6. Production treatment effects on fatty acid composition (%) of raw leg-meat patties

Fatty acid	Production Treatment					
	P		FL		RF	
	Mean	SD*	Mean	SD	Mean	SD
14:0	2.29^{ab}	0.07	2.43^{a}	0.25	2.04^{b}	0.17
15:0	0.42^{b}	0.02	0.56^{a}	0.01	0.39^{b}	0.03
16:0	23.51^{a}	0.24	23.71^{a}	0.69	23.86^{a}	1.05
16:1	2.10^{a}	0.07	2.33^{a}	0.25	1.45^{b}	0.15
17:0	1.41^{b}	0.08	1.92^{a}	0.20	1.21^{b}	0.05
17:1	1.17^{b}	0.09	1.53^{a}	0.22	0.76^{c}	0.05
18:0	13.22^{b}	0.43	11.81^{c}	0.80	16.43^{a}	0.62
18:1	44.70^{a}	0.96	45.62^{a}	1.40	44.19^{a}	1.51
18:2	7.71^{a}	0.61	7.13^{ab}	0.56	6.50^{b}	0.15
18:3	0.44^{b}	0.16	0.44^{b}	0.06	0.92^{a}	0.21
20:3	0.16^{a}	0.02	0.17^{a}	0.03	0.16^{a}	0.02
20:4	2.62^{a}	0.27	2.06^{b}	0.16	1.76^{b}	0.09
24:0	0.26^{a}	0.08	0.20^{a}	0.01	0.32^{a}	0.06
SFA	41.11^{b}	0.23	40.64^{b}	1.10	44.25^{a}	1.49
UFA	58.89^{a}	0.24	59.36^{a}	0.93	55.75^{b}	1.48
MUFA	47.96^{ab}	1.08	49.56^{a}	1.73	46.41^{b}	1.51
PUFA	10.93^{a}	1.03	9.80^{ab}	0.80	9.34^{b}	0.42
UFA/SFA	1.43^{a}	0.01	1.46^{a}	0.06	1.26^{b}	0.08
MUFA/SFA	1.17^{ab}	0.03	1.22^{a}	0.08	1.05^{b}	0.07
PUFA/SFA	0.27^{a}	0.03	0.24^{ab}	0.01	0.21^{b}	0.01

*SD = Standard deviation.

^{a,b,c} Means within the row which are not followed by a common superscript letter are different ($P < 0.05$).

MUFA percentage, and a smaller PUFA percentage difference between FL and RF in patties than in IM fat. As for individual fatty acids in patties, the most notable differences due to treatments were found in percentages of the 18:2 and 20:4 acids (the two major acids with more than one double bonds), which indicated P > RF and P > FL or RF, respectively, and the 18:0 acid (the second major saturated acid) showing RF > P or FL.

When raw patties were refrigerated aerobically, the meat color (redness) values initially were highest for RF patties (Figure 1). After 3 d of storage, both RF and P patties were redder than FL patties. After 6 d, color deterioration was extensive in all patties, with no significant redness differences observed among the three groups of patties. Results indicate that, during a normal course of ground meat storage/merchandizing at retail (i.e., aerobically-packaged ground meat placed in refrigerated display cases for no more than a few days), RF patties would likely remain redder than P and FL patties. This would be an important advantage for RF because color is the most influential factor when consumers judge the quality of fresh meat. Additionally, lipid oxidation during refrigerated storage of raw patties was lower in RF than FL patties (Figure 2). This may be explained in terms of the relationship between meat pigment oxidation and lipid oxidation. During aerobic refrigeration of raw meat, oxymyoglobin (responsible for the red color of fresh meat) is oxidized, producing hydrogen peroxide and metmyoglobin. The interaction of the oxidized pigment (metmyoglobin) and hydrogen peroxide forms ferrylmyoglobin radicals that can initiate or catalyze lipid oxidation. Such relationship between heme pigment and lipid oxidation has been previously reviewed or discussed (Rhee, 1988; Rhee et al., 1996). Since color degradation during the early part of storage was less in RF patties (Figure 1), the level of ferrylmyoglobin radicals should also have been lower in RF than FL patties. Additionally, RF patties had the lowest percentage of UFA (Table 6), the oxidizable fatty acid group. Then, why were P patties lower in lipid oxidation as compared to RF patties? The enhanced lipid stability of P patties were likely due to natural antioxidants contributed by pasture plants.

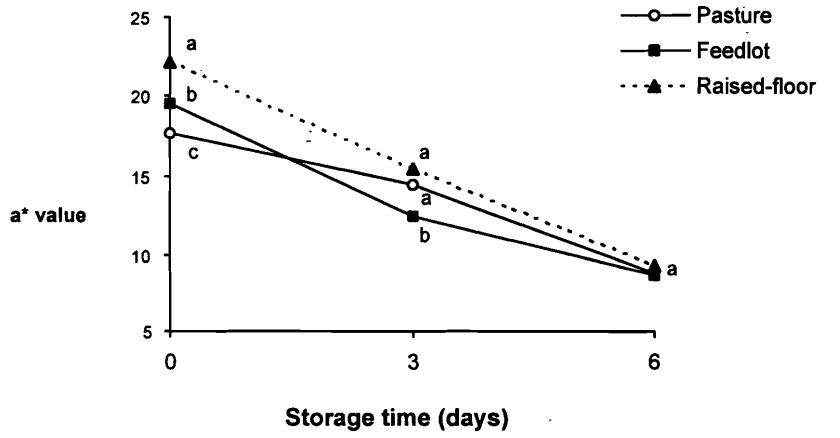

Figure 1. Production treatment effects on a* values (redness) of raw leg-meat patties aerobically stored at 4°C for 0, 3 or 6 d. Means within each storage time that do not bear a common letter are different ($P < 0.05$). Standard errors of the means: 0.99, 0.49 and 0.68 for 0, 3 and 6 d, respectively.

When cooked patties were refrigerated, more lipid oxidation occurred in RF patties than in P or FL patties (Figure 2). For lipid oxidation in cooked meat, the pigment oxidation is inconsequential because meat pigments, whether deoxymyoglobin, oxymyoglobin or metmyoglobin, are all denatured upon cooking and become denatured metmyoglobin. Since patties of all three treatments would have had the same meat pigment profile after cooking and the fat content of RF patties was similar to that of FL patties, some other factors apparently made

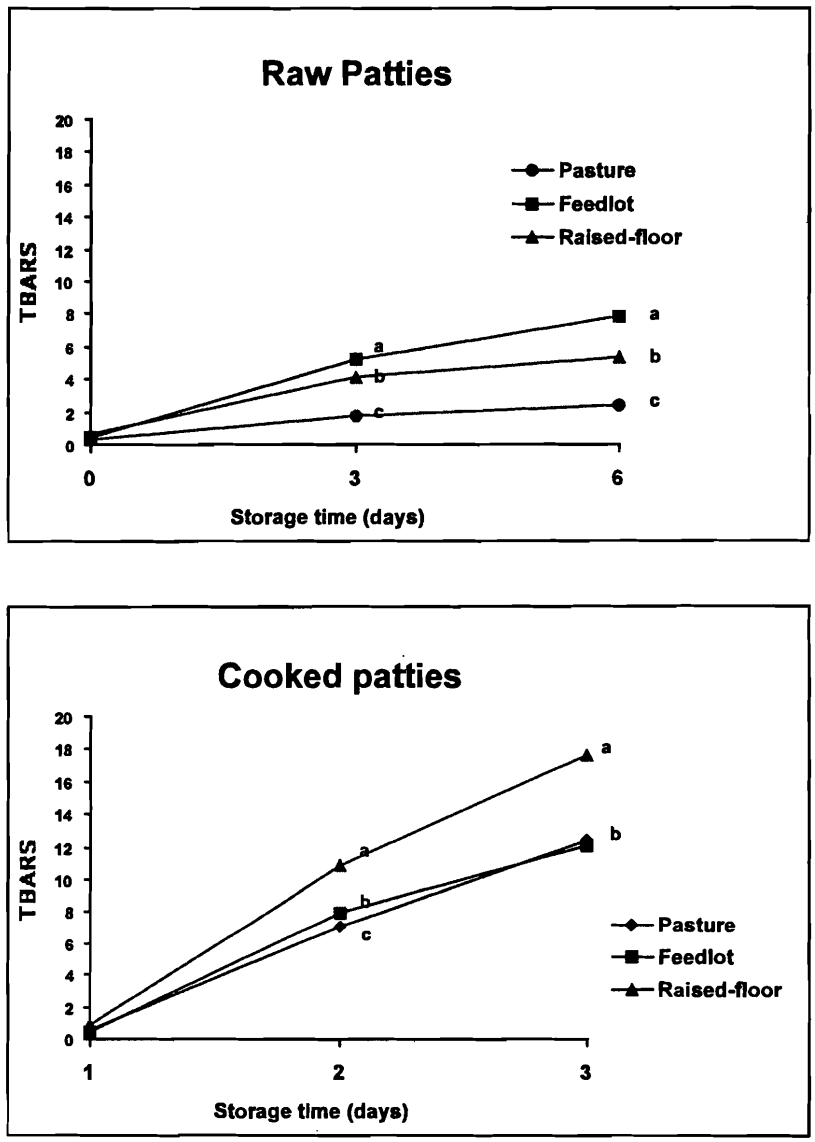

Figure 2. Production treatment effects on TBARS content (mg malonaldehyde equivalents/kg sample) of raw and cooked leg-meat patties aerobically stored at 4°C for 0, 3 or 6 d. Means within each storage day in the same graph that do not bear a common letter are different ($P < 0.05$). Standard errors of the means: 0.06, 0.42, and 0.68 for 0, 3 and 6 d, respectively, for raw patties; 0.05, 1.23, and 0.47 for 0, 3 and 6 d, respectively, for cooked patties.

RF patties more susceptible to lipid oxidation after cooking. Whether cooking might have destroyed unidentified antioxidative factors present in the RF meat is not known.

Implication

Overall, the raised-floor production management system, as refined in the current study, resulted in meat with desirable quality traits. Specifically, results indicated that this new production system could produce lean lamb meat with enhanced color and lipid stability during raw meat handling and storage.

Acknowledgment

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Production system/diet effects on carcass traits of Rambouillet and Merino x Rambouillet lambs and fatty acid profiles of their muscle and subcutaneous adipose tissues

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ABSTRACT: A new sheep production system was compared to traditional production systems for carcass traits and fatty acid profiles of intramuscular (IM) and subcutaneous (SC) fat. Rambouillet and Merino x Rambouillet lambs were assigned to three production systems varying in physical environment and diet: RF (open-sided barn with raised floor/oat hay-based diet); FL (feedlot/high-concentrate diet); P (pasture/grazing with high-concentrate supplement). Although the times-on-feed (or treatment periods) were aimed at 130 lb (59 kg) shorn final weight with 65 lb (29.5 kg) carcass weight, RF lambs were heavier than P lambs. However, dressing percentages were similar for RF and P lambs. Backfat thickness and body wall thickness were greater for RF and FL lambs than P lambs, and greater for Rambouillet lambs than Merino x Rambouillet lambs. Pasture plant samples were much higher in total saturated fatty acids (SFA) percentage compared to the feeds for FL and RF lambs and the supplement given to P lambs. Among the feeds/supplement, RF-lamb feed had a higher SFA percentage. For each breed type, the IM fat of RF lambs contained slightly more SFA (3 - 12%, or 0.03 - 0.12 fold, more) and markedly less polyunsaturated fatty acids (PUFA) - at least 45%, or 0.45 fold, less - than that of FL and P lambs. In SC fat, SFA content as well as PUFA content only tended to be higher (significantly or only numerically) with RF than other treatments. Relatively small SFA content differences among the lambs may be of little practical significance relative to human nutrition. However, lean meat from RF lambs is likely to be more stable toward oxidative quality deterioration than the FL and P lamb counterparts due to the large differences in PUFA content. Fatty acid compositions of P lamb tissues were more related to that of the supplement, which the P lambs consumed in large amounts, than to those of the pasture plants that were not adequately available during the feeding trial due to drought.

Key Words: Lambs, Production Treatments, Fatty Acids, Intramuscular Fat, Subcutaneous Fat

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Introduction

Lambs and goats traditionally have been produced in a feedlot or on the pasture/range. In an attempt to profitably produce exceptionally high quality fibers from lambs and goats, a special feeding facility was recently constructed at Texas A&M University Agricultural Research and Extension Center at San Angelo. The main feature of the covered facility with open sides was a raised/slatted wooden floor – slatted to release fecal material and urine, and raised (constructed 3.5 ft above ground) to facilitate removal of manure and provide adequate ventilation. Feeding and

watering systems were so designed that all animals would have adequate access to feed and water without contaminating them with fecal material or urine, and the labor requirement would be low. Animals on such raised/slatted floor were to be fed rations based on harvested material (such as oat hay). The objective of this study was to compare the new (raised-floor) system to traditional production systems for effects on carcass properties and fatty acid profiles of intramuscular (IM) or subcutaneous (SC) fat. The fatty acid composition of muscle foods is a primary factor that determines their shelf-life/storage stability and flavor. It also is a diet/health issue to consumers.

Materials and Methods

Lambs were raised in San Angelo, Texas. Rambouillet (R) and Merino x Rambouillet (M x R) lambs (wethers, about 4 mo of age) were first placed on a uniformity diet (Diet #1 in Table 1) for three weeks. Subsequently, the lambs (a total of 120; 20 lambs/breed type/treatment) were assigned to three production treatments which varied in physical environment and diet: an open-sided barn with raised/slatted floor designed to produce high-value wool, with animals fed an oat hay (85%)-wheat (10%)-molasses (5%) mixture (production system designated as RF); a feedlot, with animals fed typical step-up/high-concentrate rations (production system designated as FL); and a pasture, with animals given access to the pasture and a supplement after 11 wk in the pasture (production system designated as P). Table 1 shows the compositions of diets for the FL lambs and that of the supplement given to the P lambs. The feeding experiment started on June 29, 1999. Duration of each production treatment is shown as days-to-slaughter in Table 2. Days to slaughter were aimed at 130 lb (59 kg) shorn final weight with 65 lb (29.5 kg) carcass weight for each treatment. Pasture plant samples were obtained toward the end of the P treatment period (close to the slaughter time of the P lambs). The parts of each plant that the P lambs were expected to have consumed were collected by cutting with scissors. Samples were placed in plastic bags and frozen.

The slaughter and carcass evaluations were conducted in San Angelo. *Semimembranosus* muscle samples with some subcutaneous fat attached were removed (~24 h postmortem) from each carcass, double-bagged in Ziploc® freezer bags, and frozen. The muscle plus fat samples, pasture plant samples, and representative samples of the FL- and RF-lamb feeds and the P-lamb supplement were transported frozen to College Station. Upon receiving, the lamb tissue samples were individually vacuum-packaged, whereas the diet samples were double-bagged in Ziploc® freezer bags. All samples were kept at -20°C until analysis.

Total lipids were extracted by the procedure of Folch et al. (1957). Before lipid extraction, the plant samples were cut very finely with a pair of scissors (as they were too fibrous to be chopped in a food processor), soaked in distilled water (30 ml/10 g sample) for 24 h at 4°C, and drained. Each of the diet/supplement samples was finely ground in a food processor, soaked in distilled water (30 ml/10 g sample) and drained prior to lipid extraction. Total fat content was determined on aliquots of lipid extracts after solvent removal. To determine fatty acid composition, aliquots of lipid extracts were freed of solvent under a nitrogen stream and transmethylated using tetramethylammonium hydroxide in methanol (Metcalfe and Wang, 1981). Fatty acid methyl esters were analyzed using a gas chromatograph (Varian 3400) fitted with a fused silica capillary column, as described by Rhee et al. (1988). Results for each fatty acid were expressed as a percentage of the sum of the peak areas of all identified fatty acids.

The Statistical Analysis System software (SAS, 1997) was used to perform data analysis. A mixed model (PROC MIXED) was used, with animal treated as a random effect. Correlation analysis (PROC CORR) was also conducted where appropriate. Significance was established at $P < 0.05$ unless otherwise indicated.

Table 1. Percentages of ingredients in the feedlot diets and pasture supplements

	FL diets (time fed, wk)			P supplements (time fed, wk)	
	Diet #1 (1)	Diet #2 (2)	Diet #3 (3)	Suppl. #1 (6)	Suppl. #2 (14)
Diet ingredient	Ingredient percentage				
Sorghum grain	52.0	39.5	67.7	81.5	60.0
Dehydrated alfalfa meal	10.0	10.0	5.0	0	10.0
Cottonseed hulls	20.0	30.0	10.0	0	0
Cottonseed meal	12.0	15.0	12.0	9.0	10.0
Soybean meal	0	0	0	0	10.0
Molasses	4.0	4.0	3.0	4.5	4.0
Urea	0	0	0.5	0	0.5
Ammonium chloride	0.5	0.5	0.5	0	0
Calcium carbonate	1.0	0.5	1.0	0	0
Mono-dicalcium phosphate	0	0	0	0	1.0
Vitamin-mineral-antibiotic pre-mix	0.50	0.50	0.3	0	0.5
Salt	0	0	0	5.0	4.0

Results and Discussion

Initial weights of lambs were about 76 lb on average, with no significant differences among treatments or between breed types. Final shorn weights (highest for RF lambs) and carcass weights (similar for FL and RF lambs) were slightly off the targets of 130 lb and 65 lb, respectively (Table 2). The FL lambs were higher in dressing percentage than RF and P lambs. Lamb weight and carcass data indicated that RF lambs probably had greater gut fill than the other two groups. Backfat thickness, body wall thickness, and USDA yield grade were all higher for FL and RF lambs than for P lambs.

Fatty acid composition data for the feeds (the diets for RF and FL lambs and the supplements given to P lambs) and pasture (range) plant samples are shown in Table 3. Pasture plants were much higher in the percentage of total saturated fatty acids (SFA) compared to the FL-lamb feed, the RF-lamb diet, and the P-lamb supplement — 58 - 81% for pasture plants vs. 19 - 28% for the latter. Conversely, the percentage of total unsaturated fatty acids (UFA) was higher for the feeds (72 - 82% vs. 19 - 42%). Accordingly, extremely large differences were observed in the UFA/SFA ratio between pasture plants and the feeds/supplement (0.24 – 0.72 vs. 2.59 - 4.62). Most of such

differences were due to much greater amounts of polyunsaturated fatty acids (PUFA) in the lipid extracts from the latter, as can be seen from the values of the PUFA/SFA ratio (Table 3).

Table 2. Production treatment effects on carcass traits for lambs used in this study

	Initial weight (lb)	Shorn final weight (lb)	Days to slaughter	Hot carcass weight (lb)	Dressing percentage	Backfat thickness (in)	Body wall thickness (in)	USDA yield grade
Treatment								
P	75.1[a]	126.0[b]	220[a]	63.28[b]	50.21[b]	0.18[b]	0.93[b]	1.5[b]
FL	76.0[a]	124.8[b]	134[b]	68.18[ab]	54.64[a]	0.34[a]	1.43[a]	2.6[a]
RF	77.1[a]	139.5[a]	206[c]	70.99[a]	50.91[b]	0.36[a]	1.38[a]	2.6[a]
Breed type								
R	75.9[a]	131.3[a]	188[a]	69.42[a]	52.89[a]	0.32[a]	1.33[a]	2.5[a]
M x R	76.2[a]	129.0[a]	186[a]	65.61[a]	50.99[a]	0.26[b]	1.17[b]	2.0[b]

[a,b,c]Means in the same column within the same data category (treatment or breed type) which are not followed by a common superscript letter are different ($P < 0.05$).

Fatty acid compositions of the pasture plants (Table 3), which the P lambs were expected to have consumed during the production treatment, differed greatly from those of the pasture plants analyzed in our previous study on goats (Rhee et al., 2000). Plant species of the latter study were different from those of the current study, except sideoats grama, although adjacent rangeland pastures were used (in different years). In the goat study, lipid extracts from all the plant species (including sideoats grama), that were collected/analyzed, contained more UFA than SFA (vs. more SFA than UFA in the current study). The differences in pasture plants' fatty acid profiles between the two studies were most likely due to the pasture condition/rainfall during the treatment period. The summer, fall, and winter at San Angelo in the current study was very dry. Sideoats grama (the common plant species in the two studies) showed a higher SFA percentage in this study (about 60% SFA) than in the previous study on goats (about 36% SFA). Percentages of total monounsaturated fatty acids (MUFA) and PUFA for sideoats grama in the goat study were about 19% and 45%, respectively (vs. 15% and 26%, respectively, in the current study).

Among the feeds, the RF-lamb feed had a higher SFA percentage than did the FL-lamb feed or the supplement given to P lambs. For each feed and plant sample, the total PUFA percentage was greater than the total MUFA percentage. Likewise, the 18:2 acid (the predominant PUFA) percentage was higher than the 18:1 acid percentage in all samples other than tobosagrass, a pasture plant. The 16:0 acid was the major saturated fatty acid in all samples (feeds or plants), and its percentage was higher for plant samples (except broomweed).

Table 3. Fatty acid compositions (%) of diets for RF and FL lambs, supplement for P lambs, and pasture plants

Fatty acids	P supplement #2	FL diet #3	RF diet	Pasture plants					
				Broomweed	Kleingrass	Purple + wrights threeawn	Silver bluestem	Sideoats grama	Tobosagrass
12:0	0.04	0.01	0.52	21.05	5.86	3.69	5.65	6.76	2.31
14:0	0.14	0.14	0.62	3.57	3.92	3.48	4.29	6.45	5.13
15:0	0.04	0.03	0.24	5.50	0.44	0.74	0.93	0	0.76
16:0	15.85	15.27	22.84	20.99	26.68	32.12	34.90	30.69	30.43
16:1	0.52	0.52	0.28	0	0.44	0.76	0.77	1.26	1.20
17:0	0.10	0.08	0.26	4.25	0.55	1.02	1.24	0	1.40
17:1	0.03	0.08	0.04	0.07	0	0	0	0	0
18:0	1.81	1.67	2.18	3.25	7.38	5.82	7.82	8.89	12.45
18:1	29.21	31.29	10.26	6.31	12.83	10.62	13.30	13.43	20.77
18:2	49.15	48.38	26.37	7.16	18.65	22.20	14.50	21.40	17.60
18:3	2.35	1.83	34.98	2.87	2.53	4.57	2.64	4.10	2.43
20:0	0.22	0.23	0.39	3.72	10.28	20.70	5.56	4.18	2.33
20:1	0.15	0	0	0	0.40	0	0	0	0
22:0	0.14	0.17	0.61	12.11	5.26	6.70	4.43	2.83	1.69
22:1	0.10	0.12	0.06	2.99	0	0	0	0	0
23:0	0.02	0.06	0.08	1.09	0.73	1.47	0	0	0
24:0	0.14	0.12	0.26	5.06	4.04	4.73	3.98	0	1.50
Total SFA	18.48	17.78	28.00	80.59	65.15	61.84	68.80	59.80	58.00
Total UFA	81.52	82.22	72.00	19.41	34.85	38.16	31.20	40.20	42.00
Total MUFA	30.02	32.01	10.64	9.38	13.67	11.39	14.06	14.70	21.97
Total PUFA	51.50	50.21	61.35	10.03	21.18	26.77	17.14	25.50	20.03
UFA/SFA	4.42	4.62	2.59	0.24	0.54	0.62	0.45	0.67	0.72
MUFA/SFA	1.63	1.80	0.38	0.12	0.21	0.18	0.20	0.25	0.38
PUFA/SFA	2.79	2.58	2.20	0.12	0.32	0.43	0.25	0.43	0.34

Fatty acid profiles of the intramuscular (IM) fat - the total lipid extracted from *semimembranosus* muscle - are shown in Table 4 by breed type. Treatment effects on total SFA (or UFA) content

Table 4. Production treatment effects on fatty acid composition (%) of intramuscular fat

Fatty acid	Production treatment					
	P		FL		RF	
	Mean	SD	Mean	SD	Mean	SD
Merino cross lambs						
14:0	2.30[a]	0.34	1.93[b]	0.29	1.98[b]	0.51
15:0	0.31[a]	0.05	0.33[a]	0.08	0.25[b]	0.09
16:0	24.23[b]	1.46	24.69[b]	1.24	26.92[a]	2.11
16:1	1.87[a]	0.27	1.58[ab]	0.46	1.44[b]	0.75
17:0	1.16[b]	0.09	1.56[a]	0.33	1.16[b]	0.18
18:0	16.64[a]	1.27	12.70[b]	1.22	15.75[a]	1.81
18:1	44.15[b]	2.53	48.21[a]	2.13	47.63[a]	3.53
18:2	6.31[a]	1.54	6.57[a]	1.48	2.93[b]	0.58
18:3	0.45[b]	0.48	0.30[b]	0.08	1.33[a]	0.37
20:4	2.57[a]	0.70	2.13[b]	0.57	0.73[c]	0.25
Total SFA	44.64[a]	2.17	41.21[b]	2.24	46.06[a]	3.05
Total UFA	55.36[b]	2.17	58.79[a]	2.24	53.94[b]	3.05
Total MUFA	46.03[b]	2.62	49.79[a]	2.10	48.95[a]	3.52
Total PUFA	9.33[a]	2.15	9.00[a]	1.99	4.98[b]	1.00
UFA/SFA	1.25[b]	0.11	1.43[a]	0.13	1.18[b]	0.14
MUFA/SFA	1.04[b]	0.10	1.21[a]	0.10	1.07[b]	0.14
PUFA/SFA	0.21[a]	0.05	0.22[a]	0.05	0.11[b]	0.02
Rambouillet lambs						
14:0	2.20[a]	0.36	2.12[a]	0.49	2.06[a]	0.40
15:0	0.29[b]	0.07	0.38[a]	0.10	0.27[b]	0.15
16:0	24.58[b]	0.89	24.87[b]	1.23	27.37[a]	1.91
16:1	1.92[a]	0.36	1.39[b]	0.54	1.43[b]	0.22
17:0	1.06[b]	0.16	1.54[a]	0.32	0.98[b]	0.14
18:0	15.22[a]	1.70	13.50[b]	1.49	14.65[a]	1.82
18:1	45.54[b]	2.29	47.87[a]	1.73	48.75[a]	1.87
18:2	6.33[a]	1.44	6.05[a]	1.38	2.66[b]	0.41
18:3	0.51[b]	0.19	0.39[c]	0.13	1.04[a]	0.18
20:4	2.42[a]	0.84	1.92[b]	0.61	0.79[c]	0.33
Total SFA	43.35[b]	1.75	42.40[b]	1.99	45.33[a]	2.02
Total UFA	56.65[a]	1.75	53.60[a]	1.99	54.67[b]	2.02
Total MUFA	47.39[b]	2.23	49.25[a]	1.74	50.18[a]	1.94
Total PUFA	9.25[a]	2.16	8.35[a]	1.96	4.49[b]	0.75
UFA/SFA	1.31[a]	0.09	1.36[a]	0.12	1.21[b]	0.10
MUFA/SFA	1.10[b]	0.08	1.17[a]	0.08	1.11[b]	0.09
PUFA/SFA	0.21[a]	0.05	0.20[a]	0.05	0.10[b]	0.02

[a,b] Means within the row which are not followed by a common superscript letter are different ($P < 0.05$).

differed between the two breed types. For Merino cross lambs, the SFA content of the IM fat was greater with P and RF treatments than with FL treatment, with the reverse being the case for the UFA content. For Rambouillet lambs, RF resulted in the highest SFA content. For both breed types, the MUFA content in IM fat was lower with P than with FL and RF, whereas the PUFA content was lower with RF than with P and FL. When prooxidative factors are the same, qualitatively as well as quantitatively, lean meat samples with larger amounts of PUFA generally are more susceptible to oxidative quality deterioration during handling, processing and storage than those with less PUFA (Rhee, 2000).

Fatty acid profiles of subcutaneous (SC) fat are shown in Table 5. In the SC fat from Merino cross lambs, the following differences due to treatments were observed: RF > FL in SFA content; P=FL > RF in MUFA content; and RF > P in PUFA content. In the SC fat from Rambouillet lambs, however, total SFA, MUFA and PUFA contents were not significantly different among the three production treatments.

When correlation coefficients were computed from mean values, fatty acid saturation (or unsaturation) of the muscle tissue fat correlated ($P < 0.05$) with that of the feeds, including the P-lamb supplement ($r = 0.81$ for SFA, $r = -0.81$ for UFA). However, no significant ($P > 0.05$) correlation was found between SC fat and the feeds (r values of 0.68 and –0.68). Fatty acid saturation (or unsaturation) of IM fat was also correlated ($P < 0.05$) with final shorn weight ($r = 0.82$ for SFA, $r = -0.82$ for UFA), but not with other carcass traits. Fatty acid composition of SC fat did not correlate with any carcass trait.

Conclusions

Lamb diets (the feeds for feedlot and raised-floor lambs and the supplement given to pasture lambs) influenced the fatty acid composition of lamb meat (muscle) more than did breed type (Rambouillet or Merino x Rambouillet). Since little vegetation was produced in the pasture during the production treatment due to drought, P lambs consumed large amounts of their supplement diet. As such, fatty acid compositions of P lamb tissues were more related to that of the supplement than to those of the pasture plants. The muscle fat from RF lambs contained more saturated fatty acids than that of feedlot or pasture lambs. However, the differences were relatively small (although statistically significant), and may be of little practical significance relative to human nutrition. On the other hand, the PUFA content in muscle fat was much lower (more than 45% less) with RF than both P and FL treatments, and such PUFA content differences may lead to differences in oxidative stability of meat. Specifically, lean meat from RF lambs is likely to be more stable toward oxidative quality deterioration than the feedlot and pasture lamb counterparts.

Table 5. Production treatment effects on fatty acid composition (%) of subcutaneous fat

Fatty acid	Production treatment					
	P		FL		RF	
	Mean	SD	Mean	SD	Mean	SD
Merino cross lambs						
14:0	3.35[a]	0.50	3.58[a]	0.63	3.66[a]	0.64
15:0	0.61[b]	0.08	0.78[a]	0.12	0.63[b]	0.13
16:0	24.19[c]	1.47	26.98[b]	1.81	29.43[a]	2.80
16:1	1.59[a]	0.30	1.56[a]	0.63	1.42[a]	0.60
17:0	1.77[c]	0.21	2.63[a]	0.35	2.02[b]	0.19
18:0	24.57[a]	3.31	18.55[c]	2.32	21.88[b]	4.57
18:1	41.03[a]	3.54	42.65[a]	4.23	37.23[b]	6.13
18:2	2.64[ab]	0.53	2.93[a]	0.61	2.27[b]	0.71
18:3	0.25[b]	0.05	0.24[b]	0.05	1.42[a]	0.62
20:4	0.01[b]	0.03	0.08[a]	0.03	0.06[a]	0.06
Total SFA	54.49[ab]	3.57	52.53[b]	4.29	57.61[a]	7.03
Total UFA	45.51[ab]	3.57	47.47[a]	4.29	42.39[b]	7.03
Total MUFA	42.62[a]	3.68	44.22[a]	4.19	38.64[b]	6.50
Total PUFA	2.90[b]	0.55	3.25[ab]	0.63	3.75[a]	1.29
UFA/SFA	0.84[ab]	0.12	0.92[a]	0.15	0.76[b]	0.20
MUFA/SFA	0.79[a]	0.12	0.85[a]	0.15	0.69[b]	0.18
PUFA/SFA	0.05[b]	0.01	0.06[ab]	0.01	0.07[a]	0.03
Rambouillet lambs						
14:0	3.78[a]	0.64	4.07[a]	1.35	4.10[a]	0.95
15:0	0.65[b]	0.11	0.86[a]	0.21	0.65[b]	0.16
16:0	26.38[b]	3.26	26.92[b]	1.83	29.79[a]	2.71
16:1	1.76[a]	0.33	1.85[a]	0.40	1.57[a]	0.46
17:0	1.89[b]	0.35	2.57[a]	0.62	1.87[b]	0.26
18:0	23.96[a]	4.64	19.14[b]	3.79	20.04[b]	3.39
18:1	38.84[a]	8.40	41.87[a]	4.72	39.04[a]	4.68
18:2	2.38[a]	0.79	2.30[a]	0.42	1.87[b]	0.39
18:3	0.37[b]	0.15	0.35[b]	0.11	1.02[a]	0.34
20:4	0.02[c]	0.03	0.07[a]	0.03	0.05[b]	0.05
Total SFA	56.65[a]	8.00	53.57[a]	5.25	56.45[a]	5.29
Total UFA	43.35[a]	8.00	46.43[a]	5.25	43.55[a]	5.29
Total MUFA	40.59[a]	8.27	43.72[a]	4.91	40.62[a]	4.83
Total PUFA	2.76[a]	0.83	2.72[a]	0.45	2.93[a]	0.69
UFA/SFA	0.79[a]	0.19	0.88[a]	0.18	0.79[a]	0.17
MUFA/SFA	0.74[a]	0.19	0.83[a]	0.17	0.73[a]	0.15
PUFA/SFA	0.05[a]	0.01	0.05[a]	0.01	0.05[a]	0.02

[a,b] Means within the row which are not followed by a common superscript letter are significantly different ($P < 0.05$).

Acknowledgment

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Relationships among weights, ultrasound and carcass characteristics in Boer-cross goats

M.A. Carr, D.F. Waldron, T.D. Willingham

ABSTRACT: Live weights, and fat and muscle measurements from ultrasound images were obtained on Boer-cross goat kids (N = 77, average wt = 80 lb, average age = 167 d) prior to slaughter. Physical carcass measurements (muscle depth, fat depth and longissumus muscle area) were obtained on the carcasses at the cut surface between the last two ribs. Correlation analysis suggested that muscle measurements were significantly correlated with live weight (r = .67) and hot carcass weight (r = .70). Muscle depth increased .0124 sq in per lb of live weight (R^2 = .51). Ultrasound was useful for identifying differences among animals for muscle depth, but not for fat depth.

Key Words: Goats, Carcass, Ultrasound, Boer

Sheep and Goat, Wool and Mohair CPR 2002. 55-59

Introduction

Ultrasound technology has been used to predict carcass characteristics in beef (Herring et al., 1998; Stouffer et al., 1989), pork (Terry et al., 1989; Liu and Stouffer, 1995), and lamb (Edwards et al., 1989; Hopkins, 1990). This technology has practical value for a producer in predicting an animal's readiness for slaughter or for use in selection of breeding stock.

Stanford et al. (1995) attributed the lack of muscling and fat in goat carcasses to a lack of genetic improvement. However, in the years since the previous article was published, the South African Boer goat has gained popularity in the meat goat industry. Boer-cross kids produce heavier carcasses with greater fat thickness and carcass conformation (Oman et al., 1999). Therefore, the objective of this study was to estimate the relationship between longissimus muscle area, longissimus muscle depth, fat depth, carcass weight, and live weight of Boer-cross goats.

