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Texas Tech University System
Angelo State University
Management, Instruction, and Research (MIR) Center

The Angelo State University Management, Instruction, and Research Center is located on the northern shore of O.C. Fisher Lake in San Angelo, Texas. The Center is situated between the Edwards Plateau and Rolling Plains regions of Texas. Elevation of the area is approximately 1,950 ft above sea level with an average annual precipitation of 23 inches. Topography of the region is nearly flat with level clay loam soils with occasional shallow ridges and small drainages. The 235-day average growing season supports mainly warm season grasses, forbs and shrubs, including a mixture of Edwards Plateau and Rolling Plains vegetation.

The Management, Instruction, and Research (MIR) Center serves three primary objectives. The first objective is to conduct research to improve animal production, food technology, and range and wildlife management. These include studies related to improving the reproductive and nutritional efficiency of sheep, cattle, and goats in conjunction with projects designed to improve range and wildlife management practices. Some research projects are very basic in nature and designed to better understand mechanisms controlling animal and plant production. Others are applied studies with immediate implications for management.

The second objective is to serve as a demonstration site for Agricultural industry. This objective is accomplished by managing rangelands for livestock, wildlife, and food production. The development of sustainable, economically efficient management systems is a primary a focus of the MIR Center. All experiments, investigations, and research projects sponsored through the Management, Instruction, and Research Center are open for review by the public. Seminars and field days are being conducted periodically to provide to the citizens of west Texas the results of the projects being undertaken at the Center. Personnel at the Center are available to assist ranchers, farmers, and others in the region with management issues associated with their operations. Where appropriate, results of research and management demonstrations are published in area newspapers, magazines, and agricultural journals. The Center's facilities are also utilized by various agricultural groups for meetings throughout the year which include a 4-H/FFA livestock judging contest, wool and mohair judging contest, meat judging contest,land judging contest, wildlife contest, and a range and pasture evaluation contest.

The third objective of the MIR Center is to serve as a laboratory and outdoor classroom for the undergraduate and graduate programs in Agriculture. Laboratory classes are taught weekly at the MIR Center for Agriculture, Animal Science, Food Science, and Range Management courses. Undoubtedly, these "hands-on" experiences have been essential in shaping the knowledge of the department's 928 graduates since 1974.

The MIR Center is crucial for the Master of Science (M.S.) program in Animal Science. Since 1978, the department has produced 178 M.S. graduates. Several of those have continued their education at other universities by pursuing a Ph.D.

Mention of a trademark or a proprietary product does not constitute a recommendation of an endorsement of the product by Angelo State University nor does it imply its approval to the exclusion of other products that also may be suitable.

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  - Coordinator of Research.

- **Dr. Joseph Rallo**
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- **Dr. Donald Coers**
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- **Dr. Nancy Allen**
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Redberry Juniper Consumption Does Not Adversely Affect Meat Goat Reproduction

Corey J. Owens, Cody B. Scott, Charles A. Taylor, Jr., Erika S. Campbell, and Richard Brantley

ABSTRACT

Goat browsing can slow the encroachment of juniper (*Juniperus pinchottii* Sudw. and *Juniperus asheii* Buch.) onto rangelands in west central Texas, but the potential detrimental effects of monoterpenoids on reproduction are not known. We determined whether redberry juniper (*Juniperus pinchotii* Sudw.) consumption by pregnant goats caused abortions in any trimester or reduced offspring neonatal viability. In the pen feeding trial, pregnant Boer-cross nannies (n = 28) were randomly divided into four treatments; three treatments were fed redberry juniper 1 h daily for 22 d during one of the three trimesters of pregnancy and a control group was fed alfalfa pellets throughout gestation at 2% BW to meet maintenance requirements. In the pasture trial, pregnant nannies (n = 20) were placed on juniper dominated rangeland throughout gestation; juniper intake was monitored once monthly via bite count surveys and fecal NIR analysis. In both trials, birth date and weight, offspring number, sex, and vigor scores were recorded at parturition. Kids were weighed again on days 14 and 28 postpartum. In both trials, no abortions occurred as a result of redberry juniper consumption and no differences ($P > 0.05$) were observed in offspring number, vigor scores, or overall weight (based on 14 and 28 d postpartum weights). Fecal NIRS estimates for predicted juniper in goat diets was similar ($P = 0.16$) for all collection periods. Producers can continue to use goats as a management tool for slowing juniper encroachment onto rangelands without causing abortions or reductions in neonatal viability.

INTRODUCTION

Redberry (*Juniperus pinchotii* Sudw.) and ashe (*Juniperus asheii* Buch.) juniper continue to invade rangelands and become a problematic plant for ranchers in west central Texas (Ansley et al. 1995, Smeins et al. 1997). These two species of juniper were originally limited to rocky outcrops and steep canyons; however, with the suppression of wildfires, the density and location of juniper has increased. Several methods including the use of herbicides (spraying), prescribed burning, and

mechanical removal (grubbing, chaining, root plowing) are utilized to aid in the management of these unwanted species (Stueter and Wright 1983; Ueckert et al. 1994; Johnson et al. 1999). However, with rising fuel, labor, and herbicide costs, many ranchers are looking for alternative management strategies. Preliminary evidence reveals that goats can slow the encroachment of juniper onto rangelands by browsing seedlings and immature plants (Taylor and Fuhlendorf 2003; Taylor 2004).

Monoterpenoids, a class of terpenes containing two isoprene units, found in juniper are known to cause aversive postingestive feedback thereby limiting intake of the plant by most ruminants (Riddle et al. 1996; Pritz et al. 1997). Dietz et al. (2008) found goats preconditioned in a pen situation will continue to consume juniper when released back onto rangeland. This leads to the belief that goats can play an integral role in juniper management.

Although extensive research has gone into conditioning goats to consume juniper (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007), little research has investigated the potential detrimental effects of monoterpenoids on goat reproduction. Some phytotoxins inflict damage to the embryo, resulting in birth defects (Panter et al. 1992). Ingestion of ponderosa pine (*Pinus ponderosa* Laws.) needles has been known to cause abortions in cattle because of a toxin known as acetyl isocupressic acid which is converted to isocupressic acid in the rumen (Gardner et al. 1998). This toxin is also found in lodgepole pine (*Pinus contorta* Dougl. ex. Loud.) and common juniper (*Juniperus communis* L.). Other species of juniper have been suspected to cause abortions in livestock as well. For instance, Johnson et al. (1976) discovered that feeding one-seeded juniper (*Juniperus osteosperma* Torr.) to sheep in the second and early third trimester caused abortions. This juniper species along with ashe and redberry juniper contain monoterpenoids suspected as abortifactants. In west central Texas, concentrations of monoterpenoids in juniper were highest in the winter and spring (Owens et al. 1998); this timeframe directly coincides with the kidding season of most goat producers in west Texas. Because many producers use goat browsing to manage juniper, the potential effects on reproduction must be examined. Accordingly, this study was to determine if juniper consumption by pregnant goats caused abortions or reduced neonatal viability, and if so, in what trimester.

MATERIALS AND METHODS

Pen Feeding Trial

Forty-six female Boer-cross goats (25 yearling and 21 mixed age) with an average weight of 54.1 kg (± 4.9) were exposed to Boer billies for 3 mo for natural breeding. Conception dates were determined using ultrasonographic imagery (Classic Medical, Palm Scan PSM-3.5-S) at two week intervals throughout the breeding season.

Once pregnancy was confirmed, goats were allocated into treatments based on date of conception. Treatment 1 consisted of nannies fed redberry juniper in the first trimester of pregnancy; Treatment 2 consisted of nannies fed redberry juniper during the second trimester of pregnancy, and Treatment 3 consisted of nannies fed redberry juniper during the third trimester of pregnancy. Treatment 4 nannies served as the control and were not fed juniper anytime during pregnancy. At two week intervals throughout gestation, ultrasonographic imagery was used to monitor fetal development and health. Less than optimum body condition scores for pregnancy maintenance in yearling nannies and intense heat during breeding resulted in low conception rates and ultimately a variation in the number of goats per treatment.

During the first trimester, 10 randomly selected Boer-cross female goats (Treatment 1) were placed in individual pens and fed redberry juniper at 0800 hours *ad libitum* for 1 h daily for 22 d at the Angelo State University Management, Instruction, and Research (MIR) Center, San Angelo, TX (31° N; 100° W). Individual pens (1 m X 1.5 m) were elevated with expanded metal floors to allow for removal of excreta. All remaining excreta were removed from beneath pens at weekly intervals. Procedures in Treatments 2 and 3 were conducted exactly as Treatment 1 during the second and third trimesters, with 8 and 5 pregnant nannies, respectively. The remaining 5 pregnant nannies (Treatment 4) were fed only alfalfa pellets at 2% BW throughout the feeding trial.