Materials and Methods

Animals

Billies (n = 77) varying in breed composition from 3/8 to 7/8 Boer were born in October and November of 2001 and weaned in January 2002 at an average age of 84 d. All goats were placed in a feed lot and fed a finishing ration (67.5% grain sorghum, 5% dehydrated alfalfa meal, 12% peanut hulls, 4% cottonseed meal, 4% soybean meal, 4% molasses, 1% ammonium chloride, 1.4% calcium carbonate, 0.6% mono-dicalcium phosphate, and 0.5% TAES vitamin-mineral-antibiotic premix). After 83 d on feed, ultrasound fat (UFD) and muscle depth (UMD) measurements were taken on each animal, parallel to the backbone (Aloka 500, 5 MHz transducer, Auskey for Windows software) and live weight (LWT) recorded. The following morning, all goats were transported to Strube Packing, Rowena, TX for processing.

Carcass Measurements

All carcass measurements were collected 24 h postmortem at the 12th and 13th rib interface. Fat depth (FD) and muscle depth (MD) were measured 1.2 in, and body wall (BW) 4 in, from the backbone. Longissimus muscle area (LMA, in^2) and hot carcass weight (HCW, lbs) were also collected.

Statistical Analysis

Pearson correlations and simple regression analysis were performed using PROC CORR and PROC REG of SAS (1995) to determine the relationship between carcass and ultrasound measurements and live weight.

Results and Discussion

Table 1 shows the mean values for each trait. The range in liveweights is primarily due to differences in growth rate as all goats were born within a 38 day period in October and November of 2001. Table 2 summarizes the linear correlations between each measurement. The highest correlation was between LWT and HCW (r = .98). This relationship was expected because as LWT increases, HCW will also increase proportionally. High correlations for LWT and HCW with MD (r = .67 and .70, respectively) and LMA (r = .71 and .75, respectively) are also shown in Table 2. Ultrasound measurements taken on the live goats revealed moderate correlations to the physical carcass measurements as seen with UMD and MD (r = .51) and with LMA (r = .49). Although the kids in the present study are older and heavier than those in the report by Stanford et al. (1995), the correlations between muscle measurements and weights are similar. These relationships indicate an important role for the use of ultrasound on live animals to predict the animal's carcass characteristics.

Table 1. Mean values for weights and measurements on Boer-cross goats

Trait	Mean	Minimum	Maximum
Live weight, lb	79.6	51	101
Hot carcass weight, lb	39.8	25	52
Carcass fat depth, in	.12	.04	.28
Carcass muscle depth, in	1.08	.79	1.38
Longissimus muscle area, sq. in.	1.57	1.00	2.15
Ultrasound fat depth, in	.16	.10	.27
Ultrasound muscle depth, in	1.07	.75	1.32

Table 2. Pearson correlation coefficients for carcass and ultrasound measurements of Boer-cross goats

	HCW	FD	MD	LMA	UFD	UMD
LWT	.98	.35	.67	.71	.13	.58
HCW		.38	.70	.75	.10	.63
FD			.30	.22	-.09	.30
MD				.75	.05	.51
LMA					.17	.49
UFD						-.05

In Table 3, single variable regression equations are shown to predict LMA and FD from LWT and HCW. The R^2 value is an indication of how well the equation can predict the desired measurement. Therefore, the higher the R^2 value, the better the equation will predict the chosen measurement. The equations for predicting LMA with LWT and HCW as single variables have moderate R^2 values. As LWT and thus HCW increase, LMA also increased. The equation using LWT indicates that an increase of 10 lb of LWT is expected to result in an increase of .12 in^2 in LMA. The increase in LMA per 10 lb increase in HCW is .24 in^2. Figure 1 is a plot of each goat's LWT vs. their LMA with the equation fit to the data.

Table 3. Regression equations to predict longissimus muscle area (LMA) and fat depth (FD) with live weight (LWT), hot carcass weight (HCW), ultrasound fat (UFD) and muscle depth (UMD) of Boer-cross goats

Equations	R^2
LMA = .0809 + .0124 (LWT)	.51
LMA = .6005 + .0242 (HCW)	.55
FD = .3753 + .0324 (LWT)	.12
FD = .3221 + .0661 (HCW)	.14
MD = 13.5771 +.5089 (UMD)	.26
FD = 3.4455 -.1203 (UFD)	.01

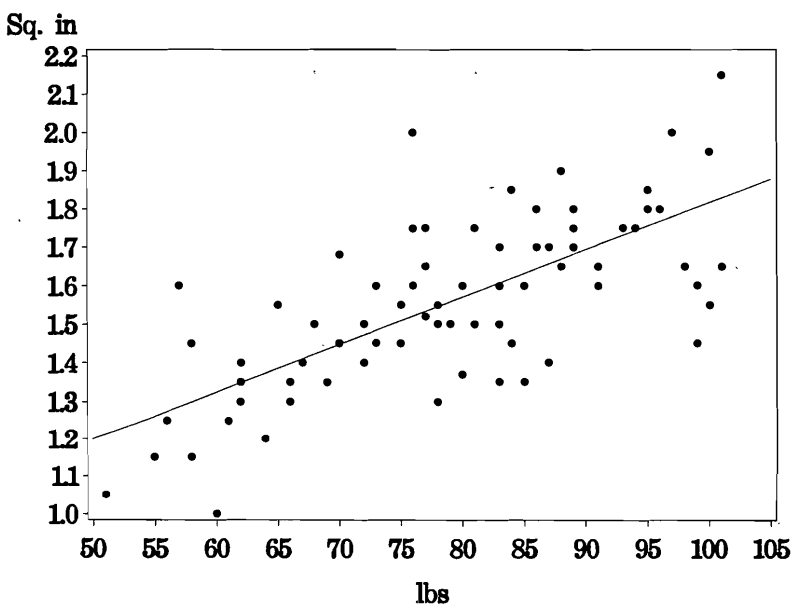

Figure 1. Longissimus muscle area versus live weight of Boer-cross kids.

LWT and HCW were less effective in predicting FD (R^2 = .12 and .14, respectively). These low R^2 values are an indicator that fat depth is not closely related to HCW or LWT. Within this group of Boer-cross goats, there was considerable variation in fat depth that was not correlated with LWT. The relatively strong correlation between LWT and both LMA and MD suggests that LWT can be used to predict LMA in goats.

The relationship between UMD and MD (Table 3) indicates that the measurements from the ultrasound images were useful, but increases in accuracy are needed in order for ultrasound measurements of muscle depth to be widely adopted as a selection tool. Using ultrasound measurements along with pedigree information can increase the accuracy of evaluations. The relationship between UMD and MD was positive, whereas the relationship between UFD and FD was not different from zero. The advantage of utilizing ultrasound is that the predictions can be made on the live animal to estimate its carcass characteristics before slaughter or as an aid to selection. However, the amount of fat over the longissimus muscle in these goats was so small that it was difficult to measure with the ultrasound equipment. Ultrasound has been more successful with species carrying greater amounts of fat such as beef or pork (Stouffer et al., 1989; Sather et al., 1995).

Implications

Live weight and carcass weight are useful for predicting longissumus muscle area in goats, but much less useful for predicting fat depth. The regression equation of LMA on LWT can be used to predict muscle area of goats of different weights. Measurement of fat depth on goat kids by ultrasound was not useful for predicting fat depth as measured on the carcass. Muscle depth measurements from ultrasound images were useful in identifying differences, but increased accuracy is required to increase the value of ultrasound as an aid to selecting goats.

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Cultivated cool season pastures for meat goats in north-central Texas

J. P. Muir

ABSTRACT: Cultivated cool-season pastures can complement range-based goat production in north central Texas, especially the understories of otherwise under-utilized pecan groves. Weight gains of Boer X Spanish nanny kids (average 55 lbs) on four grazing treatments 1) grass-only, 2) mixed grass/legume, 3) mixed grass/legume in a pecan grove, and 4) native hardwood range during two cool seasons were compared at Stephenville, Texas. Animals were stocked in the pasture at 2 head per acre and in the range at 0.8 head per acre for 8 wk in 2000, when October-May rainfall was 13 inches, and 16 wk in 2001 when rainfall was 26 inches for the same period. Nannies in the pecan grove gained 2.77 and 2.22 lbs per wk (0.40 and 0.32 lbs ADG, respectively) on average compared to 0.66 and 0.72 lbs per wk (0.09 and 0.10 lbs ADG, respectively) for the range animals during the same 8-wk periods in 2000 and 2001, respectively. Animals in both grass/legume paddocks out-gained the goats on grass-only in 2000 but not in 2001. At the low stocking rates studied, having pecan trees in the pasture did not decrease goat gains; however, trees did lower forage production and, by implication, carrying capacity. The nannies tended to select for grasses early in the season and equally for grasses and legumes as plants matured but selected plants and plant portions high in crude protein throughout the season. The use of cool-season cultivated legume/grass pastures for growing nanny kids under pecan groves in the Cross Timbers shows promise as a complement to warm-season range-fed goats.

Key Words: Winter Forages, Legumes, Ryegrass, Agroforestry

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Introduction

The Texas goat industry has a strong interest in maintaining steady weight gains through the cool season in order to meet spring holiday market demands. Traditionally, meat goats with mostly Spanish genetics are left on range during cool winter months when most native forbs are dormant, and the only non-dormant plants are a few perennial grasses and a limited number of evergreen shrubs (Gee et al., 1994). To maximize the potential of recently introduced Boer goat genetics, cultivated cool-season forages may be needed, similar to the annual grasses presently grown for cattle and white-tailed deer in the region (Gee et al., 1994; Prostko et al., 1999). There are numerous naturalized, self-reseeding annual legumes with proven adaptation to the region (Diggs et al., 1999) whose productivity and persistence (Muir and Reed, 1998; Muir, 2000) may make them ideal components of cultivated pastures designed specifically for goats.

A preliminary trial at Stephenville, TX in 1999 indicated that late winter cultivated grass or grass/legume pastures showed some promise for goat production (Weiss and Muir, 2000). Boer X Spanish nanny kids averaging 50 lbs were placed on a ryegrass/wheat pasture and a ryegrass/legume pasture in April 1999, at 5 animals per acre. During the 28 d of the trial, average

weekly gains (AWG) were 2.6 lbs (0.37 lbs ADG) per animal on grass-only and 2.3 lbs (0.33 lbs ADG) per animal in the grass/legume pasture. The animals showed a surge in AWG when the wheat reached dough stage and the goats learned to selectively harvest the seed heads. Further information was therefore needed comparing sustainable, self-reseeding grass-only (excluding wheat) to grass/legume mixtures as pastures for goats starting earlier in the winter, when plant development is much slower. In addition, there was a need to compare these pastures to those grown under pecan orchard and native hardwood range in the Cross Timbers. Pastures under orchards have been effectively used elsewhere (Rai et al., 1998) but is an underutilized system for goat production in Texas.

The objective of this study was to compare AWG of growing Boer X Spanish nanny kids, during the cool season, in a native hardwood range to those grazing cultivated, annual grass-only or grass/legume mixtures as well as grass/legume mixtures under pecan canopies. A further objective was to determine goat selectivity of grasses versus legumes as well as plant components as estimated by comparing forage crude protein of swards with and without goat herbivory.

Materials and Methods

Four production systems consisting of a 2-acre annual grass-only pasture, a 7-acre annual grass/legume pasture, a 4-acre annual grass/legume pasture under a pecan grove (30 trees per acre) and a 14.5-acre native hardwoods range, were studied. A single pasture representing each production system was established across a contiguous soil type at the Texas Agricultural Experiment Station in Stephenville, Texas. Pasture planting took place in the autumns of 1999 and 2000 but animals were introduced into the paddocks for different periods in 2000 (1/24/00 through 3/20/00) and again in 2001 (1/9/01 through 5/1/01). Differences in length of grazing were caused by differences in rainfall and subsequent differences in forage availability between year.

Before the trial began, 165 lbs of 0-46-0/acre was applied according to soil test recommendations. In both years, each pasture was lightly disked, seed was broadcast and seedbeds packed in late September or early October, depending on soil moisture. In the mixed grass/legume pastures, arrowleaf clover (*Trifolium vesiculosum* cv. 'Yuchi'), button medic (*Medicago orbicularis* cv. 'Estes'), burr medic (*Medicago polymorpha* cv. 'Armadillo'), hairy vetch (*Vicia villosa*), crimson clover (*Trifolium incarnatum* cv. 'Dixie'), and annual ryegrass (*Lolium multiflorum* cv. 'Tam90') were seeded, each at 20% of the recommended rate for pure stands (2, 2, 2, 6 and 6 lbs seed/acre, respectively) after inoculation of the legumes with specific rhizobia. Bromes (*Bromus* spp.) and black medic (*Medicago lupulina*) volunteered in all pastures and the legume was controlled with an application of Ally (1 oz/acre) in the grass-only pasture in December of 1999 and 2000. Annual ryegrass was seeded into the grass-only pasture at 30 lbs seed/acre. Following germination, the grass/legume pastures received 100 lbs 34-0-0/acre, and the grass-only pasture received 130 lbs 34-0-0/acre. The mixed grass/legume paddocks received less N to favor legume competitiveness.

Bob Duke of Utopia (2000) and Bub Hooten of Lometa (2001) supplied 38 5-7 mo old Boer X Spanish cross nanny kids averaging 55 lbs each. The grass/legume, pecan and grass-only pastures were stocked with 14, 8, and 4 goats, respectively, in similar proportions of age, weight and breed percentage in each paddock. Each pasture was stocked based on accessible surface rather than available forage in order to achieve a uniform stocking rate of close to 2 goats per acre. Initial visual estimates indicated that, at this stocking rate, sufficient herbage would be available for

selective grazing by the goats in all paddocks. The hardwoods paddock had only 12 animals, a stocking rate of 0.8 animals per acre, since visual estimates of available herbage, including shed tree leaves, indicated that this was all the system was likely to support. Free-choice water, as well as salt, was available in each paddock. Grazing was initiated each year as soon as sufficient herbage had accumulated; in order to facilitate pasture self-reseeding, animals were removed when most of the legumes and ryegrass began producing seed heads. October-May rainfall was 13 in. the first season and 26 in. the second, affecting the duration of the grazing period each year. Each goat was then weighed at two-wk intervals and data obtained was used to estimate biweekly and season-long average weekly gain as lbs weight gain per goat.

Forage quantity on offer, crude protein and grass:legume ratios for each cultivated pasture type were determined before, half way through and at the end of the trial each year. Five wire exclosures were placed along a diagonal transect in each cultivated paddock and paired 10 ft^2 samples were cut 2" above the soil surface both inside and outside the exclosures. These samples were separated into grass and legume components to provide an estimate of species composition and herbage components over time.

Biweekly goat AWG's were utilized to detect trend differences among pasture systems within observation periods. Seasonal AWG for pasture systems and year were compared for the 56-d period between January and March in which goats were on pasture in both 2000 and 2001. Duncan's multiple range test (0.05) was utilized to separate treatment season-long AWG means by year. Species composition, herbage on offer, and forage composition (pre-, mid- and post-trial for the preliminary year as well as the two primary years) were utilized as supportive data only. The forage data is presented by year while CP averages are presented for the grass/legume pasture only since trends in the other cultivated pastures were similar.

Results and Discussion

Twice as much rainfall fell in the 2000-2001 cool season (26 inches) compared to the 1999-2000 season (13 inches) resulting in nearly 50% greater herbage production by d 56 of 2001 compared to the 2000 trial (Figures 1 and 2). As a result, AWG of goats on the four pasture systems were different for each year (pasture system by year interaction P=0.01). On average, AWG was 31% higher for nannies on grass/legume pastures in 2000 compared to 2001 whereas nannies on grass-only pastures gained 10% less the first year (Table 1). Different genetics of the animals in the two years may have played a minor role in these differences despite the fact that both groups had similar percentages of Boer and Spanish blood and were of similar age and weight both years. Since available herbage mass was not limiting either year and was actually greater in 2001 when animals produced less gains, a dilution of forage quality may have occurred the second season. Unlike the 1999 trial (Weiss and Muir, 2000), where cultivated plants were mature when animals were introduced late in the season and the wheat produced an edible seed head, the goats on the grass/legume pasture during 2000 out-gained the grass-only animals by 53%. In the second year of the trial, with greater amounts of grass available early in the season, there were no differences in AWG between animals in the mixed and grass-only paddocks. The animals in the pecan grove out-produced those on grass/legume paddock in 2001 but were similar in 2000, likely an effect of the lower soil moisture that may have resulted in greater competition between trees and herbaceous forage species the first year.

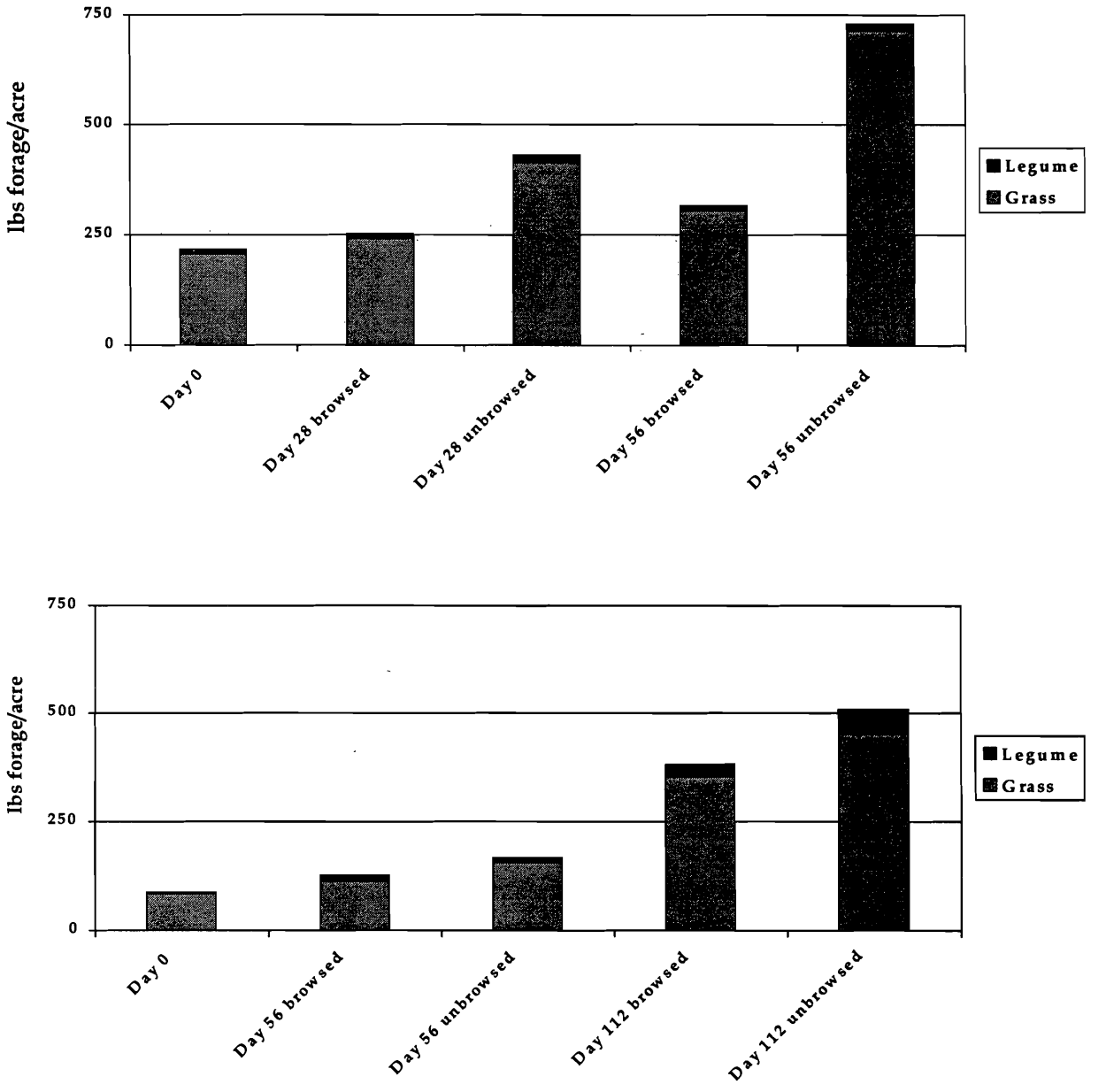

Figure 1. Biomass of herbage protected from or available to goats grazing a full-sun grass/legume mix pasture in 2000 (top) and 2001 (bottom).

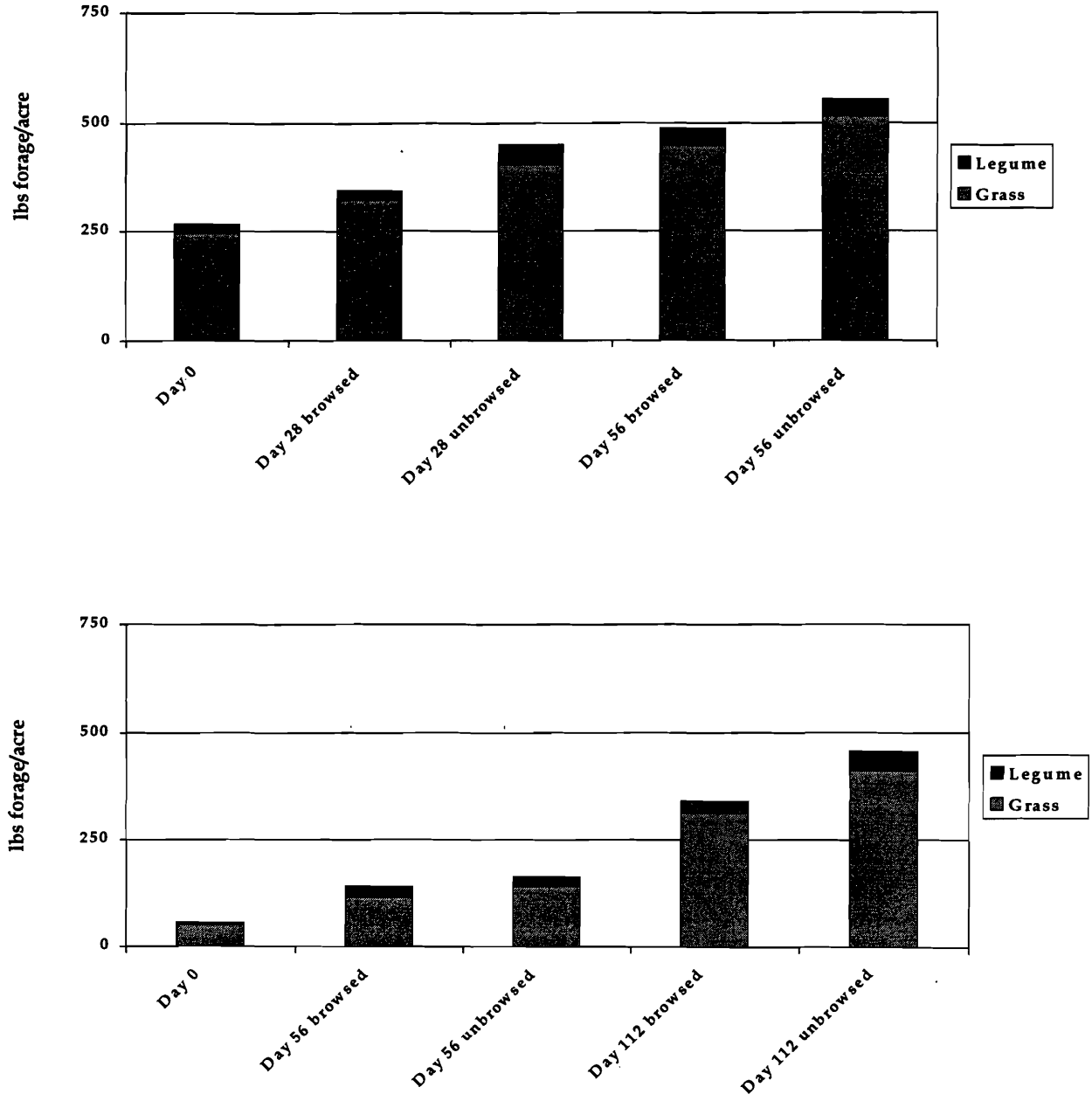

Figure 2. Biomass of herbage protected from or available to goats grazing a grass/legume mix pasture under a pecan canopy in 2000 (top) and 2001 (bottom).

Nanny kids on the range paddock produced only 29 and 38% of the average AWG for the three cultivated pastures in 2000 and 2001, respectively (Table 1). The difference was even higher if the comparison is made between the range and the pecan grove animals that produced 4.2 and 3.0 times as much AWG in 2000 and 2001, respectively. This occurred despite the fact that stocking rate was 2.5 times greater in the pecan grove. This large difference was likely due less to the forage quantity and more with the low quality of the leaf litter and the unfertilized annual grasses in the range paddock. The forage available to the goats in the hardwoods consisted primarily of sparse, dormant but evergreen *Smilax* spp. vines, growing *Bromus* spp. grasses and leaf litter of *Quercus* spp. and *Ulmus* spp. Leaf litter was plentiful but of low quality (6.2% CP and 29.7% lignin) while the grasses were constantly grazed to ground level and were of higher quality (12.8% and 3.0% lignin). As animals were forced to eat proportionately more leaf litter in wk 2-6 of both years, AWG values declined in 2000 and stagnated in 2001 (Figures 3 and 4). Note that in the 2001 trial, which lasted longer due to greater amounts of cultivated herbage, the nanny kids on range showed a marked increase in gains wk 8-16 as warmer weather brought on spring leaf production of the warm-season perennial browse species. In goat production systems where range and cultivated pasture complement each other, this time in the spring may be the most useful for returning goats to range paddocks to allow annual, cultivated pasture species to self-reseed.

Table 1. Cool season average weekly gains (AWG) of weaned Boer X Spanish nanny kids grazing native hardwoods, annual grasses, annual grass-legume pasture or annual grass-legume pasture under a pecan canopy over 56 d (pasture by year interaction P=0.01)

Pasture type	2000	2001	2000	2001
	AWG lbs/acre		ADG lbs/acre**	
Grass/legume pasture under pecan trees	2.77 a*	2.22 a	0.40 a	0.32 a
Grass/legume pasture in full sunlight	2.45 a	1.75 b	0.35 a	0.25 b
Grass only pasture in full sunlight	1.60 b	1.79 b	0.23 b	0.26 b
Hardwoods range	0.66 c	0.73 c	0.09 c	0.10 c

* Means within a column followed by different letters differ (alpha = 0.05) according to Duncan's multiple range test.
** ADG = average daily gain.

Visual estimates and the generally unchanged proportion of the legume component of the grazed paddocks both years (Figures 1 and 2) indicate that the nannies in this trial did not necessarily select for the legume component. This preference for grasses over legumes has been observed in cool climates (Penning et al., 1996) but not in warm climates (Norton et al., 1990). Evidence from the 1999 trial (Weiss and Muir, 2000) as well as late-season data from the present trial both indicate, however, that goats tended to select greater proportions of legume as the bromes and ryegrass matured in late spring. Both these grasses and the crimson clover tended to go into reproductive mode before the bulk of the legumes.

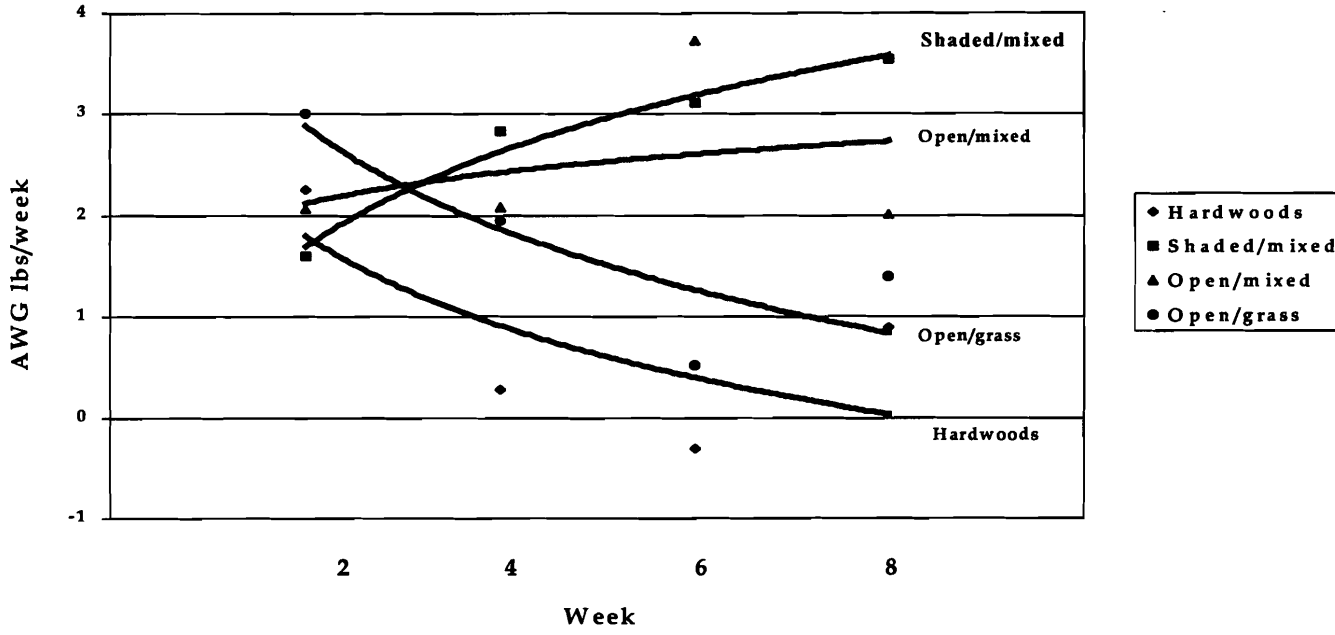

Figure 3. Weaned nanny kid average weekly gain (AWG) by 2-wk period during the 1999-2000 cool season in four pasture systems showing trend lines.

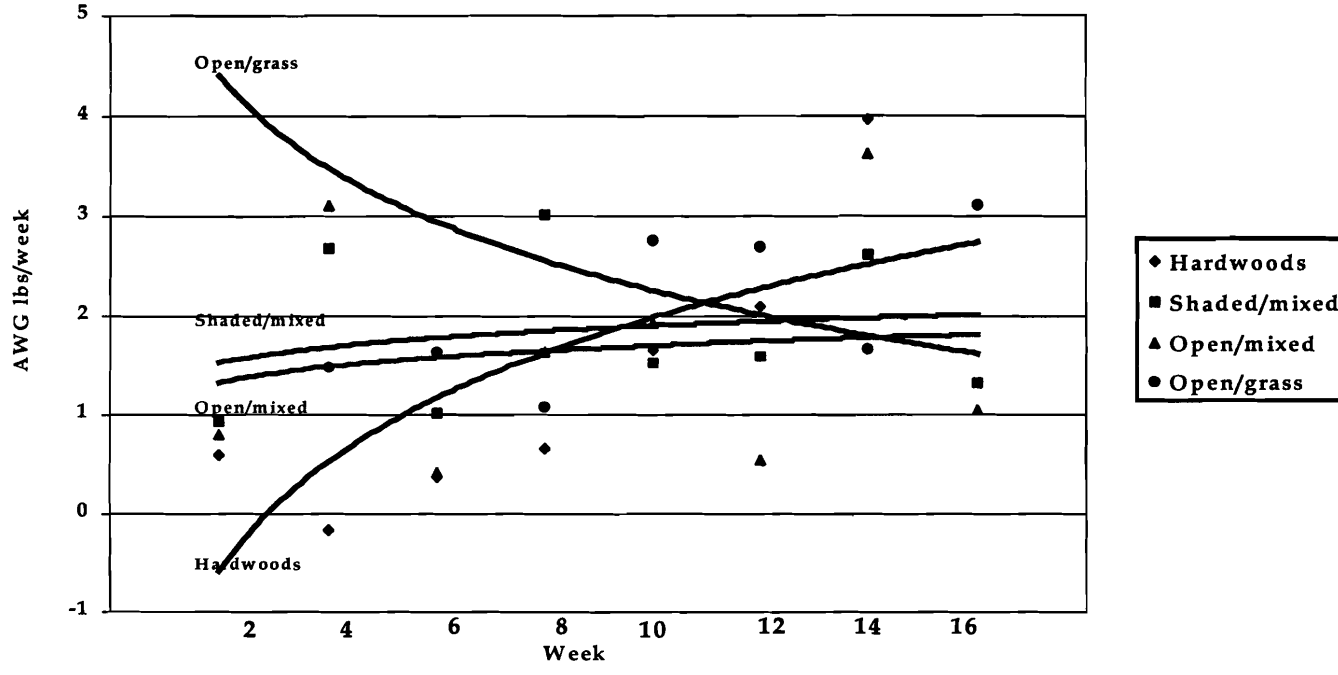

Figure 4. Weaned nanny kid average weekly gain (AWG) by 2-wk period during the 2000-2001 cool season in four pasture systems showing trend lines.

In the grass/legume paddock, legume CP levels were generally greater than grass CP although this difference was less distinct in 2000 when low soil moisture resulted in lower forage yields, thus allowing greater N concentration in the grass (Figure 5). By the end of the 56-d trial in 2000 and the 112-d trial in 2001, legume CP was greater in the ungrazed sward than in the grazed sward. indicating the same preferential selection by goats for plant portions high in N as has been observed elsewhere (da Silva et al., 1999). This trend was not as strong for grasses late in the 2000 season or for either legumes or grasses in the 1999 pre-trial (Weiss and Muir, 2000) when animals were introduced late in the season and stocking rates were quadruple of those used in this trial. The CP concentration of grasses in the grazed sward by d 112 in 2001, however, was considerably lower than in the ungrazed plants, indicating a strong selection for higher CP by the end of the trial as plants went into reproductive phases.