In June 2006, redberry juniper leaves were stripped from plants located on the Texas Agrilife Research Center, Sonora, TX and stored at 0°C until feeding. Nannies in Treatments 1-3 were fed 50 g of redberry juniper on Day 1 of the feeding trial, and amount of juniper fed was increased based on intake of individual goats throughout the remainder of feeding. At the conclusion of feeding each day, refusals were collected and weighed. To meet daily maintenance and pregnancy requirements, all

goats were fed alfalfa pellets at 2% BW each day following juniper feeding and throughout the remainder of the feeding trial (NRC 2007). Pregnancy was verified using ultrasonographic imagery at two week intervals throughout gestation. All goats were given free access to a calcium/phosphorous mineral supplement with trace minerals and fresh water throughout pregnancy.

At the conclusion of the feeding trial and just prior to parturition, all pregnant nannies (Treatments 1-4) were placed in kidding pens located on the Angelo State University MIR Center. In order to avoid pregnancy toxemia, the nannies were placed on a balanced ration based on NRC requirements for late-term pregnancy (Table 1). Each nanny was monitored daily, and at parturition, data including birth date, number of offspring, birth weight, and offspring sex was collected. Vigor scores were also assigned during the first 8 h of life based on the following scale: 0 = dead; 1 = extremely weak, no attempt to get up or stand; 2 = struggles to get up, delay in nursing; 3 = slow to get up, slow to nurse; 4 = strong but slow to nurse; and 5 = strong, nurses rapidly. Body weights of kids were collected again on days 14 and 28 postpartum.

Table 1. Ingredients and nutritional value of balanced feed ration fed to pregnant nannies immediately prior to kidding in both experiments.

Ingredients	Percent (%) in feed[a]
Alfalfa, Dehydrated	56.9
Cane Molasses	2.8
Corn	37.9
Premix[b]	2.4
Avg. Daily Feed Intake Per Head	1.4kg
Digestible Energy	2.7 Mcal/kg
Total Digestible Nutrients	62.2
Crude Protein	14.0

[a]All percentages based on 1 ton (909.1 kg).
[b]Angelo State University Premix: Lasalocid 1158 g/ton, Calcium 19.0%, Salt 19.0%, Magnesium 1.4%, Zinc 2095 mg/kg, Manganese 1015 mg/kg, Iodine 0.02 mg/kg, Copper 1.0 mg/kg, Selenium 3.9 mg/kg, Vitamin A 18,364 IU/kg, Vitamin D3 13,400 IU, Vitamin E 280 IU.

Pasture Trial

Twenty-five mixed age Boer-cross female goats were exposed to Boer billies for 3 months for natural mating. At two week intervals throughout the breeding season, pregnancy rate was evaluated using ultrasonographic imagery to determine approximate conception dates. At the conclusion of

breeding, 20 pregnant nannies consisting of a mixture of goats previously preconditioned to juniper consumption and goats naive to juniper were transported to the Texas Agrilife Research Center, Sonora, TX and placed in a 16.2 ha pasture on juniper dominated (20.3% canopy cover) rangeland for 4 months (Dietz et al. 2008). All goats were given free access to a calcium/phosphorous mineral supplement with trace minerals and fresh water during the grazing portion of the study.

To monitor juniper preference, monthly bite count surveys were conducted. Each goat was observed individually for a period of 10 min once a month during optimum grazing times in the afternoon. During this time, bite frequency and bite type was identified and recorded as either herbaceous, juniper, or other browse. Fecal samples were also obtained to evaluate predicted juniper percentage in goat diets using the fecal near infrared reflectance spectroscopy (NIRS) procedure described by Walker et al. (2007). During each observation period, nannies were scanned using ultrasonographic imagery to ensure pregnancy.

To quantify that adequate herbaceous forage was available for goats throughout the trial, clip samples were obtained during each observation period. Ten 1/3 m^2 quadrats, randomly located throughout the pasture, were clipped and bagged by species; samples were dried in a forced-air oven at 60°C for 48 h and weighed to determine dry matter forage availability.

In order to evaluate juniper monoterpene concentration and composition, fifty grams of leaf and small stem tissue was collected by hand clipping from the apical portion of sprouts from each tree and immediately placed in liquid nitrogen to halt physiological activity and prevent volatilization. Leaf tissue was then stored at -50°C in order to halt leaf tissue metabolism and monoterpene volatilization. Samples were randomly collected from three redberry and three ashe plants during each observation period.