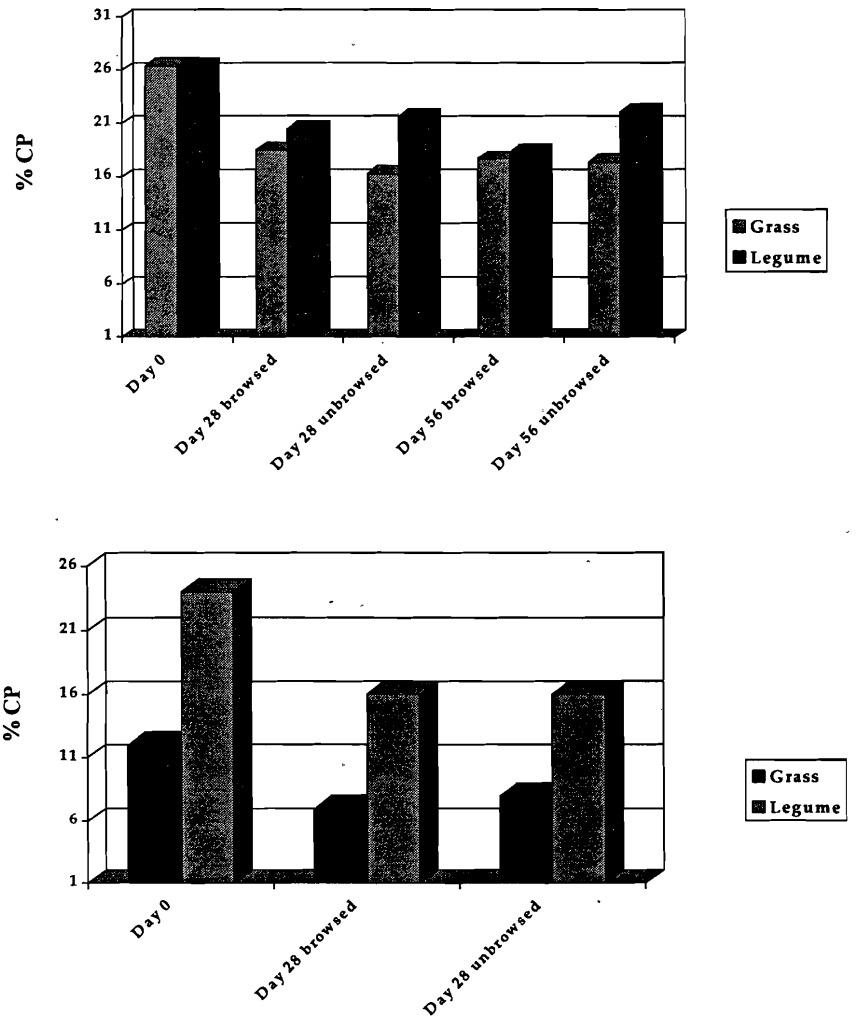

Figure 5. Crude protein (CP) concentration in herbage protected from or available to goats grazing a full-sun mixed grass/legume pasture in 2000 (top) and 2001 (bottom).

Conclusions/Implications

A comparison of cultivated pasture systems versus native range during the cool season indicates that cultivated, cool-season forages may have a promising future in regions of Texas where cool-season annuals are able to grow throughout the winter months. A mixture of annual grasses and legumes had a positive effect on animal gains, especially in low rainfall years. In addition, this mixture allowed greater selectivity for goats that appear to favor the grasses earlier in the season and the legumes later in the season as the bromes and ryegrass became lignified and produced seed heads. The exception to this was reported in the 1999 pre-trial when wheat was included and produced a palatable, high-energy seed head that the nanny kids selectively grazed.

This study also indicates that stocking rates should allow grazing pressure that permits adequate goat selection of forages high in CP. The 1999 pre-trial grass analyses showed, however, that grazing pressure may be particularly important when animals are allowed access after swards become mature late in the growing season and selection for high CP concentrations is more pronounced.

The cultivation of pecan grove under-story did not result in lower goat AWG compared to open, full-sunlight pastures. In the low rainfall years, there were no differences between these two systems despite lower herbage yields under the trees. In contrast, higher rainfall the second year resulted in greater animal gains under the pecans compared to the full sunlight pasture. There may, however, be differences in carrying capacity or goat-grazing days between mixed legume/grass pastures with and without a pecan over-story. Greater yields, especially in lower rainfall years, may favor greater production per acre in full sunlight but further research is required to confirm this as well as to determine ideal, long-term stocking rates.

Acknowledgements

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Effect of peanut meal or corn hominy on wethers pastured on coastal fertilized with high or low levels of N

J.P. Ott, J.P. Muir and L. Simms

ABSTRACT: Boer X Spanish wethers were tested at a producer's ranch for their grazing response to N-fertilized coastal bermudagrass in combination with peanut meal supplement during the summer and to dormant coastal bermudagrass in combination with corn hominy during the autumn. Higher levels of N fertilizer tended to increase both forage availability and crude protein levels, despite hay removal. During the drier year, increasing the level of peanut meal supplementation from 0.25% of body weight (BW) to 0.50% during the summer increased average daily gains (ADG) 12 and 18% for in the low and high N fertilized paddocks, respectively. The economic return of the higher level of peanut supplement was negative compared to the low levels. Feeding finishing wethers at 1.5 versus 0.75% of BW with corn hominy during the autumn months resulted in an average of 60% greater ADG over both years, although these weight gains were low (0.42-0.78 lbs/wk). The economic return for the high hominy supplement versus the lower level was positive, indicating possible usefulness of this corn byproduct for finishing older wether kids during autumn months before Christmas market peaks.

Key Words: Supplementation, Agro-industrial Byproducts, Bermudagrass, Fertilization

Sheep and Goat, Wool and Mohair CPR 2002. 70-76

Introduction

Within the Cross Timbers area, numerous acres have been planted in improved grass pastures, primarily for hay and/or cattle production. However, as urban populations spill out into this farmland, production units are continually being divided into smaller parcels making profitable cattle production less feasible. This fragmentation has promoted the growth of the goat industry on small units no longer suited for sustained cattle production. These non-traditional goat-producing units may eventually contribute significant goat production if adapted strategies are developed for the management of coastal bermudagrass pastures.

Linear increases in hay yields have been observed with increasing levels of N fertilization up to 300 lbs N in the Cross Timbers (Overman et al., 1993). Similar responses have been observed in crude protein (CP) concentration of bermudagrass (coastal and others) with increased levels of fertilization (Stichler and Bade, 1998). Studies have also found that increased amounts of N in coastal bermudagrass improve performance of livestock (Ocumpaugh et al., 1994). However, little is known about whether increasing levels of N fertilization on coastal results in enhanced performance of goats grazing those pastures.

Studies from around the world have shown that supplementing growing goats with protein-rich feeds can improve their performance on grass (Ketelaars et al., 1997; Ku-Vera, 1997), especially

as forage quality declines (Schacht et al., 1992). This improvement in animal performance has been attributed to either protein deficiencies within the rumen microbial population or protein and energy deficiencies within the animal itself. The main limitation to the use of feed supplements, however, is cost. By utilizing inexpensive and locally abundant agro-industrial byproducts such as peanut meal or corn hominy, goat producers in Texas can increase both the utilization of poor-quality grass forage as well as the quality of carcasses they sell to a market that is becoming more discerning.

Researchers at the Stephenville Texas Agricultural Experiment Station, in cooperation with local goat producers, are trying to determine if coastal bermudagrass pasture in the Cross Timbers area is appropriate for goats. The first portion of the study reported here evaluated the effect of two N fertilization levels (50 and 125 lbs N/acre) of bermudagrass pastures on forage production and gains of growing wethers from June through September. In addition, it also evaluated the effect of daily peanut meal supplementation of growing wethers at 0.25 and 0.5% body weight (BW) on those growing wethers. From October through early December, the effect of supplementing finishing wethers grazing dormant bermudagrass with corn hominy at 0.75 and 1.5% BW was also measured. The cost and economic return of the supplements was estimated, excluding the cost of labor, to give an idea of the economic viability of these supplements.

Materials and Methods

Forty-four Spanish X Boer cross wethers, 6 to 8 mo old, were obtained by Larry Simms of Three Way TX for each yr (2000 and 2001) from the first wk of June to the second wk of December. Goats were allowed a one-wk acclimation period prior to initiating peanut meal supplementation the first wk in June. The wethers, which started the trial with an initial average weight of 45 ± 8 lbs, were drenched every 28-d with an antheminic, while antibiotics were administered only when necessary to sick individuals. Water and salt were available at all times.

A 15.6-ac. coastal bermudagrass pasture belonging to Larry Simms and located in Erath County on fine sandy loam was used in this trial. Since this trial was carried out on a producer's land with the producer's goats, no controls were included in the interest of the owner. Controls normally provide a comparison between supplemented animals and unsupplemented animals or fertilized and unfertilized pasture. Since producers were unlikely to have unsupplemented goats or unfertilized pastures under these conditions, only high and low levels of peanut meal, corn hominy and N fertilizer were compared.

The 30-yr average precipitation for the area is 30 in. and rainfall at Stephenville (10 miles distance) during June - September, for 2000, 2001 and the 30-yr average was 7.3, 9.0 and 10.3 in., respectively. Exact rainfall at the study site was not recorded but was similar to that measured at Stephenville.

During the peanut meal supplement period, which lasted 12 wk, wethers were randomly assigned to four groups, with eleven goats in each study group. Each group was then assigned a treatment of low or high (0.25 or 0.5% of body weight, respectively) peanut meal supplementation and placed into a bermudagrass paddock that received a low or high (50 or 125 lbs\acre, respectively) N fertilization. This resulted in four different treatment combinations: high supplement/high fertilizer (HSHF), high supplement/low fertilizer (HSLF), low supplement/high fertilizer (LSHF), and low supplement/low fertilizer (LSLF).

Peanut meal with a guaranteed analysis of 45% CP and 80% total digestible nutrients was used as the supplement source during the warm-season when the grass was actively growing (June-September). Peanut meal was provided every afternoon at approximately 06:45 and goats were allowed 45 min to consume the supplement.

Corn hominy, furnished by Alliance Milling Co. with a guaranteed analysis of >9% CP and <7% fiber, was used as the supplement during the finishing portion of the trial (12 wk from October-December) when the coastal was dormant. The same 44 wethers (now averaging approximately 62 lbs) were assigned to two groups with equal representation from the 4 treatment combinations of the peanut meal supplementation, giving a total of 22 animals per treatment. One group was fed hominy equivalent to 0.75% BW and the second group was fed 1.5% BW.

During both trials, goats were weighed every fourteen d and, on days when the goats were weighed, supplementation was not offered until after all the goats had been weighed. Weight data collected was used to determine average daily gain (ADG) for each trial period each yr. Feed and fertilizer cost as well as gain information was used to determine the economic efficiency for each level of supplementation and fertilization.

The pastures were harvested for hay when forage availability exceeded the needed amount of the grazing animals. Soil sample recommendations were used to determine the 430 lbs/acre of 18-6-23 that was applied before goats were introduced in yr one. Following the removal of 32 tons of hay (over 2 tons/acre) in late spring of that yr, an additional application of 50 or 125 N lbs of 33-0-0 fertilizer was applied to the pastures, depending on the treatment. In yr two, 180 lbs/acre of 25-25-25 was applied to all the pasture with an additional 300 lbs/acre of 33-0-0 on the high N fertilizer paddocks. During this second yr, two cuttings removed a total of 22 tons of hay from the entire paddock. An additional 50 lbs N/acre and 125 lbs N/acre were applied to the low and high N paddocks, respectively, following each harvest.

Three cages, which excluded approximately 100 ft^2 each from grazing, were placed in each paddock. A 9-ft^2 sample was harvested from within and outside each enclosure on a monthly basis and dried to a constant weight at 55°C. Samples were then weighed and weights used to determine available grazed and ungrazed forage. The dried samples were then analyzed for CP, P, acid detergent fiber (ADF) and acid detergent lignin (ADL).

The effect of pasture fertilizer and peanut meal supplementation combinations as well as hominy supplementation on AWG were assessed via analysis of variance. Differences between the three treatment groups were considered significant at an alpha value of $P \leq 0.05$ unless otherwise specified. Means were separated using Duncan's least square residual and were considered different at $P \leq 0.05$.

Results and Discussion

Table 1 shows the forage available to the goats during the months of July through September of both yr. This does not take into consideration the forage removed as hay, which was not measured separately for each fertilizer sub-paddock. Looking only at forage outside the exclosures, the high N paddocks had more forage available to the goats during July than did the low N paddocks. This was not the case by August or September. During the first yr , which recived 20% less precipitation than the second yr, the ratio of forage outside exclosures compared to inside decreased faster over time (from 0.81 to 0.43 for July to September) in the high fertilizer paddocks, than did ratios in the low fertilizer paddocks (from 0.89 to 0.57 for the same period). This was not

the case in the second yr, indicating that coastal bermudagrass may not be able to fully utilize additional N during periods of moisture stress.

Table 1. Coastal bermudagrass forage standing biomass during two yr outside and inside exclosures in goat paddocks with high and low levels of nitrogen fertilizer

	July	August	September
	lbs herbage acre^{-1}		
2000			
Low Fertilizer Paddocks			
Inside	1707	1390	1401
Outside	1520	1199	797
High Fertilizer Paddocks			
Inside	2056	1829	1771
Outside	1658	1199	763
2001			
Low Fertilizer Paddocks			
Inside	1370	2238	1673
Outside	1195	1335	1049
High Fertilizer Paddocks			
Inside	2182	1461	1665
Outside	1381	924	1049

Late season average monthly nutrient concentration for the coastal bermudagrass, especially higher CP and lower ADL, were more favorable for adequate goat nutrition in the high N paddocks than in the low N paddocks. Although these differences may not appear to be large in the whole-plant analyses presented in Table 2, goat capacity for selective grazing may compound forage quality factors.

There was a tendency ($P = 0.15$) for goat AWG to respond to pasture fertilizer rates and peanut supplements depending on yr (Table 3). Weight gains were higher ($P = 0.001$) the second yr, most likely due to greater rainfall while a positive effect of greater supplementation was discerned only in the drier first yr. The positive response to high-N fertilization was stronger ($P = 0.02$), with wethers on those paddocks out-gaining those on low-N by 10% (1.37 lbs/wk) averaged over both yr and the two supplement levels.

There was also a tendency (supplement by yr interaction $P = 0.16$) for yr to influence wether response to autumn hominy supplement (Table 4). The difference between levels of supplement were smaller the first yr compared to the second. When averaged over both yr, however, the higher supplement resulted in 63% greater ADG (0.10 lbs/d/wether; P=0.001) than the lower supplement level. This was likely a reflection of diet substitution rather than supplementation as the bermudagrass went dormant and quality and quantity deteriorated.

Table 2. Nutrient concentrations of coastal grazed by goats during two yr in paddocks with high and low levels of nitrogen fertilizer during the second yr of the trial

	June	July	August	September
	% of Forage			
Low Fertilizer Paddocks				
Acid detergent fiber	35.1	38.1	36.7	37.3
Acid detergent lignin	4.50	5.51	5.11	6.27
Crude protein	11.1	7.1	9.8	12.5
Phosphorus	0.177	0.131	0.153	0.213
High Fertilizer Paddocks				
Acid detergent fiber	36.9	37.6	37.0	37.0
Acid detergent lignin	4.67	5.71	5.30	5.50
Crude protein	10.4	8.4	10.6	13.4
Phosphorus	0.178	0.147	0.168	0.195

Table 3. Average weekly gains (AWG) of wether kids on coastal bermudagrass fertilized at high and low levels and supplemented with peanut meal at 0.25 or 0.50% of body weight (BW) during two warm seasons*

	2000	2001
	AWG (lbs/wk/wether)	
Low Fertilizer Paddocks		
0.25% supplement	1.05	1.39
0.50% supplement	1.23	1.37
High Fertilizer Paddocks		
0.25% supplement	1.20	1.53
0.50% supplement	1.42	1.30

* Fertilizer by supplement by yr interaction $P = 0.15$.

Table 4. Average daily gains (ADG) of wether kids on dormant coastal bermudagrass supplemented with corn hominy at 0.75 or 1.50% of body weight (BW) during two autumns*

Supplement level	2000	2001
	ADG (lbs/d/wether)	
0.75% supplement	0.07	0.06
1.50% supplement	0.09	0.11

* Supplement by yr interaction $P = 0.16$.

Conclusions/Implications

Cost of bulk corn hominy in Stephenville in March, 2002, was estimated at $97/ton (4.85 cents/lb). Cost of peanut meal in March, 2002, was estimated at $198/ton (9.25 cents/lb). A comparison of high and low supplement feed costs (Table 5) indicates that the high level of peanut supplement was not economical whereas the high level of corn hominy supplement had a positive return on an additional lb LW gained. The net return per wether for the high peanut meal was likewise negative but was positive for the high corn hominy. Since the producer was unwilling to stress his animals in control treatments, the net return of the low or high levels of both supplements cannot be compared to unsupplemented wethers.

Table 5. Cost (feed only) and return (December market average of $0.95/lb wether LW) of supplementing wethers on high versus low levels of peanut meal during the summer or corn hominy during the autumn

Supplement	lbs feed	Cost ($)	Net Return	
	- - - per additional lb LW gained - - -			
High vs low peanut meal	33.4	3.09	($2.14)	
High vs low corn hominy	13.2	0.64	$0.31	
	lbs feed	Cost ($)	LW gain	Net Return
	- - - - - - - - - - per wether - - - - - - - - - -			
High vs low peanut meal	11.2	1.05	0.34 lbs	($0.72)
High vs low corn hominy	44.4	2.15	3.36 lbs	$1.04

These results raise additional questions that further feeding trials may be able to answer. Trials on-station including 0% supplement control animals will tell how much of a difference the lowest levels of supplement make on the goats. Another trial that should take place is a comparison between a straight energy supplement such as corn hominy and a protein concentrate such as peanut meal both during coastal growing season on younger wethers as well as during the dormant autumn season on both finishing as well as growing wethers.

Acknowledgements

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Effects of production systems and coats on performance, mohair growth and quality, and carcass traits of Angora male kids

J.W. Hruska, C.J. Lupton, J.E. Huston, K.S. Rhee, B.F. Craddock, W. Polk and F.A. Pfeiffer

ABSTRACT: Castrated Angora kids (112) approximately seven mo of age and weighing 59.8 ± 19.7 lb were used to compare the effects of three production systems and coats on performance, carcass traits, and mohair production and quality. The goats were assigned to feedlot (FL, 29), pasture (P, 27), and raised floor (RF, 56) treatments and coats were placed on half of the goats in each treatment. Goats in the RF and FL groups were fed *ad libitum*, while the P group was supplemented three times per wk for 4 mo. Fleece, live animal, and carcass weights and measurements were taken during and at the end of the trial. After 4 mo on experiment, the FL and RF goats were similar in body weight (BW), but heavier ($P < 0.05$) than P goats (78.1, 77.5, and 64.9 lb, respectively). A similar trend was present for carcass weights (35.1, 34.1, and 28.9 lb for FL, RF, and P, respectively). Dressing percentages were not different ($P > 0.05$) among treatments (~ 44.6%) but back fat thickness, body wall thickness, and hind leg circumference were all greater ($P < 0.05$) for FL and RF versus P goats. Goats in the FL and RF treatment also produced heavier, coarser, and longer ($P < 0.05$) fleeces than P goats (7.4, 6.9, and 6.1 lb; 32.7, 32.8, and 30.8 μm; and 5.0, 5.0, and 4.7 in, respectively). Overall, the coated kids produced higher ($P < 0.05$) yielding fleeces than those that were uncoated (73.2 versus 68.8%). However, no difference in yield was present between the coated and uncoated goats within the RF group, this being indicative of a relatively clean environment. No other effect of coat was significant. The economic analysis showed that none of the systems were profitable under the conditions of this experiment. Further analysis identified which variables would need to change in order for the systems to be profitable.

Key Words: Angora Goat, Mohair, Feeding Systems

Sheep and Goat, Wool and Mohair CPR 2002. 77-89

Introduction

The declining profitability of traditional production systems is a problem facing United States agriculture today. This is especially true in the ranching areas of West Texas. In 2000, Texas Agricultural Extension Service economists projected net returns of -$13.62, $36.77, $34.12, and -$98.09 per animal unit for cattle, sheep, meat goat, and Angora goat operations, respectively, in West Central Texas (Texas Agricultural Extension Service, 2000). The projected negative returns are particularly disconcerting when it is recalled that this region is considered one of the best in the United States for cattle and Angora goat production. The phase-out of the Wool Act and loss of wool and mohair incentive programs began in 1994. Over a two-yr period, the federal government first cut and then eliminated the program. With the loss of the incentive program and the negative projected and actual net returns, one can understand why ranchers have been down-sizing their Angora goat herds and even leaving the business all together. Since the phase-out began, Angora goat numbers have been steadily decreasing. In the time period between 1992 and 2001, the number of Angora goats in Texas showed an 87% decline from 2,000,000 to 260,000. Concurrently, mohair production decreased by 88%, while the value of the clip decreased by a factor of 69% (Texas Agricultural Statistics Service, 2001). The reported value of mohair sold in 2001 was down 63% from the previous yr. The recent economic data are somewhat distorted because only a low proportion of the clip has been sold in the past five yr. Consequently, most warehouses still have a large inventory of predominantly adult mohair. Neither the stockpile nor

this year's adult hair is being sold at the present time, while most of the kid and young goat hair production from the past four or five yr has been sold.

Without the traditional demands and markets for adult hair, it may be necessary for mohair quality (fineness, cleanliness, luster, and style) to be improved in order to access new markets. It might also be necessary to implement new production systems. One proposed system for producing higher quality fibers involves the use of housing equipped with raised, slatted floors. Wool quality and production of wether sheep has been increased using such techniques (Scarlett, 1993). The wool produced was finer, more uniform in fiber diameter, and contained almost no dirt and vegetable matter. In addition, coats were used to further increase cleanliness of the fleece. Prices were greatly increased when this higher quality wool was sold into niche markets. The same might be accomplished with mohair.

This project was designed to evaluate live animal performance, mohair quality and production, and carcass characteristics of castrated Angora kids on an indoor, raised floor system compared to that of contemporary goats in traditional feedlot and supplemented pasture production systems. Coats were tested for their effectiveness at producing cleaner, higher yielding fleeces in all three production systems.

Materials and Methods

One hundred twelve castrated Angora kids averaging 7 mo of age and weighing 59.8 ± 19.7 lb were obtained for this trial. The goats were fed a uniformity diet for three wk starting October 1, 2001. All kids had been shorn approximately six wk prior to this date. On October 22, 2001, the goats were weighed and assigned to treatment groups consisting of the feedlot (FL), pasture (P), and raised- floor barn (RF). Assignments were made in such a way that the average value and distribution of body weight (BW) were not different among the treatment groups. Coats were placed on half of the goats in each treatment group at this time. Again, the BW and distribution of goats with and without coats were not different ($P > 0.05$).

The FL treatment served as one control group and contained 29 kids that were placed in a feedlot and fed a typical feedlot ration (Table 1) on an *ad libitum* basis. Goats were checked and fed at 1315 daily. The kids had *ad libitum* access to clean, fresh water and salt.

Table 1. Dietary composition of feedlot ration L-1052*

Ingredient	Amount (%)
Cottonseed hulls	15.00
Alfalfa meal	5.00
Milo	68.50
Cottonseed meal	2.50
Soybean meal	2.50
Molasses	4.00
Ammonium chloride	0.75
Salt	1.00
Calcium carbonate	0.75

*Rumensin added at 20g active/ton

The P treatment consisted of 27 kids supplemented in the pasture as a second control group. The kids were supplemented with a salt-limiting ration (Table 2) at a rate of 3.5 lb per head on Monday, Wednesday, and Friday at 1345. This ration contained a vitamin/mineral premix the composition of which is given in Table 3.

Table 2. Composition of supplement ration L-1050 for goats on pasture*

Ingredient	Amount (%)
Alfalfa meal	4.6
Milo	67.5
Cottonseed meal	9.0
Soybean meal	4.6
Molasses	3.6
Ammonium chloride	0.7
Urea	0.2
Calcium carbonate	0.5
Vitamin/Mineral premix	0.2
Salt	9.1

*Rumensin added at 20g active/ton

Table 3. Dietary composition of vitamin/mineral premix

Ingredient	Amount (%)
Salt, plain	70.6
Potassium chloride 50%	19.1
Sulfur	5.0
TM, Manganous oxide, 60% Mn	0.6
TM, Zinc oxide, 72% Zn	0.5
Vitamin A, 30,000 IU/GM	0.7
Vitamin D, 30,000 IU/GM	0.1
Vitamin E 226,800 IU/lb	0.4
CTC, 100 g/lb	1.5
Molasses, cane	1.5

The goats were supplemented with a different ration (Table 4) at a rate of 5.0 lb per head after December 6, 2001.

Table 4. Composition of supplement ration L-1051 for goats on pasture*

Ingredient	Amount (%)
Alfalfa meal	4.6
Milo	74.3
Cottonseed meal	4.6
Soybean meal	2.2
Molasses	3.6
Ammonium chloride	0.7
Urea	0.2
Calcium carbonate	0.5
Vitamin/Mineral premix	0.2
Salt	9.1

*Rumensin added at 20g active/ton

Compared to the other two, the RF treatment is an innovative system in which 56 Angora kids were placed on the raised, slatted floor and offered a pelleted ration (Table 5) *ad libitum* for four mo. This ration was formulated to produce moderate daily gains and adequate mohair growth that would result in a minimum of 4.7 in of staple at the end of the trial. This group was observed each day at 1300 hr. At this time, the water trough was cleaned and goats were checked for any problems. Each goat in the treatment had free access to salt and water. All goats in all treatments were weighed at 28-d intervals to monitor changes in body weight and with the purpose of changing rations or supplements if gains were not adequate.

Table 5. Dietary composition of raised floor pelleted ration*

Ingredient	Amount (%)
Cottonseed hulls	20.00
Alfalfa hay	55.00
Barley grain	20.00
Molasses	4.00
Ammonium chloride	0.50
Salt	0.50

*Rumensin added at 20 g active/ton.

On January 28, 2002, each goat was shorn and the fleeces were individually packaged and taken to the Wool and Mohair Research Lab for evaluation. The fleeces were weighed to determine grease fleece weight (GFW). A set of staple samples (10) were removed from random positions on the greasy fleece and subsequently measured for "straightened" staple length using ASTM Standard Test Method D 1234 (ASTM, 2000b). The fleeces were then core-sampled (Johnson and Larson, 1978) and these samples were weighed, washed, dried, and reweighed to allow calculation of clean yield (CY) in accordance with ASTM Standard Test Method D 584 (ASTM, 2000a). Clean

fleece weight (CFW), and clean fleece production per unit of BW (CFW/BW) were also calculated. The scoured mohair was then subsampled with a minicorer and the resulting snippets (~ 1.8mm lengths of fiber) were conditioned and measured for average fiber diameter (AFD), fiber curvature (FC), and medullated fibers using the Optical Fiber Diameter Analyser 100 (OFDA; IWTO, 2000).

Three wk after shearing, the goats were slaughtered on February 5, 2002. This time period was necessary for the hair to regrow and shearing wounds to heal in an attempt to obtain a pelt credit. After 24 hr in the cooler, carcass characteristics were measured, recorded, and calculated. These traits included carcass weight, dressing percentage, back fat thickness, body wall thickness, and hind leg circumference.

Statistical analysis

The General Linear Model of SAS (SAS Inst. Inc., Cary, NC) was used to determine the effects of treatment and coat (and the interaction) on all measured body, fleece, and carcass traits. Least squares means were calculated for each trait by treatment and coat. Due to resource limitations, the treatment groups were not replicated, the kids used in the study may not have been truly representative of the breed, and the specific pasture conditions experienced during the study can never be duplicated. The significance levels used to establish differences among means reported in the tables were calculated assuming each animal was an experimental unit. Thus, some caution may be required when interpreting the results.

Results and Discussion

Treatment effects

The effects of treatment on growth and carcass characteristics are summarized in Table 6. At the beginning of the study and by design, the average body weight of goats in each treatment did not differ ($P > 0.05$). At the end of the trial, there was no difference between the weights of the FL and RF groups, however they were heavier ($P < 0.05$) than the P group (78.1, 77.5, and 64.9 lb, respectively). These weight differences are also reflected in the ADG for both the FL and RF groups that had a higher ($P < 0.05$) ADG than the P group (0.17, 0.17, and 0.05 lb/d, respectively). It was very dry before and during the trial and the pasture did not produce much vegetation, therefore, a major part of the diet of the P goats probably consisted of the salt-limiting supplements that were fed three times each wk. The FL and RF groups also produced heavier

Table 6. Treatment effects on growth and carcass properties (least squares means)

	Feedlot	Pasture	Raised Floor
N	29	27	56
Initial weight, lb	60.1	59.9	59.9
Shorn final weight, lb	78.1[a]	64.9[b]	77.5[a]
Average daily gain, lb/d	0.17[a]	0.05[b]	0.17[a]
Carcass weight, lb	35.1[a]	28.9[b]	34.1[a]
Dressing percentage, %	44.8	44.3	43.9
Back fat thickness, in	0.07[a]	0.05[b]	0.07[a]
Body wall thickness, in	0.86[a]	0.61[b]	0.79[a]
Hind leg circumference, in	2.04[a]	1.97[b]	2.04[a]

[a,b] Within a row, means with different superscripts differ ($P < 0.05$).

($P < 0.05$) carcasses than did the P group (35.1, 34.1, and 28.9 lb, respectively), which was predictable from the final weights. Dressing percentages were not different ($P > 0.05$) among the treatments, which was a different result than in the lamb trials conducted previously using these

three production systems (Lupton *et al.*, 2001). In the sheep trials, the RF group consistently had lower dressing percentages (apparently) due to more gut fill from less activity and a higher roughage diet. Back fat thickness, body wall thickness, and hind leg circumference for FL and RF goats were all greater ($P < 0.05$) than for P goats. Given the range conditions and the amount and type of supplements provided, the results were predictable. At the time of slaughter, an observation was made but not fully quantified. The P carcasses contained much less fat around the kidneys (< 2 lb) compared to the carcasses from the FL and RF treatments (~ 3 to 5 lb). Thus, most of the observed differences in the carcass weights would be accounted for by the internal fat in this region and not by more muscle and (or) bone.

Mohair growth and properties as affected by treatment are shown in Table 7. The FL and RF groups produced heavier ($P < 0.05$) fleeces than did the P group (7.4, 6.9, and 6.1 lb, respectively). The treatments produced no differences in clean yield; consequently, the FL and RF groups also produced heavier clean fleeces than did the P group (5.1, 4.9, and 4.3 lb, respectively). This was not the case when mohair production was based on unit of body weight. In this case, treatments produced no differences. The goats in each treatment produced the same amount of mohair in relation to their BW (~ 0.07 lb/lb LW, $P > 0.05$). One advantage present in the P group

Table 7. Treatment effects on mohair growth and properties (least squares means)

	Feedlot	Pasture	Raised floor
N	29	27	56
Grease fleece weight, lb	7.4[a]	6.1[b]	6.9[a]
Clean yield, %	70.3	71.2	71.5
Clean fleece weight, lb	5.1[a]	4.3[b]	4.9[a]
Clean fleece weight, lb/lb BW	0.07	0.07	0.06
Average fiber diameter, μm	32.7[a]	30.8[b]	32.8[a]
Standard deviation of fiber diameter, μm	9.0[a]	8.3[b]	8.7[a]
Coefficient of variation of fiber diameter, %	27.5	27.0	26.7
Total medullated fibers, per 10,000 fibers	111	117	104
Objectionable fibers, per 10,000 fibers	13	9	11
Flat fibers, per 10,000 fibers	64[a,b]	77[a]	56[b]
Average fiber curvature, °/mm	16.8[b]	18.8[a]	17.3[b]
Standard deviation of fiber curvature, °/mm	20.6[b]	22.7[a]	21.8[a,b]
Coefficient of variation of fiber curvature, %	123.5	121.4	125.9
Average staple length, in	5.0[a]	4.7[b]	5.0[a]
Standard deviation of staple length, in	0.4	0.3	0.4
Coefficient of variation of staple length, %	7.1	6.9	7.2

[a,b] Within a row, means with different superscripts differ ($P < 0.05$).

was that these goats produced fleeces containing finer fibers than the other two groups. However, all groups produced mohair that was coarser than the traditional description of spring kid mohair, i.e., 29.9 μm = maximum AFD even though the animals age was < 12 mo. The economic implications of producing mohair > 30 μm are quite serious because hair coarser than 30 μm is typically worth substantially less than hair < 30 μm. The total medullated and objectionable (kemp) fibers did not differ among treatments, but the P goats contained more ($P < 0.05$) flat fibers

than the FL and RF groups. The P goats produced staples having slightly higher ($P < 0.05$) average fiber curvature than those of the FL and RF groups. Higher angles of curvature indicate smaller crimps or waves in the staple. These in turn are associated with finer mohair. In fact, the P group sheared finer fleeces than the other-two treatments so the higher curvature measurements were predictable. Table 7 shows a great amount of variation among fibers, within a sample, in terms of fiber curvature. This is typical of mohair which, compared to wool, has very little crimp that is quite variable from base to tip and among staples (locks). The FL and RF groups sheared fleeces containing longer (~ 0.3 in, $P < 0.05$) staple lengths than the P group. This extra staple length together with the coarser fibers contributed to more but less valuable mohair being grown by the FL and RF groups compared to the P group. There were no differences among treatments in the uniformity (SD and CV) of the staple lengths.

Coat effects

The coats that were fitted to half the goats in each treatment did not affect any of the measured or calculated traits of growth and carcass properties as shown in Table 8. Based on earlier work with lambs, it would be expected that the coats would not affect the growth performance of castrated Angora goats (Lupton *et al.*, 2001). Table 9 shows the anticipated result of cleaner fleeces being produced by the coated goats. This was achieved without affecting or harming any of the other traits measured in the experiment.

Table 8. Coat effects on growth and carcass properties (least squares means)

	Coated	Uncoated
N	57	55
Initial weight, lb	60.1	59.8
Shorn final weight, lb	73.5	73.5
Average daily gain, lb/d	0.13	0.13
Carcass weight, lb	32.9	32.4
Dressing percentage, %	44.6	44.1
Back fat thickness, in	0.07	0.06
Body wall thickness, in	0.76	0.75
Hind leg circumference, in	20.2	20.1

Table 9. Coat effects on mohair growth and properties (least squares means)

	Coated	Uncoated
N	57	55
Grease fleece weight, lb	6.6	7.0
Clean yield, %	73.2[a]	68.8[b]
Clean fleece weight, lb	4.8	4.7
Clean fleece weight, lb/lb BW	0.07	0.07
Average fiber diameter, μm	32.1	32.1
Standard deviation of fiber diameter, μm	8.6	8.8
Coefficient of variation of fiber diameter, %	26.7	27.5
Total medullated fibers, per 10,000 fibers	110	113
Objectionable fibers, per 10,000 fibers	12	10
Flat fibers, per 10,000 fibers	64	68
Average fiber curvature, °/mm	17.7	17.5
Standard deviation of fiber curvature, °/mm	21.5	21.9
Coefficient of variation of fiber curvature, %	121.9	125.3
Average staple length, in	4.9	4.9
Standard deviation of staple length, in	0.4	0.3
Coefficient of variation of staple length, %	7.3	6.8

[a,b] Within a row, means with different superscripts differ ($P < 0.05$).