After 4 months on pasture, and just prior to parturition, the nannies were transported back to the Angelo State University MIR Center for kidding. In order to avoid pregnancy toxemia, the nannies were placed on a balanced ration based on NRC requirements for late-term pregnancy (Table 1). Each nanny was monitored daily, and at parturition data including birth date, number of offspring, birth weight, and offspring sex was collected. Vigor scores were also assigned during the first 8 h of

life based on the previously mentioned scale. Body weights of kids were collected again on days 14 and 28 postpartum.

In August 2007, fifteen g of frozen leaf material from each plant was individually combined with 150 ml of distilled water in a modified Clevenger (1928) type distillation apparatus. Hexane (5 ml) was used as a solvent for the distillate in the condensation tube, and the distillation time period was eight hours to ensure maximum recovery of monoterpenes (Owens et al. 1998; Campbell et al. 2007). Five microliters of tetradecane were added to condensate as an internal standard.

The chromatographic system consisted of a Clarus 500 GC (Perkin Elmer, Shelton, CT) equipped with an FID. The analytical column was a 30 m x 0.25 mm Rtx-5, 0.25 um (Restek, Bellefonte, PA). One microliter splitless injections (split time of 0.1 min) were made under the following conditions: the injection temperature was 200°C and the detector was 300°C. The initial oven temperature of 40°C was held for 0.5 min. The first oven ramp took the oven to 110°C at a rate of 5°C/min (0-min hold time). The final ramp of 20°C/min took the oven to its final temperature of 300°C (0-min hold time). The total run time was 23 min. The carrier gas was helium delivered at a constant 39 cm/s by employing electronic pressure control. The detector gasses were hydrogen (45.0 ml/min), and air (450 ml/min). Analytical procedure followed a modification of the procedure described in Kimball et al. (2004).

Detector responses were evaluated for each analyte over the range of 0.25-1.0 ug/ml. For each compound three hexane solutions with concentrations in the range of interest were injected into the GC in triplicate. Linear regression analyses were conducted and external standard calibrations were used by comparing detector responses of the analytes from the sample extracts to responses from commercially available standards (Acros Organics, NJ).

Intake data from the pen feeding trial was analyzed using repeated measures analysis of variance with goats (replications) nested within treatments (trimesters) and day of collection. Differences between treatments for birth weight, 14 d weight, and 28 d weight were analyzed using analysis of variance with kids nested within treatments as replications. Number of offspring born per nanny and sex were included in the analysis to determine their influence on weights of kids. Vigor scores and the average number of births were compared among treatments using a Chi-square test.

For the pasture trial, bite count data, NIRS estimates of forage preference, and forage availability were compared among sampling dates using analysis of variance. Mean birth weight, 14 d weight, 28 d weight, number of births, and vigor scores were not analyzed in the pasture trial because of a lack of a treatment effect. Means were separated using Least Significant Difference when P≤0.05 in both experiments. Data were analyzed using the statistical package JMP (SAS 2007).

RESULTS

Pen Feeding Trial

Of the 46 nannies exposed to billies, 28 nannies became pregnant and were divided into 4 treatments for the feeding trial. A combination of heat stress and yearling nannies' inability to maintain pregnancy resulted in early termination of pregnancy in 5 nannies in Treatment 1 and 4 nannies in Treatment 2 prior to feeding juniper. Therefore, 19 of the 46 exposed nannies gave birth to 34 kids resulting in a 74% kidding percentage.

Average daily juniper intake was similar (P = 0.09) among treatments during the pen-feeding phase of this study. Nannies in Treatment 1 consumed 1.1 ±0.3 g kg^{-1} of juniper per day. Treatment 2 nannies consumed 0.6 ±0.3 g kg^{-1} of juniper per day, and nannies in Treatment 3 consumed 0.5 ±0.4 g $kg^{-1}$of juniper per day. Juniper intake during Treatment 1 gradually increased through d 13 of feeding followed by a repeated pattern of decreased and increased intake throughout the remainder of the trial (Fig. 1). Goats in Treatments 2 and 3 maintained similar patterns of consumption through d 20 when Treatment 2 began to decrease intake and Treatment 3 increased juniper intake. No significant differences were observed in the treatment by day interaction.