Effects of coat within treatment

The data in Table 10 simply confirm that coats had no effect on body weight, carcass weight, or carcass properties in any of the three treatments. Table 11 shows an interesting point. Within the FL and P treatments the coated goats had much higher (~ 6%, $P < 0.05$) clean yields compared to the uncoated animals. The RF group showed no difference in clean yield between the coated and uncoated. This indicates that compared to FL and P, the raised floor system is a cleaner environment being free of dust and vegetable matter, therefore producing a cleaner fleece even without the use of coats. Even though there is no statistical comparison between the coated (only) goats in the three systems, it is observed that the FL and P goats had a higher clean yield than the RF goats. This is because the mohair on the areas not covered by the coats (legs, neck, and bellies) of the coated RF goats was contaminated with fecal material that did not fall through the slatted floor. These same areas of the FL and P goats were relatively clean. The table also shows some other small and, at this point, unexplained differences within the FL group. The coated muttons were more uniform in their fiber curvature, but the uncoated goats were more uniform in their staple length.

Table 10. Effects of coat within treatment on growth and carcass properties (least squares means)

	Feedlot		Pasture		Raised Floor	
	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated
N	15	14	14	13	28	28
Initial weight, lb	60.5	59.6	59.3	60.6	60.6	59.1
Shorn final weight, lb	79.7	76.6	64.4	65.5	76.5	78.6
Average daily gain, lb/d	0.18	0.16	0.05	0.05	0.15	0.18
Carcass weight, lb	36.1	34.0	28.7	29.0	33.9	34.3
Dressing percentage, %	45.2	44.4	44.6	44.1	44.1	43.6
Back fat thickness, in	0.08	0.07	0.05	0.04	0.07	0.07
Body wall thickness, in	0.87	0.85	0.62	0.59	0.78	0.80
Hind leg circumference, in	20.4	20.4	19.8	19.6	20.4	20.4

Table 11. Effects of coat within treatment on mohair growth and properties (least squares means)

	Feedlot		Pasture		Raised Floor	
	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated
N	15	14	14	13	28	28
Grease fleece weight, lb	7.1	7.6	5.7	6.5	7.1	6.7
Clean yield, %	73.5[a]	67.1[b]	74.1[a]	68.3[b]	72.0	71.0
Clean fleece weight, lb	5.1	5.0	4.1	4.4	5.0	4.8
Clean fleece weight, lb/lb BW	0.06	0.07	0.06	0.07	0.07	0.06
Average fiber diameter, µm	32.9	32.5	30.5	31.0	32.9	32.7
SD of fiber diameter, µm	8.7	9.3	8.1	8.5	8.8	8.7
CV of fiber diameter, %	26.6	28.4	26.5	27.6	27.0	26.5
Total medullated fibers/10,000	108	114	116	119	104	105
Objectionable fibers/10,000	16	9	8	9	11	11
Flat fibers per 10,000 fibers	56	72	78	75	57	56
Average fiber curvature, °/mm	17.0	16.5	18.8	18.8	17.3	17.3
SD of fiber curvature, °/mm	20.3	20.9	22.9	22.6	21.4	22.1
CV of fiber curvature, %	119.6[b]	127.3[a]	122.2	120.6	123.8	128.1
Average staple length, in	5.1	5.0	4.7	4.7	4.9	5.1
SD of staple length, in	0.4	0.3	0.3	0.3	0.4	0.4
CV of staple length, %	7.9[a]	6.3[b]	7.0	6.7	7.0	7.3

[a,b] Within a treatment and row, trait means with different superscripts differ ($P < 0.05$).

Economic Considerations

A budget scenario, Table 12 (originally designed by Texas Cooperative Extension Economist Wade K. Polk), was used to compare the net income per head of the three production systems. This takes into account the actual costs of feed, labor, and the amortized cost of building feedlot pens and a raised floor facility along with the cost of a grass lease on pasture. Using the actual expenses incurred in this study, FL goats had a greater return on their carcass since they were the heaviest followed by the RF and then the P goats. The mohair produced in this study will not sell as high as originally anticipated since it measured > 30 μm and will not be classified as kid hair. The feed cost for the RF group was greater than for the other two treatments because it was a custom, pelleted ration that had to be transported to San Angelo from Fort Stockton. Pellets are considered to be essential in the RF system to minimize fleece contamination by feed dust. In this scenario, net income per head in all systems was negative with the RF losing the most money, followed by P and FL.

Table 13 shows a commercially more realistic and optimistic budget for the three feeding systems and indicates incomes and expenses that would need to be present for any of these systems to be profitable. This spreadsheet predicts net income when structure and lease costs are omitted from the calculations. This approach is basically for "cash flow" or "gross margin" purposes only. The death loss, labor, and mileage are our best estimates of what might reasonably be expected when caring for a 200-head flock. In this scenario, each group would receive a commercial ration of the same value with the FL and RF groups consuming about the same quantity while the P group would be supplemented with about one third that amount considering pasture conditions to be better than in the current experiment. Feed price is that currently and locally available for goat feed. Goats would be purchased at ~ 50 lb BW about a month after they were sheared and weaned. In turn, they would be killed at a lighter weight (~ 65 lb) to optimize return from carcass and ensure adequate fineness of kid mohair. This would be achieved by modification of diet to produce slower growth. In the actual scenario (Table 12), the goats were purchased too late and were allowed to grow too much, producing a relatively large and less desirable carcass. Table 13 shows a hypothetical scenario in which goats are purchased earlier having smaller BW and at a lower price. If these goats were grown out at a slower rate and with better timing of their sale, it is conjectured that a higher price might be obtained. It would still be necessary to feed for ~ 5 mo to ensure adequate staple length for commercial and niche markets. Consequently in this scenario, the mohair prices are higher than those reported in Table 12. The prices used for the FL and P groups reflect current prices being paid for kid hair. The price assigned to the RF group is what might reasonably be expected if the hair were marketed and sold into a niche market such as hand spinning. Prices paid for offal and pelts were also added to account for normal prices being received. The fleece testing would only be required for the RF group because hand spinners will be targeted to purchase this hair and this is the cost to measure AFD, which is of some interest to these buyers. The cost of mohair packaging for the RF is also higher since these fleeces would be offered in 2 lb individually packaged packets. Mohair marketing commission is a percentage that goes to the warehouse once the mohair is sold. In this scenario it was not applied to the RF mohair because the producer is expected to personally sell this mohair to the hand spinners. Coats would be worn by the RF goats to ensure production of cleaner mohair. Medication cost takes into account deworming the goats upon arrival and tetanus shots after castration. Cost of slaughter is the normal, local price at this time, and had to be paid in the actual scenario to get the carcass data. To avoid this cost in the commercial scenario, one could take his chances at the auction. Labor and fuel costs are calculated according to the length of time the goats are on feed. These optimistic/realistic prices just show the potential of each of the production systems for offering a positive return to the feeder.

If more desirable and valuable goat meat and mohair could be produced using the values outlined in the commercial/optimistic scenario, obviously a producer could make money using any of the three systems. One thing this scenario identifies is the potential to make significantly more money if the producer has the right product and is able and willing to market it himself.

Table 12. Budget scenario for Feedlot, Pasture, and Raised Floor feeding programs-actual and estimated values

	Feedlot	Pasture	Raised Floor	
Actual and estimated values				
Death loss (200 hd flock)	0.00%	0.00%	0.00%	Actual
Labor (hr/d)	0.25	1	0.25	Actual
Mileage (miles/d)	0.5	9	0.5	Actual
Lease property (annual)	0	$2,000.00	0	Estimated
Carcass Prices Received ($/lb)	$1.53	$1.53	$1.53	Actual
Kid Prices Paid ($/lb)	$0.91	$0.91	$0.91	Actual
Income ($/Hd)				
Meat	$53.63	$44.16	$52.19	Actual carcass weight x average carcass price
Mohair	$18.48	$15.28	$17.25	Actual average fleece weight x estimated price paid ($2.50/lb)
Offal	$0.00	$0.00	$0.00	
Pelt	$0.00	$0.00	$0.00	
Total Income per Head	**$72.10**	**$59.43**	**$69.44**	
Expenses ($/Hd)				
Purchase Cost	$54.60	$54.60	$54.60	Actual initial weight (60 lb) x $0.91/lb
Death loss	$0.00	$0.00	$0.00	Death loss% x number of head - 200 x average total $'s/hd ÷ 200 hd
Feed Cost	$18.39	$11.20	$25.44	Actual total pounds fed/hd x actual cost of feed/lb
Lease property (annual)	$0.00	$10.00	$0.00	400 acres x $5.00 per acre ÷ 200 head
Shearing cost	$1.85	$1.85	$1.85	Actual
Fleece testing	$0.00	$0.00	$0.00	$7.50 for AFD if measured in USA
Cost of Packaging Mohair	$0.30	$0.30	$2.25	15 min. labor x $6.00/hr + $0.10/bag x 4 bags
Mohair Marketing Commission	$1.29	$1.07	$0.00	7% of mohair value
Coat Cost	$1.00	$1.00	$1.00	$6.00/coat with a 3 yr expected coat life, half of animals coated
Vet/medication costs	$1.00	$1.00	$0.50	
Slaughter Cost	$9.00	$9.00	$9.00	
Labor	$1.13	$4.50	$1.13	Labor hr/d x days to slaughter, 150 x $6.00 per hour ÷ 200 hd
Fuel Cost	$0.04	$0.68	$0.04	Miles traveled x days to slaughter, 150 ÷ 15 mpg x $1.50/gallon ÷ 200 hd
Structure Cost	$3.41	$0.00	$19.64	Annual payment ÷ 200 hd
Total per Head Cost	**$92.00**	**$95.19**	**$115.44**	Initial cost of $4479.80 for feedlot and $28539.94 for raised floor barn amortized over 10 yr at 9% interest
Net Income per Head	**-$19.90**	**-$35.76**	**-$46.00**	

Table 13. Budget scenario for Feedlot, Pasture, and Raised Floor feeding programs - commercial and optimistic

	Feedlot	Pasture	Raised Floor	
Assumptions				
Death loss (200 hd flock)	3.00%	3.00%	1.00%	Estimated
Labor (hr/d)	0.25	1	0.25	Estimated
Mileage (miles/d)	0.5	9	0.5	Estimated
Lease property (annual)	$0.00	$0.00	$0.00	All property owned
Carcass Prices Received ($/lb)	$1.75	$1.75	$1.75	Estimated for 65 lb LW billie kids
Kid Prices Paid ($/lb)	$0.95	$0.95	$0.95	Estimated for 50 lb billie kids
Income ($/Hd)				
Meat	$50.58	$50.58	$50.58	Estimated carcass weight (28.9 lb) x average carcass price ($1.75/lb)
Mohair	$37.50	$37.50	$75.00	Estimated fleece weights and prices received
Offal	$0.50	$0.50	$0.50	
Pelt	$7.00	$7.00	$7.00	
Total Income per Head	**$95.58**	**$95.58**	**$133.08**	
Expenses ($/Hd)				
Purchase Cost	$47.50	$47.50	$47.50	Actual initial weight (50 lb) x $0.95/lb
Death loss	$2.87	$2.87	$1.33	Death Loss% x Number of head (200) x average total $'s/hd ÷ 200 hd
Feed Cost	$16.16	$5.40	$16.16	Actual total pounds fed x actual cost of feed/lb
Lease property (annual)	$0.00	$0.00	$0.00	All property owned
Shearing cost	$1.85	$1.85	$1.85	Estimated
Fleece testing	$0.00	$0.00	$7.50	$7.50 for AFD if measured in USA
Cost of Packaging Mohair	$0.30	$0.30	$1.90	15 min. labor x $6.00 per hour + $0.10/bag x 4 bags
Mohair Marketing Commission	$2.63	$2.63	$0.00	7% of mohair value
Coat Cost	$0.00	$0.00	$2.00	$6.00/coat with a 3 yr expected coat life
Vet/medication costs	$1.00	$1.00	$0.50	Estimated
Slaughter Cost	$9.00	$9.00	$9.00	Estimated
Labor	$1.13	$4.50	$1.13	Labor hrs/d x days to slaughter, 150 x $6.00/hr ÷ 200 hd
Fuel Cost	$0.04	$0.68	$0.04	Miles traveled x days to slaughter, 150 ÷ 15 mpg x $1:50/gallon ÷ 200 hd
Structure Cost	$0.00	$0.00	$0.00	All facilities owned and paid for
Total per Head Cost	**$82.47**	**$75.71**	**$88.91**	
Net Income per Head	**$13.11**	**$19.86**	**$44.17**	

Implications

The effects of three different production systems (feedlot, pasture, and raised floor) and coats were determined on mohair growth and quality of Angora male kids. The FL and RF goats produced heavier, longer, and coarser fleeces than did the P group due to better planes of nutrition. Concurrently, Angora kid growth and carcass characteristics were evaluated in each of the three production systems. The RF system did not produce a measurably superior carcass compared to the FL nor did it produce superior (finer, cleaner) mohair. Only one way was identified to increase the desirability and possibly value of mohair and that was to place a coat on the goat. In two of the systems tested (FL and P), this action produced markedly cleaner fleeces. Requirements for profitable production and marketing systems were identified for Angora goats. A more profitable system requires better management and better timing than was available or exhibited in this study. Commercial feeders must adjust their feed so that goats gain weight slowly while producing a fine (< 30 μm) fleece with adequate staple length.

The results of this study indicate a need for further modification and evaluation of rations and of the raised floor system itself. Specifically, the floor needs to allow for more efficient release of fecal material. The use of coats proved to produce cleaner fleeces in the traditional systems (FL and P) but not in the RF system, which is a relatively dirt and dust-free environment. The FL and RF groups did produce heavier carcasses and fleeces than the P group given the conditions of the past yr (Winter 2001-2002). The pasture had very little forage and the majority of the goats' diet was supplemented. Taking all factors into account, optimal timing of purchasing and selling goats (buy low, sell high; while allowing enough time for mohair growth) is probably the most critical aspect for a profit to be realized in this business. The goats must receive a ration conducive to fine mohair production but also a slow BW gain to produce fiber and meat having optimum desirability and value. With further research and time these expectations should be attainable.

Acknowledgements

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Goat performance, forage selectivity and forage quality dynamics in three cultivated warm season pastures in north-central Texas

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ABSTRACT: Boer X Spanish does averaging 55 lbs were evaluated to determine average daily gain (ADG) and selectivity for six legumes, redroot pigweed, and crabgrass grown in full sun grass-only (FSG), full sun mix (FSM), and pecan grove shaded mix (SM) pastures during two warm seasons. Rainfall during the trial for both years was well below the 30-yr average for the warm season in north central Texas. Goats in the FSM obtained the highest (0.22 lbs day^{-1}) and the FSG goats the lowest ADG (0.01 lbs day^{-1}) during the low rainfall yr. The animals in both the SM and FSG pastures had greater ADG's whereas FSM animals were unchanged the second, higher rainfall yr, indicating that there was competition for moisture between the herbaceous forages and the pecan trees when rainfall was low and that crabgrass monocultures require more soil moisture to maintain animal gains. Legume percentage composition decreased over time for both mixed treatments in both yr, indicating goat selection for this component. The FSM pasture had the greatest standing, ungrazed forage (900 lbs ac^{-1}) the first yr, while FSG forage was greater (3900 lbs ac^{-1}) the second yr. Forbs tended to survive longer in FSM than in the SM while the grass component tended to increase in both pastures with time. Herbage analyses indicated that CP tended to decrease over time, at least partially due to animal selection.

Key Words: Goat, Forage, Grazing, Legume, Pigweed, Crabgrass

Sheep and Goat, Wool and Mohair CPR 2002. 90-98

Introduction

With roughly 1.4 million head, Texas is the leading state in goat production, representing a substantial component of the Texas agricultural economy (Texas A&M Extension Animal Science [TAMEAS], 1999). With the number of goats in the region increasing, sustainable cultivated forage systems with forbs as planned components may be able to support expansion of this industry without overstocking native pastures.

Use of pure grass range or pastures may not provide the best forage classes for a mixed-browsing animal such as goats (Lusigi et al., 1984). Utilization of alternative production systems, including cultivated silvo-pastoral pastures under the many pecan orchards in the Cross Timbers, may improve meat goat performance. Cultivated herbaceous grass-legume silvo-pastoral systems have been effectively used with goat husbandry elsewhere (Rai et al., 1998) but constitute an underutilized alternative in north central Texas.

This study compared animal-plant interactions in three different systems. The first objective was to compare grass-forb mixes under pecan canopies and in full sunlight. The second objective was to compare full sunlight grass-forb mixes with full sunlight grass-only pasture receiving higher

N fertilizer rates. Herbage yields, season duration, goat selectivity and animal gains were evaluated as a first step towards developing cultivated pasture systems specifically designed for goats.

Materials and Methods

The production systems studied consisted of a 2-acre annual grass-only pasture exposed to full sun (FSG), a 7-acre annual grass-pigweed-legume system under full sun (FSM), and a 4-acre annual grass-pigweed-legume system under shade (SM). The shaded mixed system was established within a mature pecan grove with a density of 42 trees $acre^{-1}$.

A single pasture representing each production system and treatment was established at the Texas Agricultural Experiment Station in Stephenville, Texas. The study was initiated in 1999 (7/14/99 through 9/13/99) and repeated in 2000 (6/12/00 through 8/21/00). In both yr, each pasture was lightly disced, seed was broadcast and packed and allowed 30 - 45 d, depending on precipitation, for establishment. Cultivated species included 'Red River' crabgrass [*Digitaria ciliaris* var. Red River], 'Ironclay' cowpea [*Vigna unguiculata*], "Tecomate" lablab [*Lablab purpureus*], Illinois bundleflower [*Desmanthus illinoiensis*], rayado bundleflower [*Desmanthus virgatus*], soybean [*Glycine max*], showy partridgepea [*Chamaecrista fasciculata*], and redroot pigweed [*Amaranthus retroflexus*]. Crabgrass and pigweed are typically considered weeds in the region but favorable forage quality combined with self-reseeding capabilities make these annuals promising for goat pastures (Dalrymple, 1983; Stordahl et al, 1999). Seeding rates were equal on a per acre basis and were calculated to give each species similar seeding proportion based on recommended seeding rates. Urbana® "cowpea type" inoculant was directly added to all legume seeds and the seed thoroughly mixed prior to planting. Following germination, the FSM and SM treatments received 26.7 lb N ac^{-1}, and the FSG received 39.3 lb N ac^{-1} as ammonium nitrate. A higher application rate of ammonium nitrate was applied to the FSG treatment because of the lack of legume. Application rates were based on prior soil testing, with mixed grass-forb pastures receiving less N to favor legume competitiveness.

Mr. Bub Hooten, of Lometa, TX, supplied 5-8 mo old Boer x Spanish cross does averaging 55 lbs. The FSM, SM, and FSG paddocks were stocked with 14, 8, and 4 goats, respectively. Each pasture was stocked at a uniform stocking rate of close to 2 goats ac^{-1}. Initial visual estimates indicated that, at this stocking rate, sufficient herbage would be available for selective grazing by the goats. Goats in each system were weighed three d after adapting to their respective system and this initial weight was used as a reference point for subsequent weights. Each goat was then weighed at two-wk intervals and data obtained was used to estimate fortnightly and season-long average daily gain (ADG) as lbs weight gain $goat^{-1}d^{-1}$. For this aspect of the study, each goat was considered a replication.

Forage quality and composition for each pasture was determined using sampling transects across each system at the same time intervals as the goat weights. Plant quality indicators measured as percentage of DM included acid detergent fiber (ADF; Van Soest and Robertson, 1980), cellulose, lignin, nitrogen (N; reported as crude protein by multiplying by 6.25)(A.O.A.C., 1990), and phosphorous (P) concentration. Mineral concentration of the digestate was performed utilizing semi-automated colorimetry (Hambleton, 1977) with a Technicon Autoanalyzer II. These N, P, and Fiber assay procedures comply with the official methods of analysis from the A.O.A.C. (A.O.A.C. 1990, method 7.015). Five grazing exclosures of 25 ft^2 were randomly placed within each treatment

except the SM treatment, where three exclosures were randomly placed beneath the mature pecan overstory, and three were placed in the partially shaded interspace between tree canopies to estimate differences in total yield within the same treatment. The center 10 ft^2 of each exclosure was harvested at the end of each year's trial to estimate total DM yields and provide a comparison to forage plant composition outside the exclosures.

Goat ADG was analyzed to detect significant differences across and within observation periods among pasture systems and yr. Species composition, herbage on offer, and forage composition was utilized as supportive data only, due to the lack of primary treatment (pasture) replication. Fischer's F-protected LSD was utilized to separate treatment means for the ADG data.

Results and Discussion

Goat Performance

There was a yr by pasture system interaction ($P \geq 0.05$) for season-long ADG (Table 1). Differences between yr were likely a result of variable precipitation patterns and consequent herbage availability for selection (Figures 1 and 2). Week two ADG data was excluded from the analysis in 1999 because of stress caused by coyote predation, ultimately affecting goat performance.

Table 1. Season-long average daily gains (ADG) for goats grazing full sun grass-only (FSG), full sun mixed forb/grass (FSM), and shaded mixed forb/grass (SM) pasture systems over two warm-seasons in Texas

Treatment	1999	2000	Average
	ADG lbs d^{-1}		
FSG	0.01	0.16	0.09
FSM	0.22	0.20	0.21
SM	0.09	0.22	0.16
Average	0.11	0.19	

Year by treatment interaction P=0.05, $LSD_{0.05}$=0.029 lbs d^{-1}

The FSM treatment produced the highest and most consistent total ADG both years, considering the differences in forage yields and crude protein concentrations in the two yr. Even though the accessible forage base consisted of a mixed species composition in both the SM and FSM pastures, competition between herbaceous plants and the pecan trees in the SM pastures for limited soil moisture was more acute in 1999, resulting in poorer SM animal performance that year. Goats in both the FSG and SM treatments had higher ADG in 2000. The goats in the FSG treatment produced the lowest total ADG both years. This low total ADG, when compared to the mixed plant species treatments, may be attributed to the monoculture of grasses and the exclusion of any alternate food. The goats in the FSM and SM pastures were able to select from legumes and pigweed plants that were higher in CP and lower in fiber longer in the season. Despite the fact that the crabgrass in the FSG was able to maintain higher crude protein concentrations longer than either of the other pastures, the fiber concentrations of the grasses were also higher which likely

decreased digestibility and passage rates. With the increase in fiber concentrations toward the end of the experiment, reductions in ADG may also have been caused by a reduced energy component in the diet.

Average daily gains in 2000 differed considerably from the 1999 values primarily because soil moisture conditions were better in 2000 as a result of 79% higher rainfall (Figure 1). The FSG season-long ADG was lower than both FSM and SM treatments (Table 1; $P < 0.05$) primarily because of poor animal performance eating dry grass in the FSG week 8. The higher season-long ADG obtained by goats in the FSM and SM treatments compared to 1999 can be explained by the higher June precipitation that favored plant establishment and greater persistence. Total ADG in the 2000 SM treatment was also higher because of less competition for soil moisture between the forage and the pecan trees. The result was not only higher ADGs (except for FSM animals) but a longer season as well.

Herbage Available, 1999

Dry matter (DM) availability was affected by lower-than-normal precipitation during the 1999 growing season. Total 1999 rainfall (Figure 1) during the experiment (April-September) was 5.3 in., 55% of the 30-yr average, mostly in low intensity showers, generally followed by high temperatures and winds that increased total evapo-transpiration losses. Estimated standing, ungrazed DM herbage by wk 8 in the FSG, FSM, and SM treatments was 723, 928, and 419 lbs ac^{-1}, respectively (Figure 2). Lower herbage yields in the SM treatment may have been due to competition with the pecan trees for limited subsoil moisture. However, if SM exclosures in full-sun are excluded and DM availability in the SM is estimated using only shaded exclosures, SM herbage yields (80 lbs ac^{-1}) are much lower than the other treatments.

The proportion of grass in the FSM increased over time (Figure 3). Conversely, legumes within the same treatment decreased over time, indicating a selective preference for legumes by goats while pigweed proportion decreased in the FSM but to a lesser degree than the legumes. In the SM treatment, grass percentage also increased over time but to a lesser degree, indicating decreasing preference by goats for grass or more regrowth of the forbs under the shade.

Herbage Available, 2000

In 2000, greater early-season precipitation resulted in higher available forage DM compared to 1999. April through September rainfall in 2000 (Figure 1) totaled 9.5 inches, 89.6% of the 30-yr average. In the second yr, 99% of growing season precipitation fell in the first mo with almost no precipitation for the next 60 d. Total end-of-season DM yields in the FSG, FSM, and SM were 3866, 1768, and 1473 lbs ac^{-1}, respectively (Figure 2). The FSG treatment produced over five times as much forage as in the previous, drier yr, a much higher increase than the other two treatments. This would indicate that the crabgrass, when fertilized at the higher rate, was able to respond to higher soil moisture with greater yields than the mixed species treatments with lower fertilizer N rates.

The FSM and SM treatments were evaluated in 2000 to determine percent pasture composition of grass, pigweed, and legumes (Figure 4). Treatments were uniform until wk 6when the legume proportions began to dropped in composition, they subsequently could no longer survive the stresses and were eliminated by herbivory and/or drought. Percentage grass increased over time and pigweed percentages remained static with a corresponding decrease in legume percentage.

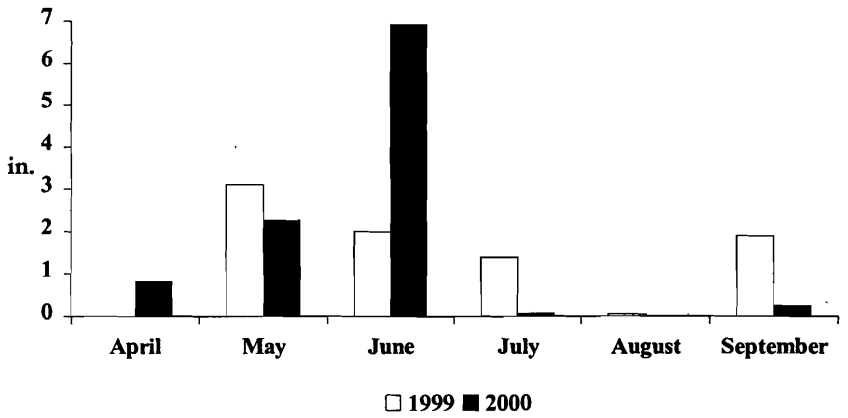

Figure 1. Monthly precipitation patterns over the 1999 - 2000 growing season.

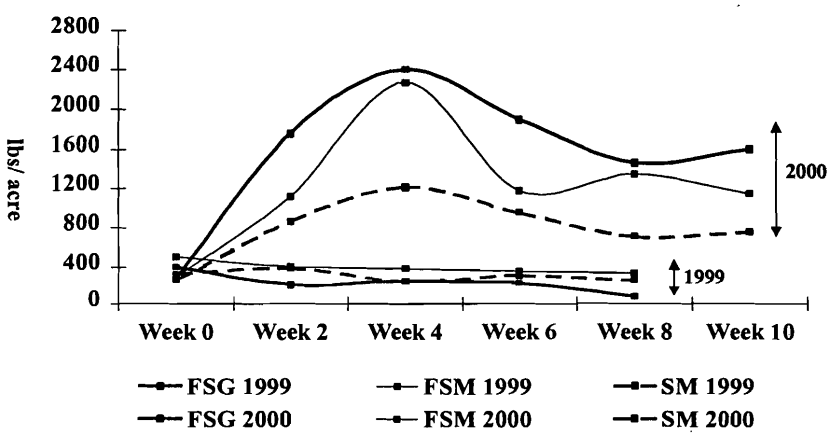

Figure 2. Forage standing crop dynamics over time (1999 - 2000).

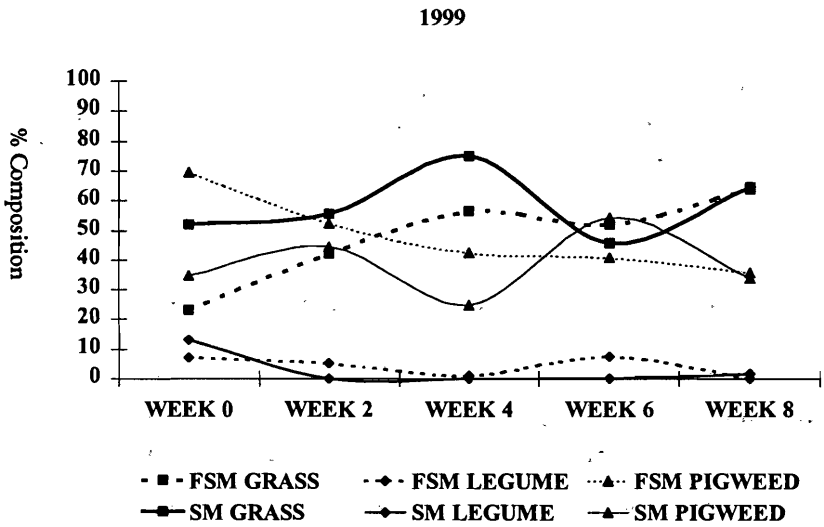

Figure 3. Growing season patterns in standing crop composition; FSM and SM treatments (1999).

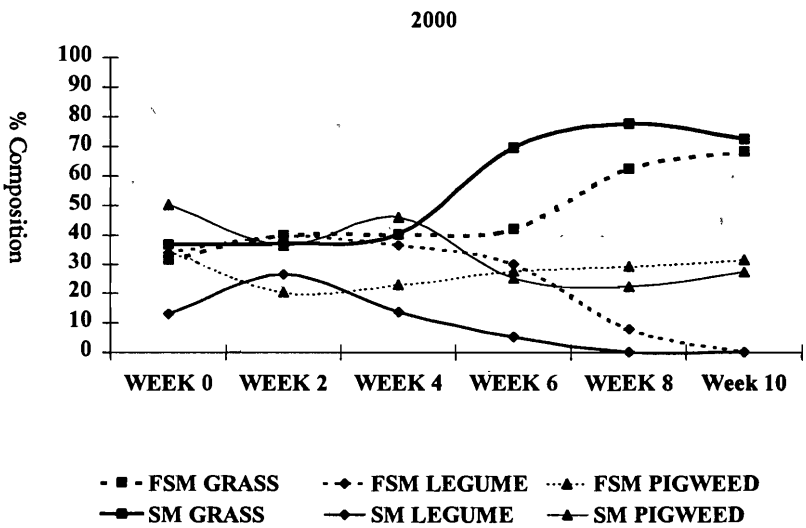

Figure 4. Growing season patterns in standing crop composition; FSM and SM treatments (2000).

Forage Quality

Plant crude protein concentrations across all pastures indicated a decreasing trend over time for both yr (Table 2). 2000 treatment pastures did, however, reach higher concentrations of crude protein, utilizing the greater amounts of initial precipitation (Figure 1). The crabgrass in the FSG did, however, have the highest grass percentage CP in four out of the five observations periods in 1999 compared to the other treatments, likely due to the higher N fertilizer rates applied. These CP percentages are consistent with Dalrymple (1983) who reported crabgrass CP concentrations ranging from 5.4% at maturity to 27.0% CP at younger stages of growth.

Table 2. Initial, mid and ending season crude protein (CP) of full sun grass-only (FSG), full sun mixed forb/grass (FSM), and shaded mixed forb/grass (SM) pasture components over two warm-seasons in Texas

Week	Grass	Pigweed	Legume
	---------- CP % of whole plant ----------		
1999			
Week 0	16.0	18.0	19.3
Week 4	11.3	10.6	13.7
Week 8	11.0	13.9	n/a
2000			
Week 0	20.9	20.0	25.1
Week 4	10.7	12.1	17.7
Week 10	8.5	6.7	n/a

Grazing exclosures were utilized to estimate ungrazed forage quality at the end of the study. Grass CP concentrations in the FSG were higher for both yr than the FSM and SM treatments. This trend is consistent with the grazed forage data over time in which FSG had higher CP concentrations throughout the study, again due to higher N applications. This was likely due to higher soil fertility as well as absence of competition with deeper-rooted pigweed and legumes. Pigweed CP concentrations were also similar between the FSM and SM treatments. Analysis of the legume fractions in the ungrazed exclosures indicated CP concentrations of 12.1 and 13.0% for the FSM and SM treatments, respectively. Fiber concentrations of the remaining forage for both treatments were similar with respect to legumes.

Conclusions

Differences among pasture systems and between yr in this study were heavily dependent on seasonal precipitation patterns. The forage yield data suggests that, for the species evaluated, full sun environments produced more consistent forage and animal gains as compared to that produced in shaded environments, regardless of rainfall. Shaded pasture achieved equal forage biomass accumulations and animal gains only in higher rainfall years for the species that were evaluated. With greater rainfall, all pasture systems produced higher forage yields but total forage

yields remained different among treatments. In the case of the FSM, higher rainfall did not translate into higher ADG, indicating that grazing pressure was ideal for maximum per animal gains both yr and stocking rates could have been increased in 2000 to maximize per area animal production. Precipitation in June did, however, extend the useful grazing period for all pastures. Crabgrass in particular appears to produce more in a full-sun environment compared to under pecan groves.

The data indicates that CP concentrations in all treatments decreased over time. Crabgrass in the FSG treatment maintained higher CP concentrations longer in the study than any other component perhaps due to greater leaf retention. A comparison of grazed and ungrazed grass at the end of the 1999 trial indicates that goats selected grass components higher in CP concentrations. Another determinant of forage quality was the modest late season precipitation that allowed for some marginal regrowth, which subsequently increased forage quality for those plants still able to utilize it. The plants that were beyond the point of regrowth, such as the crabgrass during the later periods of 1999, were unable to respond to late season moisture.

The 1999 data suggests that, in dry years, a mixed grass-pigweed-legume pasture in a full-sun environment will yield higher ADGs as compared to shaded mixtures or full sun grass-only pastures. The hypothesis that goats will obtain a higher ADG on grass-pigweed-legume pastures than on grass-only pastures is therefore validated. Regardless of the amount of precipitation, greater goat ADGs were obtained utilizing pastures that included legumes and pigweed as compared to grass-only pastures. Results from this trial also suggest that, regardless of the level of sunlight, goats in pastures with mixed grass/pigweed/legume pastures produced greater ADGs as compared to full-sun grass-only pastures.

From a forage viewpoint, the 'Ironclay' cowpea established and produced the most forage of the legume species evaluated, followed closely by 'Tecomate' lablab. The three native legume species Illinois and rayado bundleflowers, and showy partridge pea were inconsistent in germination and establishment and were essentially irrelevant to the experiment. Redroot pigweed germinated and established well and remained a large component of the standing crop throughout both seasons while 'Red River' crabgrass germinated and established well but suffered from earlier moisture stress.

In years with low warm-season precipitation such as those in this experiment, cultivated annual pasture produces very short grazing seasons. Considering the cost of establishing such pastures, these systems may not be viable in semi-arid environments. Sustainable use of the specific systems evaluated in this trial may be viable only if they can be managed for adequate self-reseeding. Legume varieties other than 'Tecomate,' which, for example, did not flower at this latitude, must be identified and tested.

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Maternal n-3 fatty acid supplementation to enhance brown fat thermogenesis in newborn lambs

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Abstract: The aim of this study was to determine whether dietary supplementation of n-3 polyunsaturated fatty acid (PUFA) during late gestation would stimulate recruitment of brown adipose tissue (BAT) in utero to improve cold tolerance of newborn lambs. Thirty twin-bearing ewes were allotted to one of six groups (n = 5) beginning 40 ± 15 d prior to lambing. Groups were randomly assigned to treatments in a 2x3 factorial arrangement with factors being: level of rumen-protected fat (2, 4 or 8%), and source of rumen-protected fat (high in saturated/monosaturated fatty acid [SMFA; Energy Booster ®] or high in n-3 PUFA; formaldehyde-protected soy/linseed lipid). Ewes were individually fed in an open-sided barn. All lambs were separated from ewes and placed in a warm chamber (25°C) within 2 h of age. At 4 h of age, all lambs were placed in a cold chamber (0°C) for 2 h and rectal temperatures (RT) measured at 15-min intervals. One lamb per twin pair was killed at 6 h of age and the other lamb was returned to the warm chamber till 22 h of age. Cold-induced RT responses were again measured for 2 h and the second lamb killed at 24 h of age. Prenatal ADG were greater in ewes fed 2 or 4% vs 8% fat supplementation, but level and sources of fat didn't affect lamb birth weights. At parturition, ewes fed PUFA diets had higher plasma concentrations of 18:2, 18:3 and 20:5, and lower concentrations of 18:1 than ewes fed SMFA diets at parturition. BAT of lambs born to PUFA-fed ewes had higher concentrations of 18:2, 20:5, and 22:6 than lambs born to SMFA-fed ewes, however, BAT mass, and GDP binding were not affected by level or source of dietary fat. Cold-induced RT responses of lambs were not affected by source of prenatal fat, but increased quadratically as level of prenatal fat increased (39.4, 39.7, and 39.1 ± .06°C for 2, 4 and 8% fat, respectively). Prenatal n-3 fatty acid supplementation altered the fatty acid profile of BAT, but did not affect BAT thermogenic activity or cold tolerance of newborn lambs.

Key Words: Polyunsaturated Fatty Acid, Brown Adipose Tissue, Lamb

Sheep and Goat, Wool and Mohair CPR 2002. 99-107

Introduction

At birth, the newborn animal is subjected to a dramatic decline in environment temperature, and this cold exposure seems to be the signal for a rapid rise in metabolic rate in conjunction with an increase its thermogenic activity. The process of heat production by non-shivering thermogensis in brown adipose tissue (**BAT**) is vital to the survival of the newborn animal exposed to a cold environment. In newborn lambs, approximately 40 to 50% of the heat during summit metabolism has been attributed to BAT metabolism (Slee et al., 1987).

Feeding can further modulate the thermogenic activity of BAT in newborn animals. Newborn lambs fed 50 mL of warm water or colostrum had increased thermogenic activity of BAT (Clarke et al., 1997; Clarke and Symonds, 1998). Prepartum fat supplementation increased plasma glucose concentrations of newborn calves, resulting in favorable responses in body temperature in cold-stressed calves (Lammoglia et al., 1999a). Prepartum fat supplementation also increased heat production in newborn calves, and potentially increased calf survival (Lammoglia et al., 1999b). Oudart et al. (1997) found that n-3 polyunsaturated fatty acid (**PUFA**) induced a marked stimulation of BAT thermogenic activity in comparison with rats fed a high-fat diet without n-3 PUFA.

Although a number of studies have investigated feeding effects on BAT thermogenesis of newborn lambs, little is known about PUFA effects. The aim of this study was to determine whether dietary supplementation of n-3 PUFA during late gestation would stimulate recruitment of brown adipose tissue *in utero*, thereby enhancing the thermogenic capacity of BAT and improving the cold tolerance of newborn lambs.

Materials and Methods

Animals and Diets

Thirty twin-bearing ewes of known mating date were allotted to one of six groups (n = 5) beginning 40 ± 15 d prior to lambing. Groups were randomly assigned to treatments in a 2 x 3 factorial arrangement with factors being: (1) level of rumen-protected fat (2, 4, or 8%), and (2) source of rumen-protected fat (high in saturated/monosaturated fatty acid [**SMFA**], or high in n-3 polyunsaturated fatty acid [**PUFA**]). Energy booster 100® (Milk Specialties Co., Dundee, IL) was used as the source of rumen-protected SMFA in the experiment. The source of n-3 PUFA was rumen-protected casein formaldehyde flaxseed oil (Rumentek Industries Pty Ltd., Sydney, Australia). All diets were isonitrogenous, and within each dietary fat level, diets were formulated to be isocaloric (Table1 and Figure 1).

Table 1. Ingredient composition (DM basis) of the diets

	PUFA[c]			SMFA[c]		
Ingredient, %	2%	4%	8%	2%	4%	8%
Cottonseed hulls	34.31	37.61	45.38	35.88	41.65	52.35
Soyplus	12.81	7.93	1.97	16.16	17.47	18.61
Urea	0.00	0.41	0.71	0.00	0.00	0.20
Corn	37.74	34.19	22.68	35.69	26.66	10.77
Limestone	1.32	1.32	1.31	1.32	1.31	1.30
Molasses	6.16	6.15	6.12	6.15	6.13	6.08
Rumentek[a]	4.97	9.72	19.16	---	---	---
Energy booster[b]	—	—	—	2.12	4.11	8.04
Vitamin/mineral	0.33	0.32	0.32	0.32	0.32	0.32
Vitamin E-20	2.36	2.35	2.34	2.35	2.34	2.33

[a]n-3 PUFA source of rumen-protected fat.
[b]SMFA source of rumen-protected fat.
[c]PUFA, polyunsaturated fatty acid; SMFA, saturated/ monounsaturated fatty acid.

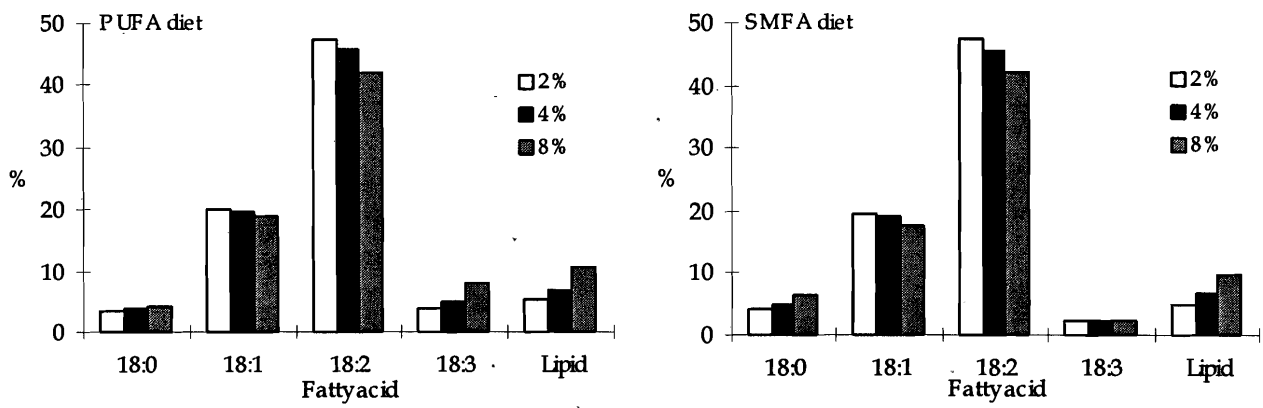

Figure 1. The major fatty acid composition of total dietary fat. PUFA, polyunsaturated fatty acid. SMFA, saturated / monounsaturated fatty acid.

Ewe Treatment

Every ewe was housed in an open-sided barn separately. Throughout the prenatal period, feed intake and body weights were measured and blood samples were collected into heparinized vacutainer tubes at 7-d intervals. Ewes were monitored at 4-h intervals prior to expected lambing. Immediately following parturition, lambs were separated from ewes, dried of amniotic fluid, weighed, and moved to the warm chamber (25°C).

Lamb Treatment

Twin lambs were randomly assigned to treatment A or B. Lambs were fed pooled bovine colostrum (30 mL/kg) at 2 h of age and normal saline (60 mL) at 4 h of age. At 4 h of age, lambs were moved to a cold chamber (0°C). Rectal temperature was recorded at 15-min intervals between 4 and 6 h of age of each twin pair. Lamb A was slaughtered at 6 h of age using an overdose of sodium pentobartitol, and exsanguinated. Perirenal adipose tissue samples were collected, and immediately snap-frozen in liquid nitrogen and stored at -80°C for analysis. At 6 h of age, lamb B of the twin pair was moved to a warm chamber until 22 h of age, after which lamb B was moved to the cold chamber again. At 8, 14 and 20 h of age, lamb B was fed the same amount of colostrums as initially. Rectal temperature was recorded at 15-min intervals between 22 and 24 h of age. Lamb B was slaughtered at 24 h of age. Perirenal adipose tissue samples were collected, immediately snap-frozen in liquid nitrogen, and stored at -80°C for analysis.

Analyses

Blood samples were analyzed for fatty acid composition. BAT samples were analyzed for cytochrome c oxidase activity, and Guanosine diphosphate (GDP) binding activity. Cytochrome c oxidase activity was used as an index of mitochondrial mass, and GDP binding activity was used as a measure of the thermogenic activity of BAT.

Isolation of Mitochondria and Cytochrome c Oxidase Activity

Mitochondria were isolated by differential centrifugation as described by Cannon and Lindberg (1979). Tissue samples were dissected, weighed, and washed immediately in sucrose buffer (250 mM sucrose, 5 mM TES-HCl, pH 7.2). Tissue samples were homogenized in 10 volumes of sucrose buffer. The homogenate was centrifuged at 10,000 x g for 10 min. The supernate and the infranatant fat cake were discarded. The pellet was resuspended to original volume in fresh sucrose buffer. The suspension was centrifuged at 800 x g for 10 min to sediment nuclei and cellular debris, and the supernate was centrifuged 3X at 10,000 x g for 10 min. The final mitochondrial pellet was resuspended to 0.5 mL in fresh sucrose buffer.

Aliquots of homogenate and mitochondria preparations were frozen at -80°C for subsequent determination of cytochrome c oxidase activity using a spectrophotometric assay (Billington et al., 1987); and protein using the modified Lowry method (Markwell, 1978). Total mitochondrial protein was determined based on mitochondrial recovery from preparations.

Guanosine diphosphate (GDP)-Binding Activity Assay

Mitochondrial GDP-binding assays were performed according to Nizielski et al. (1995). Freshly prepared mitochondria were incubated for 5 min in triplicate with a medium containing [^{14}C] sucrose (0.1 uCi/mL), 0.115 uM [^{3}H] GDP (1.0 uCi/mL), in 2 uM unlabeled GDP. Scatchard analyses of GDP binding were performed using a pooled mitochondrial sample from each group by incubation in the same medium, but with 0, 1, and 500 uM unlabeled GDP. Additionally, a competition assay was conducted by adding 200 uM GDP to maximally displace [^{3}H] GDP from GDP-binding sites to assess nonspecific binding.

Fatty acid profile

Fatty acid assays were performed according to Folch et al. (1957). One hundred milligrams of BAT was added to a chloroform: methanol solution (2:1, vol/vol) and homogenized to extract lipids. A volume of 0.74% KCl was added to the homogenate, mixed well, and centrifuged. The upper phase (lipid) was evaporated with nitrogen. A volume of 0.5N KOH in methanol was added to saponify the lipids, and 14% BF3 in methanol was added to methylate the lipids. Hexane (HPLC grade) was used to reconstitute the lipid. Gas chromatography was used to analyze the fatty acid profile of BAT and plasma lipid.

Statistical Analysis

An ANOVA was conducted for a 2 (source of rumen-protected fat) x 3 (level of rumen-protected fat) factorial arrangement of treatments. Statistical analysis of treatment effects and their interactive effects were assessed using a general linear model procedure of SAS (SAS Inst, Inc., Cary, NC). Treatment subclass means were compared using Fisher's protected LSD test.

Results and Discussion

The fatty acid compositions of the diets are shown in Figure 1. The PUFA diets had a higher concentration of 18:3 than SMFA diets. As levels of added dietary fat increased, the concentration of 18:3 was increased, and 18:2 was decreased. There were no differences in 18:0 and 18:1 among treatments.

Ewes with 8% dietary fat supplementation had lower average daily gain and require more feed per kg of gain than ewes with 2% and 4% dietary fat supplementation (Table 2). There was no source of fat effect for ADG, feed intake, or body condition score of ewes.

Table 2. The effect of source and level of fat supplementation on daily intake and weight gains of ewes

	Fat source effect[a]		Fat level effect			SE
	PUFA	SMFA	2%	4%	8%	
Average daily gain, kg/d[b]	0.58	0.54	0.64	0.63	0.43	0.03
Feed intake, kg/d	3.2	3.4	3.5	3.4	2.9	0.1
Feed/Gain[b,c]	5.9	6.6	5.7	5.9	7.2	0.3
Body condition score, 1 to 5	2.9	2.9	2.9	3.1	2.6	0.1

[a]PUFA, polyunsaturated fatty acid; SMFA, saturated/monounsaturated fatty acid.
[b]$P < .05$ for the level effect.
[c]$P < .05$ for the interaction of source and level effect.

Dietary fat supplementation modulated the fatty acid profile of the ewes' plasma at parturition (Figure 2). There were no differences in fatty acid profiles among ewes' plasma on d 0 (data not shown). At parturition, the plasma concentration of 18:1, and 20:4 of ewes with PUFA diets were lower ($P < .05$) than for ewes fed SMFA diets. Ewes fed PUFA diets had higher 18:2, 18:3, and 20:4 plasma concentrations ($P < .05$). Ewes with 2% fat supplementation had lower plasma concentration of 18:3 and higher concentration of 20:4. These results suggested that PUFA supplementation increased the plasma PUFA concentrations of ewes.

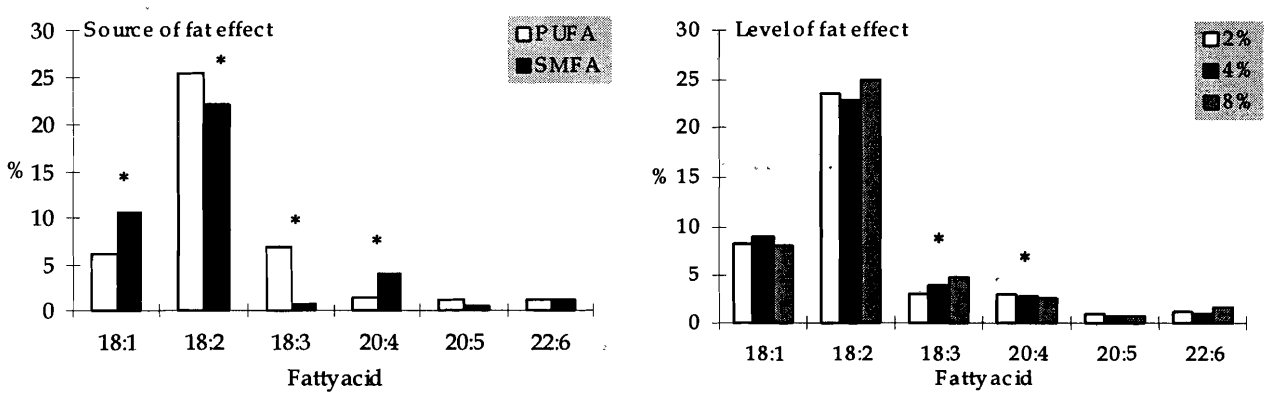

Figure 2. The effects of level and source of fat supplementation on plasma fatty acid profile of ewes at parturition. *, $P < .05$. There was an interaction ($P < .05$) between source and level effect for 18:3.

Prenatal fat supplementation did not alter the body weight, and lipid concentration in BAT of lambs (Table 3). Thermogenic activity (GDP-binding activity) was not affected by source or level

of prenatal fat supplementation. However, the cytochrome c oxidase activity of BAT was higher in lambs from SMFA-fed ewes, suggesting that lambs from SMFA-fed ewes had a higher mitochondrial mass. Lambs exposed to cold stress twice had a lower BAT mass and a higher GDP-binding activity than lambs exposed to cold stress once, suggesting that cold-stressed lambs generated heat by BAT thermogenesis. Therefore, the BAT mass of 24-h-age lambs decreased after the second cold stress in comparison to BAT of lambs at 6 h age. Also, the increased GDP-binding protein lasted at least 18 h, since 24-h-age lambs had a higher thermogenic activity.

Table 3. The effects of level and source of prenatal fat supplementation on body weight, brown adipose tissue **(BAT)** components, and thermogenic activity of newborn lambs to cold exposure

	Age effect		Fat source effect[a]		Fat level effect			SE
	6 h	24 h	PUFA	SMFA	2%	4%	8%	
Body weight (**BW**), kg	4.75	4.96	4.87	4.84	5.13	4.69	4.74	0.09
BAT mass, g/kg BW[b]	4.01	3.64	3.64	4.01	3.94	3.76	3.78	0.07
Dry matter, % of BAT	45.2	45.9	45.8	45.4	47.5	43.4	45.8	0.6
Lipid, % of BAT	35.6	36.2	35.6	36.2	38.2	33.8	35.7	0.8
GDP-binding activity, pmol/mg BAT[b]								
	182.0	209.5	195.6	195.9	179.0	215.5	192.7	6.4
Cytochrome c oxidase activity, μmol/min/g BAT[c,d]								
	13.7	13.2	12.7	14.2	14.1	13.3	12.9	0.4
DNA, mg/g BAT[d]	1.85	1.80	1.79	1.86	1.83	1.93	1.71	0.06

[a]PUFA, polyunsaturated fatty acid; SMFA, saturated/monounsaturated fatty acid.
[b]$P < .05$ for the age effect.
[c]$P < .05$ for the source effect.
[d]$P < .05$ for the interaction of source and level effect.

Neither levels nor sources of dietary fat affected the plasma fatty acid profiles of lambs (data not shown). However, BAT of lambs born to PUFA-fed ewes had higher concentrations of 18:2, 20:5, and 22:6 than lambs born to SMFA-fed ewes (Figure 3). Six-h-age lambs had lower concentrations of 18:2 and 18:3 than 24-h-age lambs. Lambs with 8% prenatal fat supplementation had a higher concentration of 20:5. The BAT fatty acid profile of lambs suggested that prenatal dietary fat supplementation modulates the fatty acid profile of BAT.

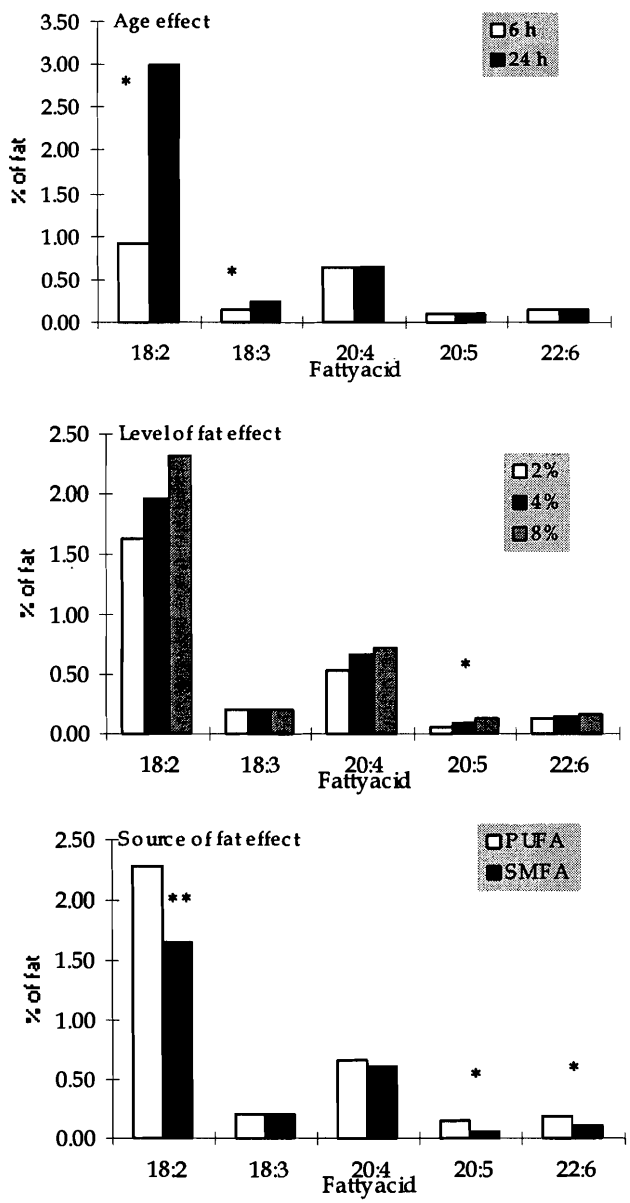

Figure 3. The effects of level and source of prenatal fat supplementation on BAT fatty acid profile of newborn lambs to cold exposure. *, $P < .05$. **, $P < .1$. 20:5 has interaction between source and level effect.

All the lambs had increased rectal temperature (**RT**) during cold exposure. Peak RT occurred after 15 min of cold exposure (Figure 4). Cold -induced RT response of lambs was not affected by source of prenatal fat, but increased quadratically as level of prenatal fat increased. Lambs with 4% prenatal fat supplementation had higher cold-induced RT response than lambs with 2 or 8% prenatal fat supplementation ($P < .01$ for h 22 to 24). Lammoglia et al. (1999a) found that feeding heifers higher supplemental fat (4.7 vs 1.7%) increased the ability of their calves to maintain body temperatures in response to cold stress. These results suggested that 4% prenatal fat supplementation caused the best cold-induced response for lambs.

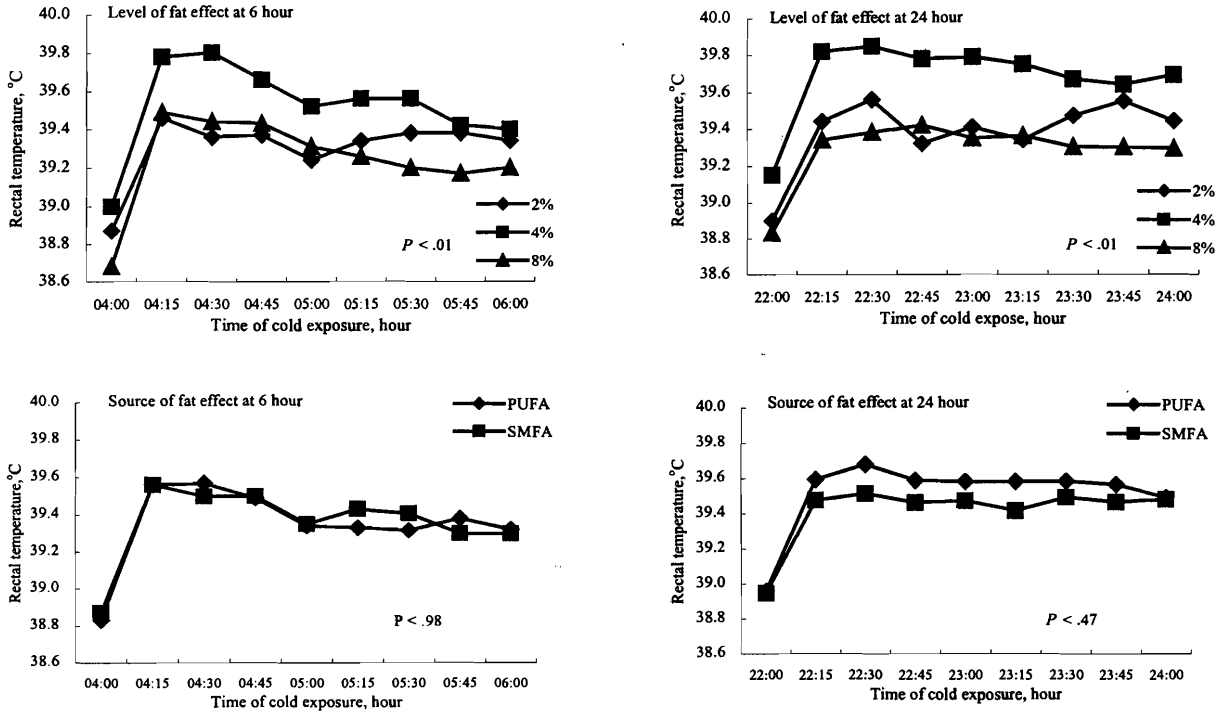

Figure 4. The effects of level and source of prenatal fat supplementation on rectal temperature response of newborn lambs to cold exposure.

Conclusions

Prenatal n-3 fatty acid supplementation altered plasma fatty acid profiles of ewes, and BAT fatty acid profiles of lambs. However, it did not affect BAT thermogenic activity of newborn lamb. Cold-induced RT responses of lambs were not affected by source of prenatal fat, but increased quadratically as level of prenatal fat increased. Lambs with 4% prenatal fat supplementation had the best cold-induced response.

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Peanut meal supplementation for growing nanny kids on woodland range

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Abstract: Goats raised on range in the south-central United States often face a forage quantity and quality deficit from July through August that may be improved by feeding protein supplements. During these months, goats preferentially browsed greenbriar and post oak while selecting against elm, all low in crude protein (CP). Peanut meal was fed to ±44 lb Spanish X Boer goat nanny kids rotationally browsing native hardwood forest under-story from May to mid-August of two low-rainfall summers (42 and 78% below the 30 yr average) at levels of 0, 0.25 and 0.50% body weight (BW). Goats in the 0 and 0.5% supplement group obtained the lowest and highest ADG ($P<0.05$), respectively, during both years. Supplementing nanny kids with peanut meal may be a viable management tool to enhance growth during dry summers.

Key Words: Cross Timbers, Protein Supplementation

Sheep and Goat, Wool and Mohair CPR 2002. 108-113

Introduction

The population of meat goats in the state of Texas increased 18% in 2001 (TASS, 2001), typical of the rising interest in goat production across the southern United States, especially in areas that have not traditionally been viewed as goat-producing areas. The Cross Timbers and Prairies region is representative of these areas. The west and east Cross Timbers, which traditionally range from open savannah to dense brush, are composed largely of post and blackjack oak (Gould, 1962) where livestock grazing capacity can be limited because of a suppressed herbage layer under the forest canopy (Bogle et al., 1989). Most areas that still remain under forest canopy do so as management decisions based on their unsuitability for use as improved or cultivated pasture. In addition, the rising cost of energy has increased the expense of clearing and maintaining brushy areas by mechanical and chemical means. These areas have traditionally been utilized for cattle production on marginal units (Bernardo et al., 1992), with limited sheep and goat focus, although the western Cross Timbers once supported substantial Angora goat production.

The use of browse by goats is probably an important factor in their survival in areas where herbaceous forage quality is poor and does not provide minimal nutrition to support cattle and sheep (Sidahmed et al., 1981). These findings indicate that goats may utilize naturally available resources in the Cross Timbers and Prairies area more efficiently than other types of livestock traditionally raised in this area.

The general assumption is that browse contains adequate levels of protein for goat production (Le Hoverou, 1980; Sidahmed et al., 1981). This assumption has been based on comparisons with temperate grass and legume species (Demarquilly and Weiss, 1970) and may not be correct when

tannins and other anti-quality factors, known to bind plant protein, are high in browse species (Papachristou and Nastis, 1996). Many researchers feel that alternative protein sources such as agro-industrial concentrates could improve productivity of range goats (Harris et al., 1956; Kronberg and Malecheck, 1997; Ramirez et al., 1991).

This study evaluated the effect and cost of daily peanut meal supplementation at three levels (0, 0.25, and 0.5% body weight) on goat average daily gain (ADG). Browse preferences, estimated plant densities, and plant quality of individual browse species during the trial period were also identified in order to better understand the effects of the supplement.

Materials and Methods

The trial spanned a fourteen-week period, from the first wk of May to the second wk of August, in both 2000 and 2001. The study site was a native woodland range located on the Texas Agricultural Experiment Station in Stephenville, Texas. Trees and brush were primarily post oak, live oak, elms, hackberry, and greenbrier. Available herbaceous forage was relatively sparse during the trial periods. The 100-yr average precipitation for May-August for the area is 11.9 in. and rainfall for these mo during the trial was 9.3 in. for Yr 1 (2000) and 3.7 in. for Yr 2 (2001). The 12-acre woodland was divided into five paddocks, each approximately 2.4 acres. The goats were rotated through each paddock at one-wk intervals, which allowed each paddock a four-wk recovery period prior to the reintroduction of goats. The degree of goat browse selectivity was measured on the 5 most abundant brush and vine species during both yr. This was done by counting tagged plant leaves before and after each rotation.

Thirty-six Spanish X Boer cross nannies, 4 to 6 mo old, were used in this trial. The nannies started the trial with an initial average weight of 44 lbs. Animals were randomly assigned to three groups that were supplemented with peanut meal (45% CP) at 0, 0.25 and 0.5% of BW. Goats were allowed a one-wk acclimation period prior to initiating supplementation the first wk in May. All goats, regardless of treatment, ran together on one common paddock, but each morning were sorted into treatment groups and fed the peanut meal. All treatment groups were provided salt, mineral, and fresh water *ad libitum*.

Goats were weighed every fourteen d. Weight data was used to determine average daily gain for that trial period, while all periods were averaged to get a 98-d total weight gain for each yr. Feed cost and gain information was used to determine the economic efficiency for each level of supplementation.

The effect of protein supplementation treatment on ADG and yr were assessed via analysis of variance. Differences among the three treatment groups were identified using Duncan's least square residual at $P<0.05$.

Results and Discussion

The amount and distribution of precipitation during the trial likely affected browse foliage availability in both yr of the study, explaining, at least in part, the differences in goat ADG observed between the two trial yr. Because of the forest canopy, which suppresses herbaceous plant growth (Bogle et al., 1989) and drought conditions during both yr, coupled with the goats' strong preference for woody species (Rodriguez Iglesias and Kothmann, 1998), herbaceous plant matter contributed very little to the goat diets.

The level of browsed foliage may be a function of the abundance of a plant species. Of the five browse species observed, greenbriar was browsed most heavily in both trial yr (Table 1). This concurs with results from Rodriguez Inglesias and Kothmann (1998) and Lopes and Stuth (1984), who also found greenbriar to be highly preferred over other browse plants. Elm was observed to be the least browsed across both yr. However, the percentage of elm foliage browsed increased with time both yr suggesting that the preferred browse species were becoming depleted during the trial alternatively selectivity may also have been influenced by changes in nutrient composition, primarily CP content among the different browse species. Greenbriar and elm species were also the most and least abundant of the five browse species, respectively, which may have affected selection.

Table 1. Browse species populations and mean percentage of tagged foliage browsed with standard error

			- - - % Foliage Browsed by Rotation - - -			
Species	Year	% Population	1	2	3	Mean Browsed
Elm	1	0.2	14.1 ± 34.7	79.5 ± 36.2	50.0 ± 35.2	47.9
	2	0.3	7.1 ± 30.3	21.5 ± 34.0	53.6 ± 34.8	27.4
Hackberry	1	5.6	64.9 ± 11.6	77.4 ± 9.7	73.4 ± 11.1	71.9
	2	5.7	61.4 ± 9.3	85.8 ± 4.9	85.8 ± 6.3	77.7
Live Oak	1	1.5	72.3 ± 28.5	97.1 ± 24.8	60.8 ± 9.5	76.7
	2	1.8	52.1 ± 32.3	92.0 ± 8.2	71.5 ± 21.5	71.9
Post Oak	1	4.7	80.2 ± 13.4	91.2 ± 9.5	87.4 ± 12.8	80.3
	2	4.7	75.0 ± 9.4	89.7 ± 6.6	94.2 ± 8.3	86.3
Greenbriar	1	88.0	75.2 ± 7.5	95.1 ± 3.8	96.3 ± 2.1	88.4
	2	87.5	69.5+7.6	96.6+1.6	98.0+1.5	88.0

Live weight gains were lower in Yr 2 than Yr 1, regardless of treatment (Table 2). Although rainfall was limited during portions of the trial in both yr, rainfall was extremely sparse in Yr 2, contributing to decreased foliage availability and a resultant 24% reduction in ADG in the second yr. This decline was most dramatic in the control group, which gained 0.06 lbs. d^{-1} less in Yr 2 than Yr 1. The two supplement groups (0.25 and 0.50%) offset this loss in weight gain slightly, gaining only 0.03 lbs. d^{-1} less in Yr 2.

Differences in goat ADG were not observed between yr until the start of the second rotation (weigh period 3; Table 2). This suggests that variation in foliage re-growth may have influenced ADG throughout the remainder of the trial. Foliage availability, which was suppressed by drought conditions during both trial yr, rather than foliage quality, may explain the depression in animal performance during portions of both yr.

Table 2. Biweekly aberage daily gain (ADG; lbs/d/animal) of goats on woodland range over two years

	Biweekly weigh period							
	1	2	3	4	5	6	7	98 d
Year 1	0.23	0.12	-0.04	0.30	0.34	0.13	0.16	0.17
Year 2	0.22	0.16	0.25	0.11	0.07	0.09	0.05	0.13
P value	>0.50	0.21	0.01	0.01	0.01	0.08	0.01	0.01

Weight gain increased as the level of peanut meal supplement increased, regardless of yr. The season-long ADG during both yr was greater for both supplemental groups compared to the control. The mean ADG for the control, 0.25, and 0.50% treatment groups was 0.12, 0.16, and 0.18 lbs d^{-1}, respectively (Table 3). Averaged over both yr, weight gains of 12.3, 15.5, and 17.3 lbs were observed for the control, 0.25, and 0.50% treatment groups, respectively. There were no significant differences in gains between the 0.25 and 0.50% supplementation levels.

Table 3. Goat average daily gain (ADG; lbs/d/animal) and 98-d gains (lbs/animal) over two years and three peanut meal supplement levels

98 d	Year	Control	0.25%	0.50%
ADG (lbs)	1	0.14a*	0.17b	0.19b
Total gain (lbs)		15.2a	17.1b	18.9b
ADG (lbs)	2	0.10a	0.14b	0.16b
Total gain (lbs)		9.3a	13.8b	15.7b

*Means in the same row followed by different letters differ ($P < 0.05$) according to Duncan's multiple range test.

Conclusions

Drought conditions existed during both trial yr and these led to a decline in browse foliage production during the last portion of the first yr and throughout the second yr. The lack of substantial foliage re-growth in the second yr severely depressed animal performance, and as a consequence, the mean weight gain per goat was 4.1 lbs less in yr 2 than in yr 1. At the trial stocking rate of 3 goats $acre^{-1}$, animal gains/acre were 51 lbs for yr 1 and 39 lbs for yr 2 for the 98 d trial.