Birth weights, 14 d weights, and 28 d weights were obtained on all kids born, and no differences (P ≥ 0.05) among treatments were observed (Table 2). The number of single and multiple births were also similar among treatments (Table 3). Number of kids born per nanny had no apparent effect (P > 0.05) on birth weight, 14 d weight, or 28 d weight. Also, vigor scores were similar among treatments (Table 3).

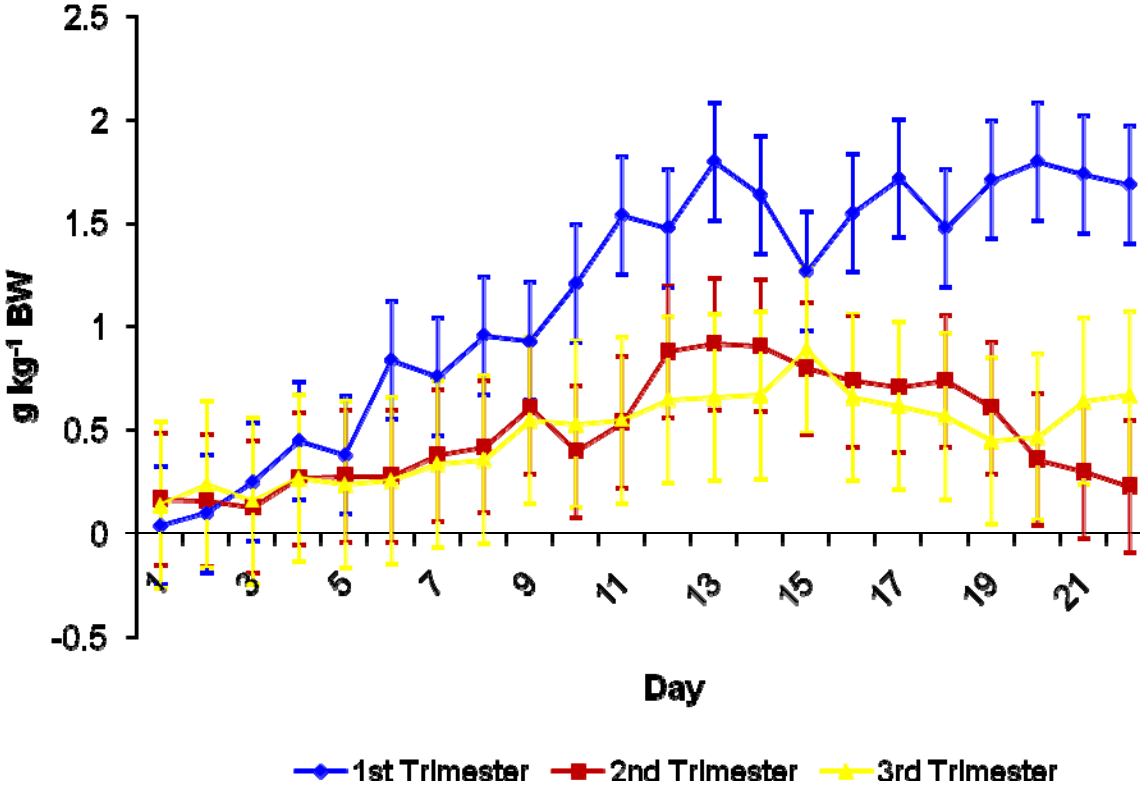

Figure 1 Average daily juniper intake for nannies fed redberry juniper *ad libitum* 1 hour daily for 22 d during each trimester of gestation in the pen feeding trial (P = 0.09).

Table 2. Birth weights (BW), 14 d weights (14W), and 28 d weights (28W) of all kids born to nannies in the pen feeding trial fed redberry juniper *ad libitum* 1 hour daily for 22 d during each trimester of gestation.

Trimester	BW (kg)	SEM	14W (kg)	SEM	28W (kg)	SEM
1st	3.7	0.2	5.2	0.8	7.6	1.2
2nd	3.1	0.2	4.6	0.8	6.9	1.2
3rd	3.3	0.1	3.2	0.7	4.3	1.0
Control[a]	3.6	0.2	5.9	0.8	9.4	1.1

[a]Nannies in control received only alfalfa pellets at 2% BW throughout the feeding trial.

Table 3. Number of kids born as singles, twins, or triplets and vigor scores of all nannies fed redberry juniper *ad libitum* 1 hour daily for 22 d during each trimester of gestation.

	Trimester			
	1st	2nd	3rd	Control[a]
Single	0	0	1	1
Twins	6	4	0	10
Triplets	3	6	12	0
Vigor Score				
0	1	1	2	0
1	0	0	1	0
2	0	0	0	0
3	0	2	0	0
4	0	1	1	0
5	8	6	9	11

[a]Nannies in control received only alfalfa pellets at 2% BW throughout the feeding trial.

Pasture Trial

Goats were released onto pasture 20 July 2006 at a moderate stocking rate based on year-round grazing (1 animal unit year / 8.1 ha). Differences between goat forage preferences throughout gestation were observed and recorded (Table 4). During the August observation period, goats tended to prefer other shrubs (algerita, liveoak, persimmon, lotebush) over the other two forage classifications. Herbaceous forage was preferred during the September observation period, and juniper was the preferred forage class during the October observation. Average available herbaceous

Table 4. Total herbaceous production (kg ha^{-1}) and preference of herbaceous vegetation, juniper, or other shrubs (percent of total bites) for pregnant nannies during 3 months of observation on juniper dominated rangeland.

	August	SEM	September	SEM	October	SEM
Herbaceous Production	1066.5	309.04	659.46	309.04	1459.2	309.04
Preference						
Herbaceous	6.8	1.1	53.7	1.1	33.9	1.2
Juniper	17.3	1.3	43.7	1.3	66.2	1.4
Other Shrubs	76.0	0.6	0.0	0.6	0.0	0.6

forage remained relatively constant throughout the trial with the exception of September where a decrease in kg ha^{-1} of forage produced was observed (Table 4).

During gestation, monthly juniper samples were taken to evaluate monoterpene concentration and composition. Gas chromatograph analysis shows total monoterpene concentrations for both ashe and redberry juniper were highest during the July and August collection periods (Tables 5, 6). A significant difference was observed in sabinene/b-pinene, cymene, and terpeneol concentrations in ashe juniper and borneol, g terpinene, and terpinen4ol concentrations in redberry juniper over the four month collection period (Tables 5, 6). Juniper intake was inversely correlated to sabinene/b-pinene (r^2 = 0.96) concentrations in ashe juniper and a terpinolene (r^2 = 0.97), terpineol (r^2 = 0.99), and total monoterpene (r^2 = 0.96) concentrations in redberry juniper. Conversely it was positively correlated to borneol (r^2 = 0.79) concentration in redberry juniper.

Table 5. Gas chromatograph analysis of monoterpene levels in ashe juniper collected during pasture trial.

Monoterpene	Month				
	July	August	September	October	SEM
alpha-pinene+	0.20	0.17	0.14	0.14	0.03
Camphene*	0.21	0.17	0.14	0.33	0.05
Sabinene/b-pinene+	0.02	0.02	0.02	0.001	0.002
Myrcene+	0.14	0.11	0.12	0.29	0.08
Cymene	0.13	0.17	0.10	0.07	0.02
Limonene+	0.91	0.95	0.72	0.69	0.19
g terpinene	0.08	0.07	0.08	0.09	0.03
a terpinolene	0.07	0.07	0.07	0.07	0.02
Linalool	0.01	0.01	0.01	0.02	0.006
Fenchyl Alcohol	0.05	0.09	0.04	0.05	0.02
Camphor*	5.32	5.86	4.73	3.67	0.85
a-citronellol	0.20	0.20	0.35	0.11	0.08
Borneol	0.40	0.46	0.25	0.12	0.09
Terpinen4ol	0.01	0.02	0.01	0.02	0.003
Terpineol+	0.01	0.01	0.02	0.05	0.002
Carvone	0.06	0.07	0.05	0.03	0.01
Bornyl Acetate*	1.88	1.70	1.64	1.24	0.36
Total	10.12	10.63	8.83	7.33	1.64

+Denotes monoterpenes inversely correlated with intake (Riddle et al. 1996)
*Denotes monoterpenes positively correlated with intake (Riddle et al. 1996)

Table 6. Gas chromatograph analysis of monoterpene levels in redberry juniper collected during pasture trial.