The results from this trial indicate that providing supplemental peanut meal to goats consuming browse can improve weight gain. The average 98-d gain per animal for the 0.25 and 0.5% supplement increased 3.17 and 5.03 lbs, respectively, over the control. The additional cost of feed for the 0.25 and 0.5% supplemented groups was $1.64 and $3.35 per goat, respectively, given a peanut meal cost of $225 per ton (Table 4), excluding labor costs. The cost of 1 lb of gain over the control was $0.52 and $0.67 (average gain of 3.2 and 5.0 lbs over the control) for the 0.25 and 0.5% supplemented groups, respectively. The thirty-six nannies used in this trial each yr were sold through local markets at the conclusion of each trial yr at an average price of $0.92/lb and $0.85/lb

for yr 1 and 2, respectively. Even at these low points in the market cycle, peanut meal supplementation at both levels may have been economical, depending on labor cost. Considering feed cost and gain potential, the 0.25% level of peanut meal supplementation is the most economical.

Table 4. Mean cost of protein supplementation by treatment for 98-d trial

	Control	0.25%	0.50%
Mean lbs gain/animal	12.3	15.5	17.3
Mean lbs gain/animal over control	---	3.2	5.0
Cost ($) of feed/animal	---	1.64	3.35
Cost ($) of feed/lb gain/animal over control	---	0.52	0.67
Net return ($) on gain (minus supplemental cost*)	10.93	12.11	12.06

* Mean sale price/lb goat was $0.89.

Acknowledgements

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Cloning and expression of ovine interferon gamma (oIFN-γ)

Z. Zhang and A. de la Concha-Bermejillo

ABSTRACT: Ovine interferon gamma (oIFN-γ) was successfully cloned and expressed in *E. coli* as a recombinant glutathione S-transferase GST fusion protein. Gene sequence analysis indicated that oIFN-γ is conserved among ruminant species, sharing 96.6% and 98.2% nucleotide identity with the bovine and caprine IFN-γ genes, respectively. The cytokine IFN-γ plays a very important role in promoting immune responses against a large number of infectious pathogens. The production of this important cellular protein in the laboratory has significant implications in the design of strategies for the therapy and diagnosis of a great variety of small ruminant diseases.

Key Words: Interferon-gamma, Ovine, Cloning/ gene expression, Glutathione S-transferase (GST)

Sheep and Goat, Wool and Mohair CPR 2002.114-120

Introduction

Interferon gamma (IFN-γ) is a type II IFN that plays a critical role in the regulation of the immune response against intracellular pathogens (viruses, protozoa parasites and some bacteria). IFN-γ is produced by activated lymphocytes and natural killer cells (white blood cells) in response to microbial threats (Yadavalli et al., 2001). Recombinant ovine IFN-γ (roIFN-γ), but not IFN-alpha (IFN-α), has been shown to restrict the multiplication of *Chlamydia psittaci*, the cause of enzootic abortion in sheep and goats, in ovine ST-6 cells (Entrican et al., 1998). Removal of roIFN-γ from these cultures resulted in a re-emergence of viable, infectious chlamydiae, which eventually killed all the cells indicating that continuous production of IFN-γ is necessary to maintain its protective effect (Brown and Entrican, 1996). Interferon-γ also inhibited the *in vitro* growth of *Toxoplasma gondii* and *Neospora caninim*, two important intracellular parasites that also cause abortion in sheep and goats (Dimier and Bout, 1996; Innes et al., 1995; Oura et al., 1993). *In vivo*, sheep produce IFN-γ in response to inoculation with *Corynebacterium pseudotuberculosis*, the causative agent of caseous lymphadenitis (Pepin et al., 1997). In addition, IFN-γ also has antiviral activity against a large variety of viruses (Shtrichman and Samuel, 2001). In view of the highly relevant role of IFN-γ on the protection against a multitude of sheep and goat diseases, the cloning, expression and production of large quantities of this protein have important implications for the therapy and control of these diseases.

Ovine IFN-γ has been expressed as a recombinant glutathione S-transferase (GST) fusion protein in host bacteria (*Escherichia coli* and *Corynebacterium glutamicum*) (Billman-Jacobe et al., 1994). However, there is no information on ovine IFN-γ gene polymorphism or the effects of nucleotide variation on its biological activity. In addition, recombinant oIFN-γ is not available in North America. The objective of the present research was to clone and express oIFN-γ and to compare its nucleotide sequence with a previously reported oIFN-γ nucleotide sequence (McInnes

et al., 1990). Results of this experiment will lead to the production of large amounts of highly pure oIFN-γ that will be used to characterize its antiviral and immunomodulatory activities.

Material and Methods

Cell culture

Ovine peripheral blood mononuclear (PBMN) cells were purified from buffy coats by Ficoll-sodium diatrizoate (specific gravity, 1.077) centrifugation as described (Juste et al., 1998). Purified PBMN cells were cultured in RPMI-1640 with 10% FBS and 10 μg/ml Concavalin A (Con A). Total mRNA was extracted from PBMN cells with Trizol (Invitrogen Corporation, Carlsbad, CA) following instructions provided by the manufacturer.

Reverse transcription-polymerase chain reaction (RT-PCR)

The quality of isolated mRNA was checked by ethidium-agarose-formaldehyde gel electrophoresis (Sambrook et al., 1989). Synthesis of single strand cDNA was carried out with the GeneAmp RNA PCR kit (Perkin Elmer Corp, Foster City, CA). The reverse transcription protocol was modified as follows: Step 1) 42 °C for 1 h; Step 2) 95 °C for 5 min; and step 3) 0 °C for 2 h. Synthesis of double stranded cDNA was carried out according to the following protocol: Step 1) 95 °C for 2 min; Step 2) 95 °C for 30 s; Step 3) 42 °C for 30 s; Step 4) 95 °C for 1 min; Step 5) 30 cycles of Steps 2 to 4; Step 6) 72 °C for 10 min; and Step 7) 4 °C hold. Upper (5' ATG AAA TAC ACA AGC TCC 3') and lower (5' ATT GCA GGC AGG AGA ACC 3') primers targeting the entire oIFN-γ gene were designed. The size of the amplified RT-PCR products was checked by electrophoresis on 0.8% agarose gels.

cDNA cloning and sequencing

To express recombinant oIFN-γ protein, the glutathione S-transferase (GST) Gene Fusion System was used (Zhan et al., 2001). For this purpose, the fresh RT-PCR products were cloned in pGEM-T easy vector according to the protocol provided by the manufacturer (Promega, Madison, WI) and screened by the blue-white colony selection. White colonies (containing recombinant plasmids) were selected and the fidelity of the inserts further verified by restriction enzyme digestion using EcoR1. Clones having the correct size were sequenced in both orientations by automated sequencing at Gene Technologies Laboratory (Texas A&M University, College Station, Texas). Sequence data were further analyzed and edited using Jellyfish software version 2.1 (LabVelocity, Inc., San Francisco, CA) and Biology Workbench program version 3.2 (University of California San Diego Supercomputer Center, San Diego, CA).

Construction of E.coli expression vector pGEX4T-γ

Two different vectors, one containing the oIFN-γ signal sequence (pGEX4T-γ) and the other without it (pGEX4T-γ_{Δ}), were generated. Primer pairs used for the clone containing the signal peptide were: forward 5' CGT **GGA TCC** ATG AAA TAC ACA AGC TCC 3' and reverse 5' CCG **CTC GAG** TTA CAT TGA TGC TCT CCG 3'. The sequence of the primers to amplify the oIFN-γ without the signal peptide sequence were: forward 5' CGT **GGA TCC** CAG GGC CCA TTT TTT AAA G 3' and reverse 5' CCG **CTC GAG** TTA CAT TGA TGC TCT CCG 3'. To facilitate cloning into pGEX4T, these primers were designed to introduce a BamHI and a Xho1 restriction enzyme site (bolded sequences) at the 5' and the 3' ends of the oIFN-γ sequence, respectively. Amplified PCR products were checked by agarose gel electrophoresis, extracted with phenol/chloroform,

precipitated with ethanol and resuspended in ultrapure water. Following endonuclease restriction enzyme digestion with BamH1/Xho1, the PCR products were cloned into the BamH1/Xho1 site of the prokaryotic expression vector pGEX-4T as a GST fusion protein using T4 DNA ligase. Ligated PCR/pGEX4T products were used to transfect *E. coli* BL21 cells using the heat-shock method (Sambrook et al., 1989). Bacterial colonies were screened for the presence of inserts using Wizard Plus Miniprep DNA Purification System (Promega Corp. Madison, WI) according to the protocol provided by the manufacturer and checked by agarose gel electrophoresis. The identity of the inserts was verified by restriction enzyme digestion with BamH1/Xho1 and further confirmed by DNA sequencing. Clones containing the desired insert were further amplified in LB broth as above and stored at -70 °C. The oIFN-γ clone containing the signal peptide sequence was designated pGEX-4T-γ, and the one without the signal sequence was designated as pGEX-4T-γ_{Δ}.

Fusion protein expression in E.Coli strain BL21

Two milliliter LB broth aliquots were inoculated with *E. coli* BL21 cells transformed with either pGEX-4T-γ or pGEX-4T-γ_{Δ} and incubated at 37 °C. When the OD_{600} reached a value of 0.5, expression of recombinant protein was induced by the addition of isopropyl-β-D-thiogalactopyranoside (IPTG) at a final concentration of 2 mM /ml. After further incubation for 4 h, bacteria were harvested by centrifugation at 4000x *g* for 15 min at 4 °C. Bacterial pellets were lysed with 200 µl of 8 M of urea (Dian et al., 2002).

Protein Analysis

Proteins from lyzed bacterial pellets were resuspended in an equal volume of 2x loading buffer, boiled for 5 min and separated under denatured conditions by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) with 5% stacking and 12% resolving gels. Separated proteins were electroblotted to nylon cellulose membranes using the mini-gel transfer apparatus (Bio-Rad, Hercules, CA) at 130 volts for about 75 min. After washing with PBS, blotted membranes were blocked with 8% horse serum at room temperature for 3 h and incubated overnight at 4 °C with goat anti-GST polyclonal antibody (Invitrogen Corporation, Carlsbad, CA) or with monoclonal antibody against bovine IFN-γ (Serotech, Raleigh, NC) at 1:500 or 1:1000 working dilution, respectively. Following three washes with PBS, membranes were incubated with 1000x rabbit anti-goat IgG or anti-mouse IgG whole molecule peroxidase conjugates (Invitrogen Corporation, Carlsbad, CA) at 4 °C for three h. Specific proteins were visualized by incubating the blots with the substrate 4-chloro-1-naphthol (CN) in H_2O_2 at room temperature until the desired color was achieved. Color development was stopped by rinsing the membranes with tap water.

Results

The entire oIFN-γ gene was successfully amplified from ConA-stimulated ovine PBMN cells and subsequently cloned into pGEM-T easy vector. The sequence data showed that the size of the oIFN-γ gene containing the signal sequence was 501 nucleotides long, and shared 96.6% and 98.2% homology with the bovine and caprine IFN-γ genes, respectively (Figure 1). This oIFN-γ gene encodes a peptide of 166 amino acids. The nucleotide sequence of the oIFN-γ gene cloned in this report was highly conserved across ruminant species. The few nucleotide changes seemed to be random and were spread throughout the whole gene. Three nucleotide differences were also observed in the oIFN-γ reported here when its nucleotide sequence was compared to that of an

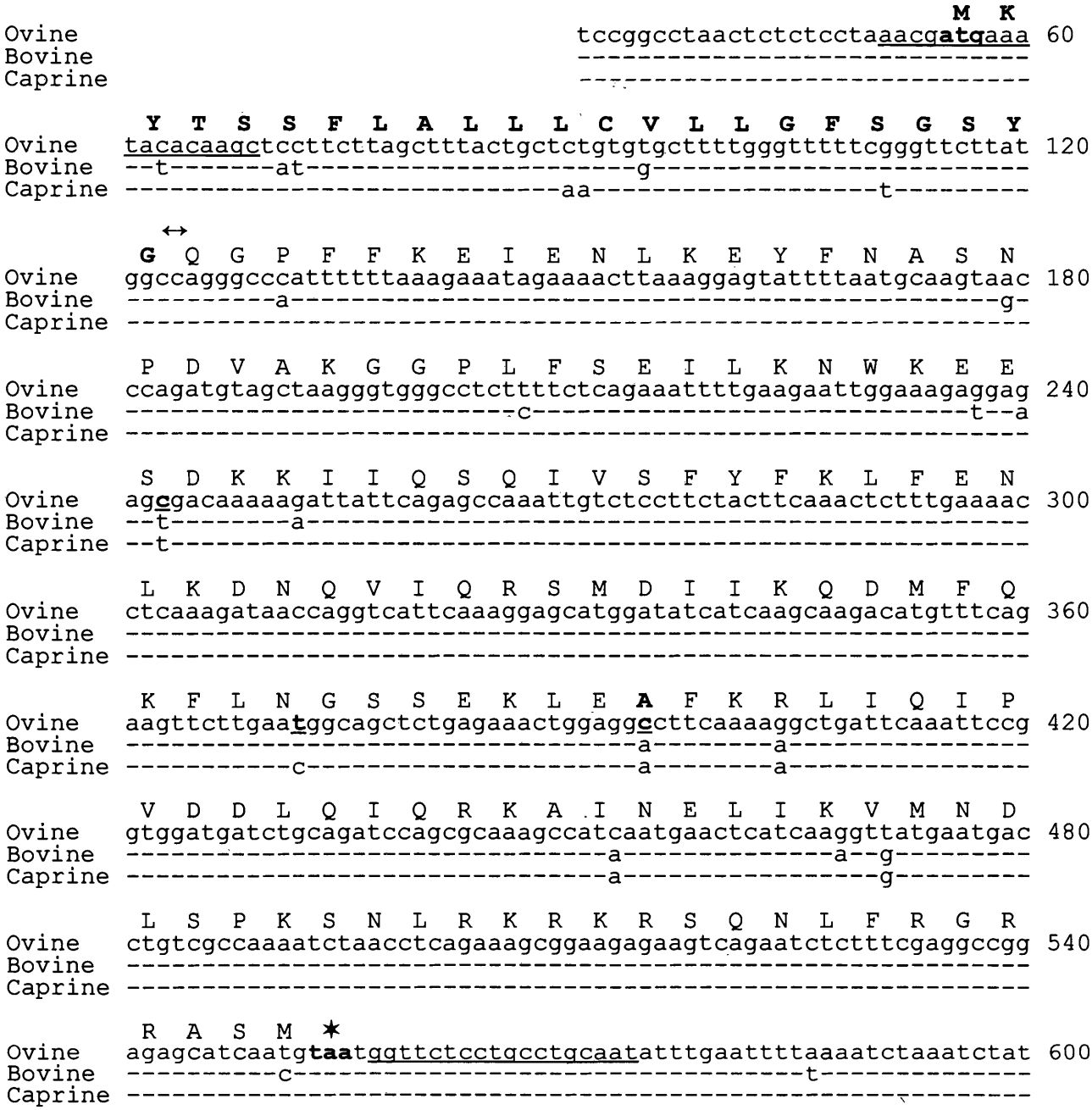

Figure 1. Ruminant interferon gamma cDNA. Complete nucleotide and deduced amino acid (capital letters) sequences of the ovine interferon gamma gene. The ovine nucleotide sequence is compared to the bovine and caprine interferon gamma sequences. For bovine and caprine sequences, nucleotides identical to the sheep sequence are shown by dashes. The three ovine nucleotides that are underlined and bolded indicate sequence differences with a previously reported ovine interferon gamma gene sequence (McInnes, CJ et al, 1990). Only one of the nucleotide differences resulted in an amino acid change (nucleotide position 385 from a to c, which resulted in the amino acid change from Aspartic acid to Alanine- D to A). The bolded amino acids residues represent the putative signal peptide. Underlined sequences represents the primers to target area.

oIFN-γ gene sequence reported previously (McInnes et al., 1990). Only one of these nucleotides changes resulted in an amino acid change (position 385 from a to c, which resulted in the amino acid change from aspartic acid to alanine).

The pGEX-4T-γ_{Δ} vector was used to transform *E. coli* BL21 cells. Immunoblot analysis of lysates of the transformed cells showed that the expressed fusion protein (GST-oIFN-γ) was recognized both by the anti-GST polyclonal antibody and by the anti-bovine IFN-γ monoclonal antibody (Figure 2). The size of the fusion protein was approximately 42 KDa; thus, corresponding to the combined expected sizes of GST and oIFN-γ. The pGEX-4T-γ vector (containing the signal sequence of oIFN-γ) was frozen, and will be used in further experiments to characterize the expression of oIFN-γ in mammalian expression vectors.

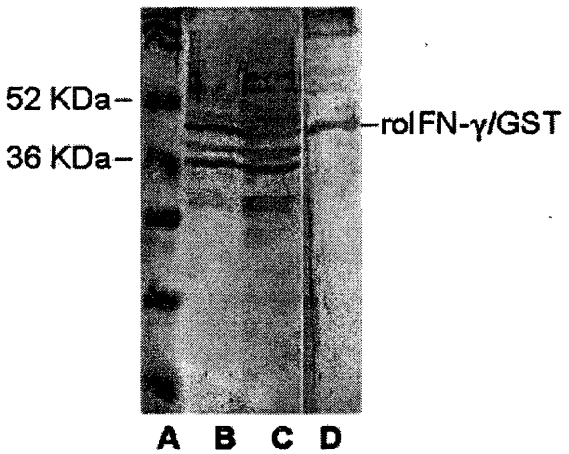

Figure 2. Western immunoblot analysis of ovine interferon gamma (oIFN-γ)/Gluthatione S-transferase fusion protein. Lane A = protein molecular weight markers (MWM); Lane B = Lysates of *E. coli* BL21 cells transformed with vector pGEX-4T-γ, induced with isopropylthio-β-D-galactoside (IPTG) and probed with goat anti-GST polyclonal antibody. The fusion oIFN-γ/GST protein corresponds to the darkest bands at approximately 42 Kda. Lane C = Lysates of non-induced *E. coli* BL21 cells transformed with vector pGEX-4T-γ. Lane D = Lysates of *E. coli* BL21 cells transformed with vector pGEX-4T-γ, induced with IPTG and probed with mouse anti-bovine IFN-γ monoclonal antibody.

Discussion

The cytokine IFN-γ plays a very important role in promoting innate and adaptive immune responses. The absence of IFN-γ production or cellular responsiveness in humans and experimental animals significantly predisposes the host to microbial infection. More recently, an anti-proliferative role of IFN-γ that prevents the development of primary and transplanted tumors has been identified (Ikeda et al., 2002). As a result of this multifunctional activity, the cloning, expression and production of oIFN-γ is of paramount importance. Furthermore, the whole blood bovine IFN-γ test has proven to be a practical ancillary test in the diagnosis of bovine tuberculosis (Buddle et al., 2001; Llamazares et al., 1999). More recently, the IFN-γ test also has been used as a supportive tool for the diagnosis of subclinical paratuberculosis in cattle (Jungersen et al., 2002).

Therefore, the availability of recombinant oIFN-γ could lead to the development of an oIFN-γ-based test for the diagnosis of ovine paratuberculosis (Johne's disease).

In the experiment reported here, oIFN-γ without the signal peptide was successfully expressed in *E. coli* as a GST fusion protein. The signal peptide is a sort sequence at the N-terminal of proteins that help them be secreted out of mammalian cells. This signal is not necessary for proteins expressed in bacteria.

A previous report from Australia indicated that the homology between bovine and ovine IFN-γ DNA sequence was 93% (Radford et al., 1991). The DNA sequence of the oIFN-γ gene cloned in the present report showed that this clone is more conserved across ruminant species and shares a 96.4% and 98.2% nucleotide sequence homology with the bovine and caprine IFN-γ genes, respectively (Beyer et al., 1998; Cerretti et al., 1986). Western immunoblot analysis using a rabbit polyclonal antibody against GST showed that the fusion protein has the correct expected combined size of GST and oIFN-γ. As judged by the intensity of the bands in the Western blot, the fusion protein was expressed efficiently. Currently, there are no monoclonal or polyclonal antibodies against oIFN-γ available in the US. For this reason, we used a commercially available monoclonal antibody against bovine IFN-γ to identify recombinant oIFN-γ in the Western blot analysis. This antibody reacted with a protein of the same size as the one recognized by the anti-GST antibody, confirming that the expressed protein is a fusion between oIFN-γ and GST. Further studies are underway to purify oIFN-γ (cleave it from GST), and to characterize the antiviral, immunomodulatory and antiproliferative activities of recombinant oIFN-γ.

Acknowledgments

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Genetic diversity among soremouth virus strains

J. Guo, C.A. Taylor, Jr., and A. de la Concha-Bermejillo

ABSTRACT: In this study the genetic diversity of the soremouth virus interferon resistant (VIR) gene, a gene that encodes the information for a viral protein that blocks the immune response of the host, from twenty strains was characterized at the molecular level. The study included several soremouth virus strains obtained from Texas goats affected with severe or mild soremouth, two sheep soremouth virus strains from Great Britain, four virus strains from different lots of the Texas Agricultural Experiment Station (TAES) soremouth vaccine and two isolates from Musk ox from Minnesota. The VIR gene from each strain was first amplified by the polymerase chain reaction (PCR), then cloned into a TA vector and sequenced. Sequences were aligned, edited, the deduced amino acid sequences obtained, and used to construct phylogenetic trees.

The VIR gene from all sheep strains grouped closely in the same branch of the phylogenetic tree, indicating that there has been very few genetic mutations of these strains throughout the yr. On the other hand, the VIR gene from goat soremouth virus strains was more heterogeneous. This resulted in the goat strains being scattered through out the genetic tree forming two major clusters. Strains from goats belonging to the same owner were genetically closer to each other than to strains from a different owner, indicating that soremouth virus strains tend to remain endemic in each location. The strains obtained from musk ox were genetically more closely related to the sheep strains than to the goat strains, suggesting that soremouth in this species may have originated from a sheep strain. One experimental vaccine strain, in which sheep and goat soremouth scabs were mixed and grown in sheep, was phylogenetically more related to the other sheep strains than to the goat strains. This implies that soremouth virus strains co-evolve with the host. In this study, there was no association between the amino acid sequence of the soremouth VIR gene and the degree of disease induced by a particular strain, indicating that although this gene may be involved in blocking the initial immune response of the host, it may not be an important determinant of virulence.

Key Words: Soremouth, Genetic Diversity, Ovine, Virus Interferon Resistant (VIR) Gene

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Introduction

Soremouth is one of the most common infectious diseases of sheep and goats (de la Concha-Bermejillo et al., 1998). Soremouth also affects wild ruminants and humans. The disease is caused by a parapoxvirus that is very resistant to adverse environmental conditions, and the virus persists in infected premises from yr to yr (de la Concha-Bermejillo, 1995; Livingston and Hardy, 1960; McKeever and Reid, 1986; Moyer et al., 2000). Soremouth clinical disease is more common in young lambs and kid goats. In the majority of cases, the infection is self limiting, and lesions

regress spontaneously 4 to 6 wk after initial appearance (de la Concha-Bermejillo et al., 1999). Using restriction enzyme analyses of soremouth virus DNA, investigators have shown genetic heterogeneity among strains affecting sheep (Robinson et al., 1982). However, strains affecting goats have not been characterized. Experimentally, goats can be infected with soremouth virus obtained from sheep, and there is a widespread belief that soremouth virus affecting sheep and goats is the same virus. Still, during soremouth outbreaks in premises where sheep and goats are raised together, often only one species is affected, suggesting that there may be some strains that replicate primarily in sheep and others that preferentially infect goats. This theory is supported by the fact that soremouth virus vaccines produced in sheep do not protect goats against clinical disease (de la Concha-Bermejillo et al., 1999).

Parapoxviruses, such as soremouth virus, are among the largest mammalian viruses and contain over 139 kb of genomic DNA (Fleming et al., 1993). Parapoxviruses replicate efficiently in the host despite the presence of a fully competent immune system. This is the result of several evolutionary genetic mechanisms that these viruses have developed to evade the immune response of the host (Buddle et al., 1984; de la Concha-Bermejillo et al., 1999; Haig et al., 1997; Pye, 1990). Specifically, soremouth virus contains a virus interferon resistance (VIR) gene located in the left terminal region of the virus genome (Haig et al., 1998; McInnes et al., 1998). The VIR gene encodes the information for a dsRNA-binding protein that inhibits the antiviral activity of interferons and may play a role in virus persistence and reinfection (Haig and Mercer, 1998). The objectives of the present study were to characterize the genetic diversity of the VIR gene among several soremouth virus strains, and to determine if there was an association between the VIR gene DNA nucleotide sequence and soremouth virus strain pathogenicity.

Material and Methods

Source of Soremouth Virus Strains

Twenty soremouth virus strains were included in this study. The origin and characteristics of these strains are presented in Table 1.

Extraction of Soremouth Virus DNA from Scab Material

Soremouth virus DNA was extracted from skin lesions as described with some modifications (Gilray et al., 1998). Briefly, 50% scab suspensions in Hanks'Balanced Salt Solution were homogenized in tissue mortars. Then, 100 µl of 10% SDS and 20 µl of proteinase K (10 mg/ml. Promega Co. Madison, WI) were added to 900 µl of each of the tissue homogenates. The mixtures were incubated at 37 °C for 2 hr, and DNA was extracted once each with an equal volume of phenol; phenol:chloroform and chloroform. One tenth volume of 3M sodium acetate (pH 5.2) and 2.5 volumes of 100% ethanol were added to the final aqueous phase to precipitate the DNA. The DNA pellets were washed once in 70% ethanol, air dried, and suspended in TE buffer.

Amplification of the Soremouth Virus Interferon Resistant (VIR) Gene by the Polymerase Chain Reaction (PCR)

The complete VIR gene from each of the soremouth virus strains described in Table 1 was amplified by PCR using primers (forward primer 5' aag ctt aga agc tga tgc cgc ag 3'; reverse primer 5' gga tcc aca atg gcc tgc gag tg 3') designed using a previously published sequence of the soremouth virus strain NZ2 VIR gene (McInnes et al., 1998). PCRs were carried out in a 50µl reaction volume containing 5µl of 10 x PCR buffer (10mM Tris-HCl and 50mM KCl), 5µl of DNA

Table 1. Summary of soremouth virus strains characterized in this study

Case ID	Species	Breed	Origin	Year	Severity of Disease
Orf 1, Orf-6, Orf-7	Caprine	Boer	West Texas owner A	2000	Severe
Orf-8	Caprine	Boer	West Texas owner A	2001	Severe
Orf-25	Caprine	Angora	West Texas owner A	1995	Mild
Orf 9, Orf-12, Orf-13, Orf-15, Orf-16	Caprine	Boer	West Texas owner B	2001	Severe
Orf-26	Caprine	Boer	West Texas owner C	1998	Mild
Orf-3	Caprine	Boer	East Texas	2001	Severe
Orf-4	Ovine	Rambouillet	Vaccine containing sheep & goat scab	2001	NA
Orf-5	Ovine	Rambouillet	Vaccine sheep scab	1963	NA
Orf-22	Ovine	Rambouillet	Vaccine sheep scab	1964	NA
Orf-24	Ovine	Rambouillet	Vaccine sheep scab	1996	NA
Orf-GBa	Ovine	Unknown	British (Gene bank)	1998*	Severe
Orf-GBb	Ovine	Unknown	British (Gene bank)	1998*	Mild
Orf-27, Orf-29	Musk ox	NA	Minnesota	2001	Severe

* Year of publication (McInnes et al., 1998).

template, 200 μM dATP, dTTP, dCTP, dGTP, 0.4 μM of each primer, 25 μM $MgCl_2$ and 0. 5μl of Taq polymerase (Promega Corp. Madison, WI). PCR amplifications were performed in a thermocycler (GeneAmp PCR 2400, Perkin Elmer) for 30 cycles of denaturation at 94°C for 1 min, annealing at 55°C for 30 sec and extension at 72°C for 30 sec. The PCRs were ended at 72°C for 7 min. The amplified DNA products were resolved by agarose gel electrophoresis and analyzed with an IS-1000 Digital Imaging System (Alpha Innotech Corp. San Leandro, CA). DNA bands having the correct size were excised from the gels, purified and DNA used for cloning and sequencing (de la Concha-Bermejillo et al., 1995).

Cloning and Sequencing of the Virus Interferon Resistant (VIR) Gene

The purified PCR products were cloned into pGEM-T easy Vector (pGEM-T vector system, Promega Corp., Madison, WI) following instructions by the manufacturer. Nucleotide sequencing was performed by automated sequencing at Gene Technologies Laboratory (Texas A&M University, College Station, Texas). Sequences were read on an automated sequencer (Applied Biosystems DNA Sequencer 373A, Norfolk, CT).

Construction of Phylogenetic Trees

DNA sequences were assembled and edited with the JellyFish software package (LabVelocity, Inc. San Francisco, CA), and the deduced amino acid sequences aligned with ClustalW multiple sequence alignment (University of Washington. Seattle, WA). Distance matrixes were calculated using PRODIST. A consensus phylogenetic tree was constructed by the Neighbour-Joining method.

Results

After PCR amplification of viral DNA using primers and conditions specific for the soremouth VIR gene, bands corresponding to the correct expected size for the gene of interest were amplified from all twenty soremouth strains included in this study. Amplified bands were purified, cloned and sequenced. The VIR gene was of the exact same size in all strains (552 bp) and shared 90 to 100 % nucleotide and amino acid sequence identity among them.

The attributes of the 20 soremouth virus strains characterized in this report are summarized in Table 1. Twelve strains were obtained from goats, eleven of which belonged to three different owners in west Texas and one to an owner in east Texas. Seven of the goat strains were obtained from kids of the 2001 crop, three from the 2000, one from the 1998 and one from the 1995. With the exception of one case (Orf-25), all goats were Boers (or Boer crosses). Ten of the twelve goat strains were from clinical cases with severe soremouth and two with mild disease. Four of the sheep strains were obtained from soremouth vaccine lots produced in 1963, 1964, 1996 and 2001. The latter was an experimental lot that was produced by scarifying a mixture of sheep and goat scab into the skin of susceptible sheep. Two additional gene sequences corresponding to strains from British sheep were obtained from Gene Bank. The two musk ox strains were obtained from lesions in two different locations in the skin of the same animal, which suffered from severe soremouth.

The consensus phylogenetic tree constructed with the VIR gene deduced amino acid sequences of the twenty soremouth virus strains showed that all sheep strains branched closely together, regardless of the geographical region where or the yr in which they were obtained (Figure 1). On the other hand the goat strains were more heterogeneous and grouped into two major branches.

Strains from goats belonging to the same owner tended to cluster together, with the exception of orf-25, which in spite of belonging to west Texas producer A, was more related to the strains obtained from goats of west Texas owner B. The VIR gene of the two strains obtained from musk ox were genetically closer to the sheep strains than to the goat strains. There was no clustering of the soremouth virus strains associated to the degree of disease (mild = self limiting lesions in skin of lip and nostril; severe = persistent widespread lesions) induced by each strain.

Discussion

Soremouth is a common infectious disease of sheep and goats. Because in the majority of cases, soremouth lesions are mild, and affected animals recover spontaneously within 4 to 6 wk, many sheep and goat producers live through the soremouth outbreaks without providing any medical treatment to affected animals. In the last four to five yr, severe cases of soremouth in goats have been described. In the majority of these cases, affected goats had been vaccinated against soremouth and were full Boer or Boer crosses. Previous experiments have shown that none of the two soremouth vaccines available in the US (one licensed for use in sheep and goats and the other for sheep exclusively) protected goats against challenge with virulent soremouth virus (de la Concha-Bermejillo et al., 1999). This suggests that soremouth virus strains affecting goats may be genetically different to the strains affecting sheep.

Genetic analysis of the VIR gene of 20 different strains of soremouth virus showed that all the strains are remarkably similar and share 90 to 100% sequence identity at the amino acid level. In spite of this similarity, all the sheep soremouth virus strains clustered together in the same branch of the phylogenetic tree, indicating that sheep strains exhibit more similarity among them than the goat strains. This genetic proximity among the sheep strains was evident even when strains obtained in recent yr and those present in the TAES vaccine strain produced in the 1960's were compared. A great similarity in DNA and amino acid sequence also existed between the sheep soremouth virus strains from Great Britain and from Texas. Furthermore, when an experimental lot of the Texas Agricultural Experiment Station (TAES) soremouth vaccine was prepared by mixing scab from sheep and from goat and then amplified by skin scarification in sheep, the resulting soremouth virus strain continued to group with the sheep strains. These results suggest that the host species may play a role in selecting strains that grow well, or are better adapted to that particular species, and that the soremouth virus genome is remarkably stable during replication in sheep.

The two virus strains obtained from an outbreak of severe soremouth in musk ox from a Minnesota zoo were more closely related to the sheep strains than to the goat strains. The reason for this is not clear. However, during the outbreak at the zoo some domestic sheep from the "pet zoo" section were affected also. It is possible that these sheep were the source of virus for the musk ox.

Soremouth virus strains from goats were more heterogeneous and clustered into two major branches which diverged from the sheep strains. Owner seemed to have an effect in the positioning of goat strains within the tree, so that strains obtained from clinical cases belonging to a particular owner grouped together in the same branch. This would suggest that soremouth virus strains may have a tendency to remain endemic in specific locations. Case orf-25 was an exception, because even though it belonged to owner A, it was genetically more similar to the strains obtained from goats belonging to producer B. The reason for this is unclear. Because only one case behaved in this manner, it may be speculated that this strain is an outlier. Alternatively,

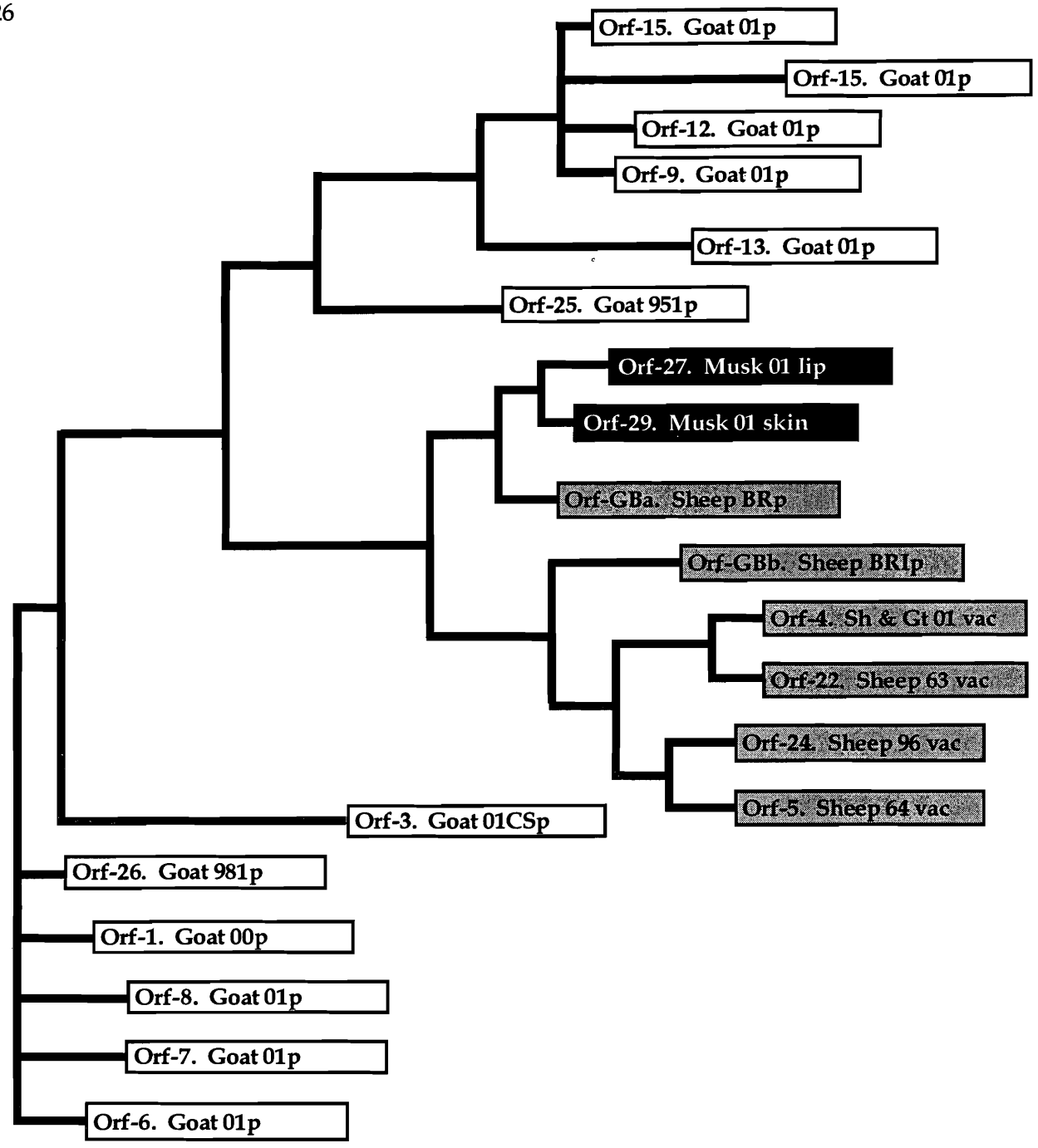

Figure 1. Consensus phylogenetic tree of the soremouth virus interferon resistant (VIR) gene constructed by the Neighbor Joining method. The tree shows the genetic diversity among 20 soremouth virus strains from goats (white boxes), sheep (gray boxes) and musk ox (black boxes). The case identification (Orf-#) is indicated in each box, followed by the species from which the strain was harvested, and the last two digits of the year when the strain was obtained. A letter "p" indicates that the strain was pathogenic (induced severe disease), and "lp" indicates that the strain had low pathogenicity (induced mild disease). Other abbreviations are: BR = British; GB = Genetic Bank; vac = vaccine; CS = College Station.

differences in breed (Angora versus Boer) or yr (1995 versus 2000 or 2001) may have had an effect on the genetic make up of the VIR gene in this strain. Associations between the yr of the outbreak, the goat breed or the virulence of the strain and the genetic branch were not evident. These results suggest that individual factors in each goat may influence the rate of virus mutation; thus, resulting in random nucleotide changes in the VIR gene nucleotide sequence during virus replication in this species.

We chose to characterize the soremouth VIR gene because it encodes the information for a protein that blocks the antiviral effects of interferons (Haig and Mercer, 1998). Some authors have suggested that the VIR gene may play a role in virus pathogenicity (Brandt and Jacobs, 2001; Haig et al., 1998; Haig and Mercer, 1998; McInnes et al., 1998). However, in the study presented here there was no association between the amino acid sequence of the soremouth VIR gene and the type of disease induced by a particular strain, indicating that although this gene may be involved in blocking the initial immune response of the host, it may not be an important determinant of virulence.

The molecular characterization of viruses is important because it provides information on the genetic diversity among strains. Our results show that the soremouth VIR gene is highly conserved among all members of the parapoxvirus group. Because of different evolutionary pressures, genes within an organism evolve at different rates. The low degree of variability in amino acid sequence of the VIR gene suggests that the nucleotide sequence heterogeneity in hypervariable regions of the viral genome may be more pronounced. Based on the limited information available on the genetic diversity of the soremouth virus envelope gene, it is expected that a similar relationship in the genetic tree will be maintained among soremouth virus strains (Inoshima et al., 2001). Currently, we are sequencing and analyzing additional segments of the soremouth virus genome. This will provide additional information on the genetic evolution of this virus. Genetic diversity between soremouth virus strains from sheep and goats could explain in part the failure of sheep soremouth vaccines to protect goats against this disease.

Acknowledgments

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Ovine progressive pneumonia research at the Texas Agricultural Experiment Station: What we have learned in the last decade

A. de la Concha-Bermejillo

Abstract: Ovine progressive pneumonia (OPP) is a chronic disease of sheep caused by ovine lentivirus (OvLV), also called OPP virus. Economic losses that result from this disease include the cost of treatment of secondary infections, losses associated with reduced productivity of affected animals, animal deaths, and loss of marketing opportunities as a result of restrictions that countries impose on the importation of sheep from places where the infection exists. Ovine progressive pneumonia is considered one of the most important diseases of sheep in North America. For over a decade, a major effort of the veterinary research program at the Texas Agricultural Experiment Station-San Angelo (TAES-SA) has been the understanding of basic concepts on the epidemiology, transmission, diagnosis, treatment and prevention of this disease.

A major finding was that the prevalence of OPP in range sheep of western Texas was significantly lower than in sheep from other states. This divergence in infection rate may be the result of differences in flock management practices and climate. Because production objectives, sheep breeds and management are changing in Texas, producers in this state need to be aware of the potential risk of introducing this infection into their flocks.

We also determined that some of the commercially available ELISA tests used to identify infected sheep are unreliable. Although the agar gel immunodiffusion (AGID) test has high specificity, the test may be unable to detect sheep infected with slow replicating OPP virus strains. Preliminary results indicate that a new commercially available "competitive" ELISA may be more sensitive than the AGID test and other ELISA formats.

Close contact transmission between infected and non-infected sheep under western Texas environmental conditions does not seem to occur, but semen of OPP-infected rams that have concurrent inflammatory lesions in the reproductive tract may be a source of virus for non-infected ewes. Recombinant ovine interferon-tau (roIFN-τ), a new antiviral drug, has proven to be highly effective in reducing virus replication *in vitro* and *in vivo* and in preventing OPP virus-induced disease in lambs that are treated soon after infection. Due to its high cost, treatment of OPP with roIFN-τ is not economically feasible at this point. The utilization of gene delivery vectors or slow-release drug delivery systems may help overcome this barrier.

Past attempts by other investigators to produce a vaccine for OPP have failed. Recently, we genetically engineered an OPP virus in which one viral gene (dUTPase) was replaced by the green fluorescent protein (GFP) gene (a gene from jelly fish). This recombinant OPP-GFP virus is attenuated for pathogenicity *in vitro* and *in vivo*. Because it contains the GFP gene, it can be easily differentiated from wild type OPP virus. For these reasons, the OPP-GFP virus could be used as a vaccine to protect sheep against OPP.

Key Words: Ovine Progressive Pneumonia (OPP), Ovine Interferon-Tau (roIFN-τ), Recombinant Lentivirus, Vaccine

Sheep and Goat, Wool and Mohair CPR 2002. 129-138

Introduction

Ovine progressive pneumonia (OPP), also called maedi-visna, is a chronic disease of sheep produced by ovine lentivirus (OvLV), a member of a family of viruses called Retroviruses (Joag et al., 1996). This family also includes caprine arthritis encephalitis virus (CAEV) of goats and the human immunodeficiency virus (HIV), the cause of AIDS in humans (de la Concha-Bermejillo et al., 1995b). Ovine lentivirus or OPP virus produces a persistent infection in infected sheep. Therefore, infected animals remain infected for life and are the source of virus for other sheep (de la Concha-Bermejillo, 1997). For this reason, infection with OPP virus is a major concern to sheep producers worldwide, not only for the economic losses it causes as a result of decreased animal productivity and death of affected animals, but also for the national and international barriers that are imposed to countries and flocks where the infection exists (de la Concha-Bermejillo et al., 1998a; Pekelder et al., 1994; Petursson et al., 1990; Smith, 1992). In a survey conducted among small ruminant veterinary practitioners and producers throughout the United States, OPP was considered among the most important diseases of sheep (de la Concha-Bermejillo et al., 1998a).

Sheep infected with OPP virus often develop a complex disease characterized by chronic inflammation (swelling) of the lungs (pneumonia), lymph glands (lymphadenitis), joints (arthritis), mammary gland (mastitis) and less often brain (encephalitis) (Cutlip et al., 1979; Cutlip et al., 1988). As a result of this, OPP virus-infected sheep may show signs of progressive respiratory failure without fever that affects animals 2-3 yr or older (Brahic and Haase, 1981). Initially, affected animals lag behind when driven to pasture, and after exercise the respiration becomes rapid and shallow. As the disease progresses, the respiration becomes gradually more difficult, and affected sheep develop open-mouth breathing with extension of the neck and flaring of the nostrils to gasp for air. These sheep also show gradual loss of weight and body condition despite good appetite. Once clinical disease becomes apparent, sheep die within one yr usually due to respiratory failure or secondary bacterial infections (Bulgin, 1990).

More than one clinical manifestation may coexist in the same flock or animal (Petursson et al., 1990). Over 60% of ewes in OPP-affected flocks may present evidence of mammary gland swelling. This form of the disease is characterized by diffuse, symmetrical hardening of the udder ("hardbag") and reduction in milk production, although the scant amount of milk may have a normal color and consistency (Houwers et al., 1988). The gland's and milk's appearance in mastitis caused by OPP virus is different from mastitis caused by bacteria ("blue bag"). In the latter the gland is asymmetrical, may develop lumps and the milk may contain flakes and clots. Lambs born to ewes with mastitis caused by OPP virus are constantly hungry and have poor growth, particularly in ewes with twins or triplets (Lechner et al., 1997).

Sheep with arthritis due to OPP become lame and lose body condition despite having good appetite. These clinical signs occur typically two to three yr after infection. The condition begins insidiously with weight loss and swelling of the carpal and tarsal joints. Other joints are less frequently affected (Harkiss et al., 1995; Kennedy-Stoskopf et al., 1989; Narayan et al., 1992). In the US, the form of the disease affecting the brain occurs only occasionally, but it is a common manifestation in some infected flocks in Europe (Constable et al., 1996; Georgsson, 1994). Sheep affected by this form of the disease may show gait abnormalities, initially affecting the hindquarters. Then, there is progressive weakening of the hind legs that results in posterior paralysis. The disease eventually leads to complete immobility of affected sheep. These animals lose body condition, and twitching of the lips and facial muscles or blindness may be observed

(Georgsson, 1994; Oliver et al., 1981). This form of the disease needs to be differentiated from scrapie (de la Concha-Bermejillo, 1997).

THE MAJORITY OF SHEEP FLOCKS IN WESTERN TEXAS ARE FREE OF OPP VIRUS. TEXAS SHEEP PRODUCERS COULD BENEFIT FROM THIS COMPETITIVE ADVANTAGE WHEN SELLING SHEEP.

For the last 11 yr, TAES-SA has maintained a very active OPP research program. We were the first to isolate OPP virus from a ram in Texas and demonstrate the presence of the infection in the state (de la Concha-Bermejillo et al., 1992). Subsequently, we were interested in finding out the extent of OPP virus infection in sheep flocks of western Texas. Previous reports indicated that approximately 26% of all sheep in the US were persistently infected with OPP virus (Cutlip et al., 1992). However, in this study there was great variability in the prevalence of OPP in different states and flocks. While OPP seroprevalence in the Rocky Mountain region was 49%, only 9% of sheep in the Northern Atlantic region were positive. Another study found that the average OPP seroprevalence in a large Idaho sheep range flock was 58% (Gates et al., 1978). To determine the prevalence of OPP in sheep from western Texas, we collected over two thousand serum samples from sheep in that part of the State. To our surprise, only 0.05% of the tested sera were positive for OPP. Furthermore, the majority of OPP positive sheep in these flocks were animals that had been bought from states with high OPP prevalence. We concluded that the low prevalence of OPP in sheep from western Texas may be the result of differences in flock management (lambing on pasture versus pen lambing) and climate (hot and dry) that is unfavorable for the survival of OPP virus in the environment (de la Concha-Bermejillo et al., 1998b). Of great importance in this study was the finding that acquiring replacement sheep from states with high OPP seroprevalence represented a risk of introducing the infection in non-affected flocks. Production objectives, breeds of sheep, and management practices are changing in some flocks in western Texas. Sheep producers in Texas need to maintain awareness of the risks of introducing this disease in their flocks. Replacement sheep should always be tested for OPP.

THE AGAR GEL IMMUNODIFFUSION (AGID) TEST MAY BE A GOOD METHOD TO SCREEN OPP VIRUS-INFECTED FLOCKS, BUT MAY FAIL TO DETECT SOME INDIVIDUAL INFECTED SHEEP.

Having determined that OPP prevalence in western Texas sheep was much lower than the National average, we were interested in finding out the best test to detect infected sheep. Serological methods, including several ELISA formats and the agar gel immunodiffusion (AGID) test, have been the methods of choice to test for OPP antibodies in sheep (Brodie et al., 1998; de la Concha-Bermejillo, 1997). To determine the specificity (ability of a test to detect non-infected animals as negative) and sensitivity (ability of a test to detect infected animals as positive) of the AGID test and two recombinant ELISAs, the three tests were compared using serum samples collected weekly from sheep experimentally inoculated with OPP virus or placebo. Our results showed that the specificitiy and sensitivity of the two ELISA tests were variable. While an ELISA test originally developed by Dr. J. Kwang from the US Meat Animal Research Center in Clay Center Nebraska had a specificity of more than 94% and a sensitivity of 86%, the results of an ELISA test performed by a private veterinary diagnostic laboratory were unreliable. The specificity and sensitivity of the AGID test were 100% and 91.5%, respectively. These results suggest that the AGID test may be a good screening test to identify OPP infected flocks (Juste et al., 1995). However, because the time of seroconversion may be as long as 12 wk or more, repeated testing

of sheep is recommended. In addition, a recent experiment by this research group using sheep experimentally infected with a slow replicating, genetically modified OPP virus showed that the AGID test was unable to detect infected sheep (author's unpublished observation). At the same time, antibodies against OPP were detected in the sera of four lambs by a new "competitive" ELISA that uses a monoclonal antibody against the surface envelope protein of CAEV, but that crossreacts with OPP virus (Ozyoruk et al., 2001). Although this competitive ELISA seems to have high sensitivity to detect OPP serum antibodies, further testing using clinical samples will be necessary to confirm this observation.

CLOSE CONTACT BETWEEN OPP VIRUS-INFECTED AND NON-INFECTED SHEEP UNDER WESTERN TEXAS WEATHER AND MANAGEMENT PRACTICES MAY NOT BE A RISK OF OPP TRANSMISSION.

Close contact between infected and non-infected sheep, ingestion of colostrum or milk from infected ewes, and the transplacental route are thought to be the methods of OPP virus transmission (Brodie et al., 1994; DeMartini et al., 1999; Petursson et al., 1990). However, the most important route of OPP virus transmission is still controversial. Once OPP infection is introduced, eliminating the infection from the flock is difficult and expensive. Another important issue regarding the OPP research program at TAES-SA was to assess the risk of spreading the infection into Texas OPP-free flocks by introducing infected sheep. For this purpose, we experimentally infected 32 lambs with OPP virus in the spring and kept them in shaded, open pens for eight months. Eight non-infected lambs were introduced into the same pens and kept together for the entire length of the experiment as contact non-infected controls. The OPP status in these forty lambs was determined biweekly for eight months by ELISA, virus isolation and the polymerase chain reaction (PCR), the latter a highly sensitive technique to detect OPP virus DNA in cells and tissues. While all virus-inoculated lambs became infected with OPP virus, none of the non-infected contact controls was detected as positive by any of these tests. These results suggest that introducing OPP virus into OPP-free flocks by mingling infected and non-infected sheep in open pens under western Texas weather conditions does not represents a risk of transmission (Aber et al., 1998). However, because there are differences in sheep breed susceptibility, variations in yr to yr weather conditions, and virus strain virulence (Cutlip et al., 1986; de la Concha-Bermejillo et al., 1995a; Lairmore et al., 1988), we still recommend that replacement sheep be acquired from OPP-free flocks or that all new sheep test negative before being introduced into the premises.

OPP-INFECTED RAMS ARE POTENTIAL SOURCES OF VIRUS FOR NON-INFECTED EWES.

Veneral transmission is the most common route of transmission for HIV, a human lentivirus similar to OPP virus (Levy, 1993). However, information about the potential transmission of OPP virus through contaminated semen was non existent. We were the first research group in the world to report that OPP-infected rams that have inflammatory lesions in the reproductive tract shed the virus in the semen (de la Concha-Bermejillo et al., 1996). In this study, OPP-infected rams co-infected with *Brucella ovis*, the cause of ram epididymitis, excreted large amounts of OPP virus in semen. On the other hand, OPP virus-infected rams without epididymitis did not shed the virus in semen. These results indicate that OPP virus-infected sheep with inflammatory lesion in the reproductive tract may be potential sources of OPP virus for non-infected sheep.

OPP VIRUS REPLICATES RAPIDLY SOON AFTER INFECTION. REPLACEMENT SHEEP MUST BE QUARANTINED AND TESTED FOR OPP SEVERAL TIMES BEFORE MIXING THEM WITH OTHER SHEEP.

As mentioned previously, OPP virus is a lentivirus. The name lentivirus was given to this group of viruses because they were thought to replicate slowly (lenti means slow). Previously, it was believed that after initial infection, OPP virus would hide in tissues of infected sheep (remain latent), and that several yr later for unknown reasons, the virus would start multiplying; only then, inducing clinical disease (Bulgin, 1990). We were the first research team to demonstrate that this theory was incorrect. To prove this, we inoculated 16 lambs with OPP virus. Every other wk after infection, the amount of OPP virus in blood was measured. What we found was that OPP virus replicated to high titers soon after infection. In most sheep, the maximum virus titer in blood was reached between 4 and 6 wk. Then, a strong immune response by the infected animal partially controlled virus replication causing a decline in virus titer by 8 wk after infection. From then on, there is a constant battle between the sheep's immune system and OPP virus. In this battle, the virus first replicates rapidly; then, the immune system partially controls the virus. A small amount of remaining virus in the infected sheep mutates; thus, escaping the initial immune response and producing a new spike in blood virus titer. This is followed by a secondary immune response against the new mutated virus. Eventually, the constant fight between new virus mutants and the immune system leads to tissue damage and the development of clinical disease. A major finding of this project was that because during the first few wk after infection infected sheep have high titers of virus in blood but lack antibodies against the virus, shedding and transmission of the virus are more likely to occur during this period (Juste et al., 1998). For this reason, sheep producers obtaining replacement sheep from flocks where the infection exists should quarantine new sheep for several wk and test them several times before mixing them with other sheep.

SOME SHEEP MAY BE GENETICALLY PREDISPOSED TO THE DEVELOPMENT OF OPP VIRUS-INDUCED PNEUMONIA.

Using artificially created identical twin lambs, we had shown previously that sheep genetic factors play a major role in determining the susceptibility to OPP virus-induced disease (de la Concha-Bermejillo et al., 1995a). To determine if some breeds of sheep were more susceptible to OPP virus-induced pneumonia, thirty-two lambs from four breeds (Barbado, Rambouillet, Suffolk and Florida Native) representing seven flocks were inoculated with OPP virus and response (infectious virus, proviral DNA load and antibody profiles) was evaluated in order to estimate variation among breeds. The degree of OPP virus-induced pneumonia was evaluated by microscopic examination of lung sections, 8 months after virus inoculation. Our hypothesis was that OPP virus-induced disease was controlled by host genetic factors. Although differences among breeds were observed, there were also substantial differences that were attributed to flock of origin, suggesting that resistance/susceptibility to OPP virus-induced pneumonia may be related to individual genetic factors of the host. Despite this, breed differences were apparent, and these differences facilitated their classification as susceptible, intermediate, or resistant to developing OPP virus-induced pneumonia. Overall Barbados appear to be a more susceptible breed while Suffolks may be more resistant (Aber et al., 1998).

RECOMBINANT OVINE INTERFERON-TAU (ROIFN-T) INHIBITS OPP VIRUS REPLICATION AND PREVENTS THE DEVELOPMENT OF OPP VIRUS-INDUCED PNEUMONIA.

There are no effective treatments available for OPP. Since the discovery of HIV as the cause of AIDS in humans, a series of antiviral drugs have been developed. Ovine interferon-tau (oIFN-τ) is a new type of interferon with potent antiviral, immunomodulatory and antiproliferative activities. A series of experiments were conducted to determine the effectiveness of roIFN-τ on OPP virus replication *in vitro* and *in vivo*. *In vitro*, it was found that the amount of OPP proviral DNA measured by PCR, the number of OPP virus-induced syncytia, and the amount of infectious virus were reduced by 90 to 99% in cell cultures treated with roIFN-τ compared to the placebo-treated controls ($p<0.01$). Recombinant oIFN-τ also reduced other parameters indicative of OPP virus replication, such as reverse transcriptase activity, and protected cells from OPP virus-induced cell destruction. Results of experiments to determine the optimal dose of roIFN-τ followed a logistic model, in which roIFN-τ anti-OPP virus activity augmented with increasing amounts of IFN up to 100 AVU/ml, after which its activity remained fairly constant (Juste et al., 1996).

The *in vivo* antiviral effects of roIFN-τ were studied in 26 newborn lambs inoculated intratracheally with OPP virus strain 85/34 or placebo (Juste et al., 2000). Six of the OPP virus- and three of the placebo-inoculated lambs were treated with roIFN-τ once a d for 30 d starting at post-inoculation (PI) d 0 and twice a wk thereafter (early treatment). Six of the OPP virus- and three of the placebo-inoculated lambs were treated with roIFN-τ once a d for 30 d starting at PI d 150 and twice a wk thereafter (late treatment). Six OPP virus-infected and 2 non-infected lambs were treated either early or late with non-transformed *Pichia pastoris* supernatants (placebo) and used as controls.

Cell-associated viremia was determined every other wk by an end point dilution method. All experimental animals were killed at 27 wk post-inoculation and histologic sections of lung were examined and scored for the degree of lymphoid interstitial pneumonia (LIP) and bronchus-associated lymphoid tissue (BALT). A 90% reduction in OPP virus titers was observed at 4 wk post-treatment in the experimental group that received early IFN treatment ($p<0.01$). Significant differences in virus titers were also observed at wk 2 and 6 ($p<0.05$). Scores of LIP/BALT degree were significantly higher in infected lambs treated with placebo or late interferon regime than in the non-infected lambs or in the infected lambs that received early IFN treatment. LIP scores were not significantly different between non-infected and OPP virus infected lambs treated early with IFN. Results of these experiments indicate that roIFN-τ significantly decreases OPP virus replication *in vitro* and *in vivo* and prevents the development of OPP virus-induced LIP when infected animals are treated during the initial phases of the infection (Juste et al., 2000).

RECOMBINANT OIFN-T ENHANCES THE IMMUNE RESPONSE OF THE HOST AGAINST OPP VIRUS.

We examined the effects of recombinant ovine IFN-τ (roIFN-τ) on blood mononuclear cells in OPP virus-infected and mock-infected lambs using a panel of monoclonal antibodies directed against various cell surface markers. Cells expressing the CD4, the CD8, and the γδ markers (cells expressing these markers are critical in the immune response against viruses) were elevated in all the groups at different time intervals over the course of this study in comparison to wk 0. Higher proportions of $CD4^+$, $CD8^+$, $\gamma\delta^+$ and L-selectin$^+$ (the latter is a cell surface adhesion molecule important in cell migration) and lower proportions of MHC class II^+ cells were found in roIFN-τ-treated, OPP virus-infected lambs when compared to the placebo-treated, OPP virus-infected

lambs ($P \leq 0.05$) (Singh et al., 1997). rOvIFN-τ also increased the proportions of primary antiviral $\gamma\delta^+$ and $CD8^+$ immune cells in the lung of OPP virus-infected lambs (Singh et al., 2001). These results suggest that in addition to direct antiviral activity, roIFN-τ modulates the proportions of circulating cytotoxic and helper lymphocytes in response to OPP virus infection. This immunopotentiator effect of roIFN-τ may contribute to the therapeutic effect of this protein by promoting the killing and elimination of OPP virus-infected cells. Furthermore, when we evaluated the toxic side effects of roIFN-τ, we found that red and white blood cells in sheep treated roIFN-τ remained within normal values through out the six month daily-treatment trial (de la Concha-Bermejillo et al., 2000). This indicates that roIFN-τ at the dose used in our experiments is non-toxic for sheep.

A GENETICALLY ENGINEERED OPP VIRUS THAT EXPRESSES THE GREEN FLUORESCENT PROTEIN (GFP) GENE IS A PRIME CANDIDATE TO BE USED AS A VACCINE TO PROTECT SHEEP AGAINST OPP.

Currently, there are no commercially available vaccines to protect sheep against OPP. For the last four yr, we have been working to develop OPP viruses that are attenuated for pathogenicity (do not cause disease), but induce a strong protective immunity. For this purpose, we genetically engineered an OPP virus that contains the green fluorescent protein (GFP) gene (OPP/GFP virus); (Zhang et al., 2000). This recombinant virus is attenuated for pathogenicity *in vitro* and *in vivo*. Lambs vaccinated with OPP/GFP virus had lower titers of virus in blood after being challenged with pathogenic OPP virus than one non-vaccinated lamb. These preliminary results suggest that the OPP/GFP recombinant virus could be used effectively as a vaccine to protect sheep against OPP.

Conclusions

Although the prevalence of OPP in range sheep of western Texas is significantly lower than that in other sheep-producing states, Texas sheep producers need to be aware of the risks of introducing the infection into their flocks. Existing serological tests to identify infected animals vary in their sensitivity and specificity and in some cases may be unreliable. Shedding of OPP virus in the semen of rams with epididymitis may be a risk factor for spreading the virus to non-infected sheep. Recombinant IFN-τ is an effective but expensive OPP treatment. The use of recombinant OPP viruses with reduced replication ability and pathogenicity may be the best way to prevent OPP clinical disease.

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RESEARCH BRIEF

Location and breed effects on cashmere production by goats

C. J. Lupton, A. R. Dooling, K. Lankford, and F. A. Pfeiffer

Three groups of contemporary, fiber-producing goats representing two genotypes (Cashmere (C), higher producing and Spanish (S), lower producing were maintained for three yr at three diverse locations in the USA to study the effects of location (environment and local customary management) on cashmere production and fiber characteristics. The initial number of goats was 20 yearling castrate goats/genotype/location. Initially (using yearling weights and fleeces) and within genotype, body weight, raw fleece weight, cashmere yield, cashmere down production, cashmere average fiber diameter, and cashmere average staple length were not different among groups. The goats were maintained on pasture and supplemented with local hays in an attempt to achieve and maintain target body weights. The three locations were San Angelo (TX), Dillon (MT), and Willow (AK). Each year, fleeces were shorn before the commencement of shedding in January (TX), March (MT), and April (AK). Most of the measured traits were affected by location, breed, and year (confounded with age). The location x breed interaction was significant for two traits (body weight and cashmere production per unit of body weight; the breed x year interaction was significant for three traits (body weight, scoured yield, and cashmere production per goat); the location x year interaction was significant for more than half the traits; the location x breed x year interaction was significant for one trait (scoured yield). Only the main effects of location and breed are discussed in this research brief. The main effects of location (Table 1, both genotypes, data from three production years) were: average body weight in AK < MT < TX (68.3, 86.4, and 108.9 lb, respectively, $P < 0.0001$); average raw fleece weight in AK < MT = TX (0.98, 1.08, and 1.13 lb, respectively, $P < 0.005$); average cashmere yield in AK > MT > TX (27.3, 21.3, 17.4 %, respectively, $P < 0.0001$); average cashmere down production in AK > MT > TX (0.004, 0.003, and 0.002 lb/lb BW, respectively, $P < 0.0001$); average cashmere diameter in AK = MT < TX (17.3, 17.4, and 18.6 μm, respectively, $P < 0.0001$); and average cashmere staple length in AK = MT > TX (3.0, 2.8, and 2.5 in, respectively ($P < 0.0001$). The main effects of breed (Table 2, data from three production yr) were: average body weight of C < S (81.8 vs 99.9 lb); average raw fleece weight of C > S (1.19 vs 0.96 lb); average cashmere yield of C > S (24.7 vs 17.5 %,); average cashmere down production of C > S (0.004 vs 0.002 lb/lb BW,); average cashmere diameter of C and S were not different (17.8 μm); and average cashmere staple length of C > S (3.0 vs 2.4 in). This information may assist producers and scientists in this country and abroad to better understand the effects of environment on cashmere production and fiber characteristics.

Key Words: Goat, Cashmere, Environment

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Table 1. Main effects of location on body weight, cashmere production, and fiber characteristics of two breeds of goat

	Alaska	Montana	Texas	SE
N	73	133	122	
Body weight, lb	68.3[c]	86.4[b]	108.9[a]	1.8
Raw fleece weight, lb	0.98[b]	1.08[a]	1.13[a]	0.03
Scoured yield, %	92.4[b]	92.5[b]	95.0[a]	0.3
Clean fleece weight, lb	0.91[b]	1.00[a]	1.07[a]	0.03
Cashmere yield, %	27.3[a]	21.3[b]	17.4[c]	0.9
Cashmere weight, lb/goat	0.25[a]	0.22[b]	0.19[c]	0.01
Cashmere weight, lb/lb BW	0.004[a]	0.003[b]	0.002[c]	0.0002
Guard hair weight, lb/goat	0.65[c]	0.78[b]	0.89[a]	0.02
Guard hair weight, lb/lb BW	0.010[a]	0.009[a]	0.008[b]	0.0003
Cashmere fiber diameter, μm	17.3[b]	17.4[b]	18.6[a]	0.1
SD, μm	3.7[b]	3.6[b]	3.9[a]	0.03
CV, %	21.7[a]	21.1[b]	21.0[b]	0.2
Guard hair staple length, in	3.3[a]	3.1.[a,b]	3.0[b]	0.08
SD, in	0.5	0.5	0.5	0.02
CV, %	16.0	15.4	16.4	0.6
Cashmere staple length, in	3.0[a]	2.8[a]	2.5[b]	0.08
SD, in	0.5	0.4	0.4	0.02
CV, %	17.6	17.2	18.4	0.8

[a,b,c] Within a row, means having different superscripts are different ($P < 0.05$).

Table 2. Main effects of breed on body weight, cashmere production, and fiber characteristics of Cashmere and Spanish goats

	Cashmere	Spanish	SE
N	167	161	
Body weight, lb	81.8[b]	99.9[a]	2.0
Raw fleece weight, lb	1.19[a]	0.96[b]	0.03
Scoured yield, %	92.5[b]	94.3[a]	0.2
Clean fleece weight, lb	1.10[a]	0.91[b]	0.02
Cashmere yield, %	24.7[a]	17.5[b]	0.6
Cashmere weight, lb/goat	0.27[a]	0.16[b]	0.01
Cashmere weight, lb/lb BW	0.004[a]	0.002[b]	0.0001
Guard hair weight, lb/goat	0.83[a]	0.75[b]	0.02
Guard hair weight, lb/lb BW	0.010[a]	0.008[b]	0.0002
Cashmere fiber diameter, μm	17.8	17.8	0.1
SD, μm	3.8	3.7	0.03
CV, %	21.3	21.0	0.2
Guard hair staple length, in	3.6[a]	2.7[b]	0.04
SD, in	0.6[a]	0.4[b]	0.02
CV, %	15.9	15.9	0.5
Cashmere staple length, in	3.0[a]	2.4[b]	0.04
SD, in	0.5[a]	0.4[b]	0.01
CV, %	17.6	17.9	0.6

[a,b] Within a row, means having different superscripts are different ($P < 0.05$).

RESEARCH BRIEF

Location and season effects on mohair production by Angora goats

F.A. Pfeiffer, C.J. Lupton, and A.R. Dooling

Angora goats, which produce long, white, lustrous fibers known as mohair, were introduced into the US from Turkey in 1849. They have since been raised under many diverse environments with mixed results. This experiment was designed to determine effects of two different US environments on mohair production and fiber characteristics. Sixty yearling, castrated goats obtained from a Texas source were shorn so that mohair fleece (6-mo growth) and fiber properties could be determined. Subsequently, 20 relatively uniform goats were assigned to each of two groups such that average body weight (BW), grease fleece weight (GFW), clean yield (CY), clean fleece weight (CFW), clean mohair produced/unit of bodyweight (CFW/BW), average fiber diameter (AFD), average staple length (ASL), and medullation (MED, KEMP, TOTMED) were similar between groups. One group (TX) remained close to San Angelo, Texas, and the other (MT) was re-located to Dillon, Montana. They were maintained on pasture and supplemented with local hays for 3 yr. Each year, animals were shorn and weighed in February or March (Spring) and again in August or September (Fall) and their fleeces were re-tested. Location x season interactions were significant for all properties measured except CY, AFD, MED, KEMP, and TOTMED. The CY in MT > TX (79.9 vs 76.1%), whereas AFD in MT < TX (32.9 vs 36.0 μm, $P < 0.0001$). The MED, KEMP, and TOTMED were not different (0.85, 0.15, and 1.00 %, respectively, $P > 0.14$) between locations. In MT (Table 1), BW (91.7 vs 71.4 lb), GFW (7.3 vs 4.6 lb), CFW (5.7 vs 3.7 lb), CFW/BW (0.07 vs 0.05 lb/lb), and ASL (5.3 vs 4.1 in) were greater ($P < 0.05$) in Fall than in Spring. Differences are consistent with harsh, cold winters and summers in which abundant feed was available. In contrast, GFW (7.1 vs 8.2 lb) and ASL (4.5 vs 5.2 in) in TX were smaller ($P < 0.05$) in Fall than in Spring. The TX goats had similar ($P > 0.05$) BW (102.7 vs 105.6 lb), CFW (5.5 vs 6.0 lb), CFW/BW (0.06 vs 0.06 lb/lb), and AFD (35.9 vs 36.1 μm) in Fall and Spring. The TX data are consistent with relatively mild winters and harsh, hot summers. The lower production of MT goats was offset to some degree by greater unit value of the finer mohair.

Key Words: Angora Goat, Location, Season

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Table 1. Effects of location and season on body weight, mohair production, and fiber characteristics of Angora goats

	Montana		Texas		
	Fall	Spring	Fall	Spring	SE
Bodyweight, kg	41.6[b]	32.4[c]	46.6[a]	47.9[a]	1.1
Grease fleece weight, kg	3.3[b]	2.1[c]	3.2[b]	3.7[a]	0.1
Clean yield, %	81.6[a]	78.3[b]	79.1[b]	73.2[c]	0.8
Clean fleece weight, kg	2.6[a]	1.7[b]	2.5[a]	2.7[a]	0.1
Mohair production/unit BW, g/kg	65.9[a]	53.4[b]	55.2[b]	56.6[b]	1.8
Average fiber diameter, μm	32.7[b]	33.0[b]	35.9[a]	36.1[a]	0.3
SD fiber diameter, μm	8.1[b]	8.0[b]	8.5[a]	8.5[a]	0.2
CV fiber diameter, %	24.5	24.2	23.6	23.5	0.4
Average staple length, cm	13.5[a]	10.4[c]	11.4[b]	13.3[a]	0.2
SD staple length, cm	1.3[a]	1.3[a]	1.0[b]	1.3[a]	0.1
CV Staple length, CM	10.3[b]	12.2[a]	8.9[b]	9.9[b]	0.6
Total medullated fibers, %	0.9	1.0	0.9	1.1	0.08
Med fibers, %	0.8	0.8	0.8	0.9	0.07
Kemp fibers, %	0.1	0.2	0.1	0.2	0.02

[a,b,c] Within a row, means having different superscripts are different ($P < 0.05$).

New technology for producing, evaluating, and marketing exceptionally high quality wool

C.J. Lupton, J.E. Huston, K.S. Rhee, B.F. Craddock, W. Polk, and F.A. Pfeiffer

ABSTRACT: An experiment was designed to establish the technical and economic feasibility of concurrent production of high quality, high-value wool and highly desirable lean carcasses. Specifically, we investigated the effects of three physical environments (feed lot (FL), pasture (P), and an innovative raised, slatted floor structure (RF)), including diets (3, different for each environment) coats, and marketing methods (2) on the quality, quantity, and price of wool and meat produced by Rambouillet wether lambs. Most of the anticipated advantages of the RF system were realized, though fecal contamination on the slatted floor required some corrective measures. The combination of diet, RF environment, and coats resulted in lean, desirable carcasses and relatively long, fine, and uniform wool. A market for this type of wool was accessed in which prices received were more than five times greater than commercial levels for comparable wool. Higher meat and wool prices or/and lower facility and feed costs are required to make the RF system profitable. Different genetics will be required to produce more valuable wool.

Key Words: High Quality Wool, Lamb Feeding

Sheep and Goat, Wool and Mohair CPR 2002. 144-155

Introduction

Low wool prices and production of over-fat lambs are two problems that have plagued the sheep industry for many yr. Since wool is an international commodity, a U.S. producer can only exert a relatively small amount of influence on the value of his clip (unless he is prepared to sell into a niche market). Traditionally, wool from feed-lot lambs has been worth much less than comparable range-produced wools because of excessive dirt penetration, contamination with black fibers, lack of uniformity, and short staple length. Theoretically, if wool from lambs on feed could be kept clean and was allowed to grow to staple length, it would usually be worth more than wool from mature sheep of the same breed.

Research, health, and consumer groups have advised the sheep industry for yr to produce a leaner product. However, it is often more profitable for feeders to produce over-fat lambs than lean lambs. Recent innovations in marketing, particularly the attempts by Ranchers' Lamb of Texas to provide retail ready cuts of lamb and pay producers on a carcass weight/quality grid (rather than on weight alone) may correct this situation and finally provide lamb feeders with a financial incentive to produce leaner lambs.

This project was designed to develop technology for the concurrent production of high quality wool and lean meat by sheep. More specifically, to establish the economics of producing exceptionally high-value wool under intensive indoor management compared to in a feed lot and

on the range; and to determine if high-value animal fibers can be profitably produced concurrently with highly desirable, lean carcasses for the U.S. meat market.

Materials and Methods

An experiment was designed to investigate the effects of physical environment, nutrition, fleece protection, and marketing method on the quality, quantity, and price of wool and meat produced by growing lambs. The three environments were an open-sided barn with a raised, slatted floor (RF), a feed lot (FL, control), and a pasture (P, control). Expected advantages of the raised floor are listed in Table 1. All lambs were of the Rambouillet breed. Animals on the raised floor were fed a pelleted mixture of 85% oat hay, 7.5% barley, and 7.5% molasses. This diet was designed to produce a relatively slow rate of gain so that wool longer than 3.75 inches could be produced while the animals were attaining slaughter weight.

Table 1. Expected advantages of open-sided, raised and slatted floor barn system

» Clean, healthy environment
» Reduced exposure to internal parasites
» Protection from predation
» Reduction in energy expenditure of animals
» Improved comfort, cooler in summer, warmer in winter
» Cleaner fleeces
» More uniform fibers (fiber diameter and staple length)
» More consistent products (fibers, pelts, and meat)
» Seed-free, consistent quality manure, improved disposal
» Applicable to most U.S. environments

Lambs in the feed lot were provided with typical step-up rations (Table 2). The diets were designed to produce relatively fast rates of gain. Lambs in the pasture received a salt-limiting supplement (Table 2) after one mo in the pasture. It was planned for the P lambs to gain at the same rate as the RF lambs. Fleeces were either protected with coats (C) or were not protected (U). Marketing of the lamb wool was achieved in the traditional manner through the Texas warehouse system or it was sold using an innovative technique (WWW). Target specifications for lambs and high quality wool are shown in Tables 3 and 4, respectively.

We obtained 143 Rambouillet male castrated lambs (wethers, about 5 mo of age) and fed them as a single group (Table 2, Diet 1) for three wk. Subsequently, the lambs were assigned to treatment (blocked by weight, 82.4 ±6.6 lb), and the feed trial was initiated on September 1, 2000.

The FL lambs were shorn on 11/14/00 allowing 34 d for wool regrowth prior to slaughter on 12/18/00 (108 d on feed). The P lambs were shorn on 12/14/00 allowing 33 d for regrowth prior to slaughter on 1/16/01 (137 d supplemented in the pasture). The RF lambs were shorn on 1/25/01 allowing 21 d for regrowth prior to slaughter on 2/15/01 (167 d on feed). A yr earlier, pelts had no value; during this experiment, pelts with 3-5 wk wool re-growth had some value, hence this shearing schedule.

Table 2. Percentages of ingredients in the feed lot diets and pasture supplements, 2000 - 2001 experiment

	Diet (time fed, wk)		
Feed lot	1 (1)	2 (14)	
Pasture	1 (1)	2 (3)	3 (15.5)
Ingredient			
Sorghum grain (milo)	65.50	67.75	60.00
Dehydrated alfalfa meal, 17%	10.00	5.00	10.00
Cottonseed hulls	10.00	10.00	0
Cottonseed meal, 41%	10.00	12.00	10.00
Soybean meal, 47.5%	0	0	10.00
Molasses	3.00	3.00	4.00
Urea	0	0.50	0.50
Ammonium chloride	0.50	0.50	0
Salt, mixing	0	0	4.00
Calcium carbonate	0.50	1.00	0
Monodicalcium phosphate	0	0	1.00
Vitamin-mineral-antibiotic pre-mix	0.50	0.50	0.25
TOTALS	100.00	100.00	100.00

Table 3. Target specifications and expectations for lambs in raised floor treatment

» Initial age	4 - 6 mo
» Initial weight	70 lb
» Final age	12-13 mo
» Final shorn weight	130 lb
» ADG	0.3 lb/d
» Carcass weight	65 lb
» Fat thickness	0.20 in
» USDA yield grade	2.0

Table 4. Target specifications and expectations for fleece production

» Grease fleece weight., lb	> 8
» Clean yield, %	> 60
» Vegetable matter content, %	< 0.3
» Staple length, in	> 3.75
» Fiber diameter, microns	< 19
» Uniform, bright white, sound	

All lambs were slaughtered and carcasses were evaluated at the Ranchers' Lamb of Texas, Inc. facility in San Angelo. Fleece and fiber measurements were made at the TAES Wool and Mohair Research Lab in San Angelo. At the time we were taking carcass measurements (about 24 hr post mortem), a small amount of lean meat from the semi-membranosus muscle was removed from 10 carcasses from each treatment, double bagged in Ziploc® freezer bags, and frozen. In addition, the hind legs were removed from these 10 carcasses and also double bagged in plastic sacks prior to freezing. The frozen samples were delivered to Dr. Rhee for analysis. The results of these analyses are reported elsewhere in this collection of progress reports.

Statistical Analysis

The General Linear Model of SAS (SAS Inst. Inc., Cary, NC) was used to determine the effects of treatment and coat (and the interaction) on all measured body, fleece, and carcass traits. Least squares means were calculated for each trait by treatment and coat because unequal numbers of lambs were in each treatment. It should be pointed out that due to resource limitations, the treatment groups of animals used in this experiment were not replicated, the lambs used in the study may not have been truly representative of the breed, and the specific pasture conditions experienced in the study can never be duplicated. The significance levels reported in the tables were calculated assuming each animal was an experimental unit. Thus, some caution is required in interpreting the results.

Results and Discussion

The effects of treatment on growth and carcass characteristics are summarized in Table 5. As planned, FL lambs gained at a higher rate than P and RF lambs. However, P lambs gained at a faster rate than RF which was not as planned. The summer and fall of 2000, and the winter of 2001 were very dry. Little vegetation was produced on the range. Consequently, a high proportion of the diet consumed by the P lambs consisted of the "supplement" that was supplied to them. Shorn slaughter weights of FL, P, and RF lambs were similar. Carcass weights of FL and P were very similar but > RF. Inspection of the dressing percentages indicates the RF lambs probably had significantly higher gut fill prior to slaughter compared to the P and FL lambs. This observation was consistent with previous data (Lupton et al., 2000). The back fat thickness of the FL lambs was > P = RF. Body wall thickness measurements exhibited the same trend as back fat thickness and average daily gain, i.e., FL > P > RF. Interestingly, hind leg circumference showed a different trend with P lambs showing the greatest development and FL the least. This was probably related to the relatively long distances walked by the P lambs each day compared to the others. Although the RF lambs probably moved around less than the FL lambs, they were older at slaughter, thus allowing the leg muscles a longer time to grow. The P and RF carcasses were also a little longer (about 0.8 in) than the FL lambs, again probably due to being older at slaughter. Most of the lambs in this experiment graded choice (C) except for three prime (P; two in the RF group and one in the FL group). The subjectively determined USDA Yield Grades were almost identical for FL and RF (about 2.1), this being slightly lower than the P lambs. When assessing USDA yield grades, a USDA inspector takes into account the fatness (primarily) and muscling of the whole carcass. Calculated yield grade (CYG) on the other hand uses only back fat thickness (BFT) in the formula:

$$CYG = 0.4 + 10 * BFT$$

Table 5. Treatment effects on growth and carcass properties (2000 - 2001 experiment)

	Treatment		
	Feedlot	Pasture	Raised floor
N	27	28	88
Initial weight, lb	82.4	82.3	82.4
Shorn final weight, lb	130.4	130.9	134.0
Average daily gain, lb/d	0.51[a]	0.41[b]	0.36[c]
Carcass weight, lb	67.3[a]	68.1[a]	63.6[b]
Dressing percentage	51.7[a]	52.0[a]	47.6[b]
Back fat thickness, in	0.29[a]	0.22[b]	0.20[b]
Body wall thickness, in	1.26[a]	1.14[b]	1.11[b]
Hind legs circumference, in	27.5[c]	28.3[a]	27.9[b]
Carcass length, in	45.7[b]	46.4[a]	46.6[a]
USDA quality grade*	1P, 26C	28C	2P, 86C
USDA yield grade	2.11[b]	2.32[a]	2.08[b]
Calculated yield grade	3.26[a]	2.55[b]	2.37[b]
Average days to slaughter	108	137	167

[a,b,c] Within a row, means with different superscripts differ ($P < 0.05$).
* C = choice, G = good, P = prime

Consequently, it is not too surprising when these two estimates of yield differ. In this case, FL carcasses had considerably higher average CYG (3.26) compared to P and RF (2.55 and 2.37, respectively). Average d to slaughter were 108 (FL), 137 (P) and 167 (RF). We were able to hold the lambs on the raised floor for this extended period of time (necessary to produce a fleece having adequate staple length) without producing any carcasses that did not "break" (i.e., the spool joints of younger sheep break easily. In the current U.S. marketing system, a large discount is applied to carcasses in which the spool joints do not break). The longer time to slaughter results in substantially greater feed consumption by the RF and P groups versus FL.

Table 6 summarizes treatment effects on wool growth and properties. As expected, grease and clean wool production of RF lambs > FL and P. However, somewhat surprisingly, clean yield of RF fleeces = FL > P. The level of 54.5% is quite high for FL lambs but was in fact identical to that reported previously (Lupton et al., 2000). Average fiber diameters (AFD) also followed the previously reported trend with P fleeces being finer than FL and RF fleeces being intermediate (19.4, 20.2, and 19.6 μm, respectively). Comfort factors followed the same trend as AFD's. Due to the different periods of wool growth (birth to approximately one mo before slaughter), RF lambs produced longer wool than P > FL. The uniformity of staple length as indicated by CV was greater for the RF compared to P fleeces but not different to the much shorter FL fleeces. A potential downside of producing longer wool is that a longer period is available in which to produce changes in fiber diameter. One way to investigate this property (uniformity of fiber diameter along the length of the fiber) is to make multiple measurements on the same fiber and calculate variability (SD and CV). This is reported as along-fiber AFD, SD, and CV. Table 6 indicates that

along-fiber AFD's are almost identical to those obtained when a random sample was used. However, the CV's of along-fiber diameter clearly show that RF are more uniform than P which are more uniform than FL. Although these differences are only small, they are statistically significant ($P < 0.05$) and important in terms of the overall experimental objective which was (*inter alia)* to produce more uniform wool. Average fiber curvature (a measure of crimp magnitude and propensity) did not differ among treatments ($P > 0.05$). Similarly, staple strength and position of break were not different, a noteworthy achievement for the RF lambs producing longer wool (with, therefore, a greater chance of producing weak points in the staple).

Table 6. Treatment effects on wool growth and properties (2000 - 2001 experiment)

	Treatment		
	Feedlot	Pasture	Raised floor
N	27	28	88
Grease fleece weight, lb	5.90[c]	6.68[b]	9.02[a]
Clean yield, %	54.5[a]	52.3[b]	54.6[a]
Clean fleece weight, lb	3.19[b]	3.48[b]	4.92[a]
Average fiber diameter, μm	20.2[a]	19.4[b]	19.6[a,b]
Standard deviation of fiber diameter, μm	4.3[a,b]	4.0[b]	4.3[a]
Coefficient of variation of fiber diameter, %	21.4[a,b]	20.7[b]	22.1[a]
Comfort factor, % fibers < 30 μm	98.2[b]	99.1[a]	98.7[a,b]
Along-fiber average fiber diameter, μm	20.3[a]	19.4[b]	19.6[a,b]
Standard deviation of along-fiber diameter, μm	0.9[a]	0.8[b]	0.8[b]
Coefficient of variation of along-fiber diameter, %	4.4[a]	4.3[b]	4.1[c]
Average fiber curvature, ^{0}/mm	97.9	95.1	97.8
Standard deviation of fiber curvature, ^{0}/mm	64.3	63.9	63.8
Coefficient of variation of fiber curvature, %	65.8	67.4	65.5
Average staple length, in	2.46[c]	2.88[b]	3.42[a]
Standard deviation of staple length, in	0.19[b]	0.24[a]	0.23[a]
Coefficient of variation of staple length, %	8.0[a,b]	8.5[a]	6.9[b]
Average staple strength, N/ktex	32.9	34.8	33.8
Position of break (0-1)	0.37	0.38	0.39

[a,b,c] Within a row, means with different superscripts differ ($P < 0.05$).

Table 7 summarizes the effects of coat on growth and carcass properties. Because coats were not used on the P group, these effects are reported within treatments. In the heat of summer particularly, we had anticipated that wearing a coat might slow down the rate of growth. This again proved not to be the case. Importantly, coats had no effect on any of the other growth and carcass traits with the one exception that uncoated RF lambs had slightly higher dressing percentages than the coated RF lambs.

Table 7. Coat effects (within treatment) on growth and carcass properties (2000 - 2001 experiment)

	Treatment				
	Feedlot		Pasture	Raised Floor	
	Coated	Uncoated	Uncoated	Coated	Uncoated
N	13	14	28	45	43
Initial weight, lb	82.1	82.8	82.3	82.1	82.8
Shorn final weight, lb	127.8	132.9	130.9	135.6	132.4
Average daily gain, lb/d	0.49	0.53	0.41	0.38	0.35
Carcass weight, lb	66.0	68.6	68.1	63.8	63.5
Dressing percentage	51.8	51.6	52.0	47.1[b]	48.0[a]
Back fat thickness, in	0.29	0.28	0.22	0.19	0.21
Body wall thickness, in	1.28	1.24	1.14	1.08	1.14
Hind legs circumference, in	27.4	27.6	28.3	28.0	27.8
Carcass length, in	45.4	46.0	46.4	46.7	46.5
USDA quality grade*	1P, 12C	14C	28C	1P, 44C	1P, 42C
USDA yield grade	2.08	2.14	2.32	2.04	2.12
Calculated yield grade	3.27	3.24	2.55	2.30	2.45
Average days to slaughter	108	108	137	167	167

[a,b] Within a treatment and row, trait means with different superscripts differ ($P < 0.05$).
* C = choice, G = good, P = prime

Table 8 summarizes coat effects on wool growth and properties. As planned, C fleeces tended to be higher yielding than U fleeces but the differences were not significant ($P = 0.17$ for FL and 0.28 for RF). There was an indication that variability of fiber diameter (SD and CV) was lower in the coated RF lambs than in the U fleeces. This observation is consistent with previously reported data (Lupton et al., 2000) so this effect (coated lambs produce more uniform fiber than uncoated lambs) may indeed be real. Coated fleeces were slightly longer than uncoated fleeces.

Table 8. Coat effects (within treatment) on wool growth and properties (2000 - 2001 experiment)

	Treatment				
	Feedlot		Pasture	Raised Floor	
	Coated	Uncoated	Uncoated	Coated	Uncoated
N	13	14	28	45	43
Grease fleece weight, lb	5.82	5.95	6.68	9.05	8.99
Clean yield, %	55.5	53.5	52.3	55.0	54.1
Clean fleece weight, lb	3.22	3.17	3.48	4.98	4.87
Average fiber diameter, μm	20.3	20.1	19.4	19.6	19.6
Standard deviation of fiber diameter, μm	4.4	4.2	4.0	4.0[b]	4.6[a]
Coefficient of variation of fiber diameter, %	21.7	21.0	20.7	20.5[b]	23.7[a]
Comfort factor, % fibers < 30 μm	97.9	98.4	99.1	98.8	98.5
Along-fiber average fiber diameter, μm	20.4	20.2	19.4	19.6	19.5
Standard deviation of along-fiber diameter, μm	0.9	0.9	0.8	0.8	0.8
Coefficient of variation of along-fiber diameter, μm	4.4	4.5	4.3	4.1	4.1
Average fiber curvature, ^{0}/mm	96.8	99.1	95.1	96.3	99.2
Standard deviation of fiber curvature, ^{0}/mm	63.6	65.0	63.9	62.9	64.7
Coefficient of variation of fiber curvature, %	66.0	65.7	67.4	65.5	65.4
Average staple length, in	2.55	2.37	2.88	3.51[a]	3.33[b]
Standard deviation of staple length, in	0.20	0.19	0.24	0.23	0.24
Coefficient of variation of staple length, %	8.0	7.9	8.5	6.6	7.1
Average staple strength, N/ktex	35.8	29.9	34.8	32.3	35.3
Position of break (0-1)	0.38	0.36	0.38	0.37	0.41

[a,b] Within a treatment and row, trait means with different superscripts differ ($P < 0.05$).

Table 9 summarizes our progress to date using the RF system and coats with respect to the original targets. In addition, it is emphasized that the RF system produced fleeces that were more uniform than the other two systems in terms of fiber diameter and staple length. Table 9 also indicates the fleece properties that still require improvement in order to meet the original goals. These are: clean yield (needs to be higher); fiber diameter (needs to be lower); and, staple length (needs to be longer). To meet this need, a small flock (50 ewes) of genetically fine Rambouillet sheep was assembled. These ewes have been bred for the last two yr to genetically fine Rambouillet and Merino rams, the latter also having higher yielding and longer fleeces than the average Texas fine-wool ram. Using lambs of this breeding in our RF/C treatment, we plan to produce fleeces that will more closely approach the target specifications.

Table 9. Summary of progress to date

Property	Target	RF Lambs 2000 Experiment	RF Lambs 2001 Experiment	Status in 2001
Age at slaughter, mo	12	12-13	12-13	OK
Final shorn weight, lb	130	131	134	OK
ADG, lb/d	0.30	0.34	0.36	OK-
Carcass weight, lb	65	66.6	63.6	OK
Back fat thickness, in	0.20	0.35	0.20	OK
USDA Quality Grade*	P, C	P, C	P, C	OK
USDA Yield Grade	2.0	2.6	2.1	OK
Grease fleece weight, lb	> 8	9.0	9.0	OK
Clean yield, %	> 60	58.0	54.6	X (genetic)
Vegetable matter, %	< 0.3	< 0.3	< 0.3	OK
Fiber diameter, microns	< 19	20.5	19.6	X (genetic)
Staple length, in	> 3.7	3.7	3.4	X (genetic)
Staple strength, N/ktex	Sound (>30)	36.7	33.8	OK

*C = choice, G = good, P = prime.

We collaborated with an agricultural economist (W. Polk) who produced a budget scenario (Table 10) for the three lamb feeding systems that took into account the cost of building a feed lot pen, leasing pasture, and building a raised-floor barn, among many other variables. The budget scenario is available in spreadsheet format where an individual can enter his own values and the program will automatically re-calculate the "bottom line," i.e. Net Income per Head.

Table 10. Budget scenario for Feedlot, Pasture, and Raised Floor feeding programs

	Feedlot	Pasture	Raised Floor	
Assumptions				
Death loss (200 hd flock)	3.00%	3.00%	1.00%	
Labor (hr/d)	1	1	0.25	
Mileage (miles/d)	0.5	9	0.5	
Lease property (annual)	0	$2,000.00	0	
Carcass Prices Received ($/lb)	$1.50	$1.50	$1.57	Because of the three separate time periods in which the sheep were
Lamb Prices Paid ($/lb)	$0.85	$0.85	$0.85	marketed, the carcass prices for the feedlot and pasture sheep were adjusted and averaged to Feburary 20, 2001 prices.
Income ($/Hd)				
Meat	$100.95	$102.15	$99.85	Actual carcass weight, average carcass price.
Wool	$1.77	$3.96	$32.85	Actual and projected prices received.
Offal	$0.80	$0.80	$0.80	
Pelt	$7.00	$7.00	$9.00	
Total Income per Head	$110.52	$113.91	$142.50	
Expenses ($/Hd)				
Purchase Cost	$62.90	$62.56	$62.56	Actual initial weight x $0.85/lb
Death loss	$3.32	$3.42	$1.43	Death Loss % x number of head - 200 x avg total $'s/head ÷ 200 head
Feed Cost	$24.65	$20.12	$44.57	Actual total pounds fed x actual cost of feed per pound
Lease property (annual)	$0.00	$10.00	$0.00	400 acres x $5.00 per acre ÷ 200 head
Shearing cost	$1.85	$1.85	$1.85	
Fleece testing	$0.00	$0.00	$3.00	$19.50 if measured in USA
Cost of Packaging Wool	$0.30	$0.30	$2.25	15 min. labor x $6.00 per hr + $0.10 per bag x 4.5 bags
Wool Marketing Commission	$0.12	$0.28	$0.00	7% of wool value
Coat Cost	$0.00	$0.00	$2.00	$6.00 per coat with a 3 yr expected coat life
Vet/medication costs	$1.00	$1.00	$0.50	
Slaughter Cost	$9.00	$9.00	$9.00	
Labor	$4.05	$6.60	$1.52	Labor hrs/d x days to slaughter x $6.00 per hr ÷ 200 head
Fuel Cost	$0.03	$0.99	$0.05	Miles traveled x days to slaughter ÷ 15 mpg x $1.50/gallon ÷ 200
Structure Cost	$3.41	$0.00	$19.64	head
Total per Head Cost	$110.63	$116.11	$148.36	Annual Payment ÷ 200 Head (Initial cost of $4479.80 for Feedlot and $28539.94 for Raised Floor Platform amortized over 10 yr at 9% interest)
Net Income per Head	-$0.11	-$2.20	-$5.86	

Using our own TAES web site (http://sanangelo.tamu.edu/wmrl/handspin.htm) we were able to list and subsequently sell most of the coated RF fleeces (after thorough skirting) at a price of 5^{00}/greasy lb. The remainder of the wool was sold through traditional warehouse channels. These values are reflected in the spreadsheet (Table 10). In 2001, carcass prices varied somewhat with slaughter time across the three treatments. However, these differences were not related to carcass qualities so for the spreadsheet, carcass prices were averaged and the same price was used across treatments.

Inspection of the budget scenario reveals the potential advantage and the downside of the RF system, i.e., increased wool income and cost of feed and structure, respectively. What is not so obvious are some of the actual and potential (future) advantages, e.g., healthier sheep (reflected in death loss rates), less labor, and at some point in the future, higher prices for leaner carcasses, as well as the potential for production of the organic products, wool and lamb meat. Prices greater than 5^{00}/lb are required to make the RF/C system "cash-flow." The initial cost of the structure and the relatively high cost of the pelleted, high-roughage diet obviously makes the system cost prohibitive unless these exceptionally high wool prices or/and better prices for lean carcasses can be obtained. An alternative approach is being investigated. The International Textile Center at Texas Tech University has supplied us with exceptionally strong, tear-resistant fabric that is being used to construct coats that should withstand pasture conditions. If clean, uniform, high quality wool can be produced concurrently with lean carcasses under pasture conditions, this P/C lamb feeding system could be profitable.

In summary, (at least) the following requirements should be present for any degree of success with the RF system of lamb feeding: (1) an initial substantial investment in the facility, (2) the correct sheep genetics, (3) a desire to work with wool and (primarily) handspinners in order to obtain wool prices >5^{00}/lb for fully skirted fleeces, (4) recognition that the size of this market is limited and that competition is keen, (5) a lamb carcass market that fully rewards leanness, and (6) patience, since points 2, 3, and 5 above will not occur overnight. It will take time to achieve the correct genetics, build a good reputation with the handspinner clients, and to convince lamb buyers that one should be paid more for lean lambs than for fat lambs.

Implications

(1) The economics of producing high-value lambswool under intensive, indoor conditions have been established and compared to two traditional systems. A financial spreadsheet was developed that permits changing all income and expense items with subsequent recalculation of net income per head. This spreadsheet is available to interested parties.

(2) The conditions for profitably and concurrently producing high-value wool and lamb meat have also been identified.

(3) The anticipated advantages of the open-sided, raised, slatted-floor barn system have been realized.

(4) A system has been devised and evaluated for feeding lambs that would be practical in most U.S. environments. The substantially higher returns from niche versus mainstream marketing has to be considered in the light of extra production cost and the extra effort required for niche marketing.

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Predicting resistance to compression of wool fibers

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ABSTRACT: Resistance to compression (R/C) is the force per unit area required to compress a fixed mass (weight) of wool to a fixed volume. The unit of measure is kilopascal (kPa). Together with other important characteristics such as staple length (SL) and average fiber diameter (AFD), R/C is used to predict processing and product performance of wool. Thus, RC has an effect on the value of some raw wools. Objective measurement of R/C requires several preparation steps (washing, drying, carding, and conditioning) and a specialized testing apparatus not generally available in U.S. wool testing labs. On the other hand, fiber diameter distribution is now routinely measured by fast, accurate, automated instruments. Recently, the capabilities of one such instrument, the Optical Fiber Diameter Analyser 100, were expanded to include concurrent measurement of fiber diameter and fiber curvature (FC) distributions. One hundred and four samples of wool representing a broad cross section of commercially available types were individually quantified using standard methods for SL (mean = 3.8 in, range 2.4 to 7.2 in), AFD (24.1, 18.0 to 43.1 μm), FC (82.9, 20.0 to 121.1 °/mm), clean yield (CY; 67.1, 41.4 to 88.7%), vegetable matter content (VM; 1.6, 0.1 to 6.7%), crimps/unit length of staple (CR; 9.9, 1.8 to 17.8 crimps/in), and R/C (9.1, 6.7 to 13.1 kPa) in order to study the relationships between R/C and the other measured traits. Resistance to compression was shown to be significantly ($P < 0.05$) but not highly correlated with SL, AFD, FC, CY, and CR (r = -0.36, -0.21, 0.57, -0.52 and 0.42, respectively). As expected, FC was highly correlated with CR and AFD (r = 0.94 and -0.83, respectively). Stepwise multiple regression analysis was used to predict R/C using all the measured variables (and their standard deviation (SD) values for all traits except CY and VM). The resulting equation was: RTC = -2.13 + 0.22 * AFD + 0.07 * FC, r^2 = 0.54. No other variables met the 0.01 significance level for entry into the model. We concluded that for textile applications in which a specific RTC is required, it will still be necessary to measure this characteristic directly since it cannot be accurately predicted using other raw fiber traits.

Key Words: Wool, Resistance to Compression, Fiber Traits

Sheep & Goat, Wool & Mohair CPR 2002. 156-159

Introduction

The value and usefulness of wool or other animal fibers are determined by several important physical properties and characteristics. The important properties of wool include average fiber diameter (AFD), clean wool fiber present (CWFP), vegetable matter present (VMP), staple length (SL), and staple strength (SS) followed by less, yet still important properties, which include color, crimp, character/style, and resistance to compression (RC). The latter is particularly important when the end-use is one in which bulk properties are critical, for example, in fine worsted knitwear, suiting materials, futons, and carpets. Resistance to compression is a measurement of

force per unit area required to compress a fixed mass of clean wool to a fixed volume (Blakeman et al., 1991). The unit of measurement is kilopascal (kPa). Teasdale (1986) reported that RC measurements are also useful in predicting processing performance and in determining the characteristics of the resulting fabrics. Wools with low RC values tend to be more efficiently processed on the worsted system with less fiber breakage and less card waste, which results in stronger, less bulky, and more lustrous yarns and fabrics. High RC wools tend to be more difficult to process and result in bulkier yarns and fabrics that are more resistant to felting making these fibers more suitable for such textiles as sweaters, carpets, and futons. End-use in these types of wools is very important. One drawback in measuring RC is that it is quite time-consuming and expensive, but with the development of the Optical Fibre Diameter Analyser (OFDA), wool characteristics such as AFD, and fiber curvature (FC) can be measured concurrently, quickly, and accurately. This experiment was designed to determine how well RC can be predicted using OFDA-measured variables and a manual measure of crimps/unit length of staple, CWFP, and VMP. Baxter (1996) reported a linear relationship between core bulk and a combination of FC, AFD, and standard deviation (SD) of AFD.

Experimental Procedure

One-hundred and four white wool samples were selected for testing, these being representative of millions of pounds of commercially available sale lots considered to be typical of a wide range of U.S. wools. Many of these samples were obtained by American Sheep Industry Association personnel from U.S. Wool Marketing Association sale samples. Others were obtained directly from marketing agencies around the country. These samples were characterized using standard test methods to determine RC (Agritest, 1988), SL (ASTM, 2000a), CWFP (ASTM, 2000b) and VMP (ASTM, 2000c). In addition, staple samples were manually measured for crimps per inch (CR). Further, the samples were mini-cored and the OFDA was used to measure AFD (ASTM, 2000d), and FC (OFDA, 1998). Multiple stepwise linear regression analysis was used to establish relationships and the degree of correlation among the various characteristics measured in this study (SAS, 1996).

Results and Discussion

The means, standard deviations, and ranges of values for the traits measured in this study are summarized in Table 1. Resistance to compression was shown to be significantly ($P < 0.05$) but not highly correlated with SL, AFD, FC, CWFP, and crimps (CR) per inch of staple ($r = -0.36, -0.21, 0.57, -0.52$, and 0.42, respectively, Table 2). As expected, FC was highly correlated with CR and AFD ($r = 0.94$ and -0.83, respectively). Stepwise multiple regression analysis was used to predict RC using all the measured variables (and their SD values for all traits except CWFP and VMP). The resulting equation was:

$$RC = -2.13 + 0.22 * AFD + 0.07 * FC, r^2 = 0.54$$

No other variables met the 0.01 significance level for entry into the model. We concluded that for textile applications in which a specific RC is required, it will still be necessary to measure this characteristic directly since it cannot be accurately predicted using other raw fiber traits.

Table 1. Means, variabilities, and ranges of measured traits (N=104)

TRAIT	MEAN	SD	MIN	MAX
SL, in	3.79	0.83	2.40	7.18
SLSD, in	0.48	0.16	0.19	1.09
SLCV, %	12.90	3.85	6.79	23.71
CWFP, %	67.12	10.79	41.39	88.70
VMP, %	1.60	1.45	0.06	6.70
RC, kPa	9.11	1.36	6.67	13.14
CR, cr/in	9.90	3.61	1.75	17.70
CRSD, cr/in	1.85	0.76	0.26	3.15
CRCV, %	19.26	5.78	8.12	44.62
AFD, µm	24.14	5.34	17.95	43.09
FDSD, µm	5.30	1.65	3.40	10.09
FDCV, %	21.70	2.65	16.10	28.70
FC, °/mm	82.92	23.68	20.00	121.10
FCSD, °/mm	54.54	11.96	19.00	73.00
FCCV, %	67.71	7.56	55.33	95.78

Key to abbreviations: SL = staple length; SLSD = standard deviation of staple length; SLCV = coefficient of variation of staple length; CWFP = clean wool fibers present; VMP = vegetable matter present; RC = resistance to compression; CR = average crimps per unit length; CRSD = standard deviation of CR; CRCV = coefficient of variation of CR; AFD = average fiber diameter; FDSD = standard deviation of fiber diamter; FDCV = coefficient of variation of fiber diameter; FC = fiber curvature measured in degrees per unit length; FCSD = standard deviation of FC; and FCCV = coefficient of variation of FC.

Table 2. Correlation coefficients and probability values for resistance to compression versus other traits

TRAIT	r	P
SL	-0.36	.0002
AFD	-0.21	.0299
FC	0.57	.0001
CWFP	-0.52	.0001
CR	0.42	.0001

Implications

For textile applications in which a specific resistance to compression is required, it will still be necessary to measure RC directly because it cannot be accurately predicted using other raw fiber traits.

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