Monoterpene	Month				
	July	August	September	October	SEM
alpha-pinene [+]	0.40	0.37	0.31	0.32	0.06
Camphene*	0.08	0.10	0.09	0.11	0.02
Sabinene/b-pinene [+]	3.98	3.32	2.77	2.80	0.70
Myrcene [+]	1.00	0.95	0.76	0.81	0.14
Cymene	0.01	0.01	0.01	0.01	0.002
Limonene [+]	0.92	0.98	0.79	0.74	0.13
g terpinene	1.08	0.95	0.75	0.62	0.09
a terpinolene	0.44	0.39	0.31	0.29	0.04
Linalool	0.04	0.03	0.03	0.04	0.01
Fenchyl Alcohol	0.03	0.03	0.03	0.03	0.0006
Camphor*	1.24	1.35	1.29	1.21	0.23
a-citronellol	0.07	0.12	0.14	0.07	0.05
Borneol	0.01	0.03	0.03	0.05	0.005
Terpinen4ol	2.77	2.39	1.91	1.53	0.24
Terpineol [+]	0.12	0.11	0.09	0.08	0.008
Citronellol	0.09	0.08	0.09	0.01	0.06
Carvone	0.002	0.002	0.001	0.002	0.0005
Bornyl Acetate*	0.31	0.28	0.29	0.56	0.20
Total	12.58	11.48	9.70	9.26	1.51

[+]Denotes monoterpenes inversely correlated with intake (Riddle et al. 1996)
*Denotes monoterpenes positively correlated with intake (Riddle et al. 1996)

Fecal NIRS data obtained from samples collected revealed relatively equal amounts of predicted juniper in goat diets between observation periods. Predicted juniper in goat diets was similar for all collection periods.

Twenty-five nannies were exposed to billies and 18 nannies gave birth to 34 kids resulting in a 136% kidding percentage. Data collected on birth weights, 14 d weights, and 28 d weights of all kids born to nannies in the pasture trial did not

reveal any apparent differences. All weights were similar to those weights of kids in the pen feeding trial through the duration of the trial.

DISCUSSION

Based on the results from this study, monoterpenoids found in redberry and ashe juniper do not appear to have a negative effect on goat reproduction. No differences in vigor scores immediately postpartum were observed in kids from any treatment group in either trial. Likewise, all kids from both trials, no matter how many siblings, maintained similar growth patterns based on birth, 14 d, and 28 d weights throughout the duration of the study. These results indicate that juniper intake does not inhibit

offspring growth and development. Unlike results from Johnson et al. (1976) where abortions occurred in sheep fed juniper (1 lb of plant per day) via stomach pump in the second and third trimesters, no incidences of abortions or teratogenic effects (birth defects) were observed in this study. Goats appear able to metabolize monoterpenes found in juniper better than sheep and are therefore able to avoid toxin-induced abortions.

During the breeding portion of this trial, intense heat and drought-like conditions reduced conception rates in mature nannies. Also, yearling nannies obtained for this study just prior to breeding were not in optimum body condition for breeding and pregnancy maintenance. Both of these factors resulted in a variation in number of nannies per treatment in the pen feeding trial. Heat stress also resulted in early pregnancy termination in 5 and 4 nannies, during the first and second trimester feeding trials, respectively prior to feeding juniper. No incidences of early pregnancy termination were observed in the third trimester or control nannies. As a result, overall kidding percentage in both trials suffered due to environmental conditions and was not caused by juniper consumption.

Goats can be preconditioned in a pen-fed situation to consume juniper, a plant they would otherwise avoid, once released onto pasture (Ellis et al. 2005; Dietz et al. 2008). Avoidance occurs because of monoterpenoids contained in juniper associated with aversive postingestive feedback (Riddle et al. 1996; Pritz et al. 1997). Goats in the pen feeding trial, although offered juniper for a longer period of time (22 d), tended to consume less juniper than goats in previous studies. Monoterpenoid levels tend to be higher in the winter and spring (Owens et al. 1998). However, seasonal rainfall variations can effect monoterpenoid concentrations (Riddle et al. 1996). Gas chromatograph analysis of redberry juniper fed to goats revealed higher concentrations of monoterpenes inversely correlated to intake than that of a study conducted by Dietz et al. (2008). The severity of the drought-like conditions which occurred during the summer feeding trial appear to have played a role in elevating monoterpenoid levels in the juniper resulting in reduced overall intake. Also, r^2 values for intake may have been arbitrarily higher than Dietz et al. (2008) because of low sample size.

Herbaceous production in the pasture trial remained relatively constant throughout gestation with lower overall production in September. This decline may be a result of lack of significant rainfall

along with greater preference for herbaceous forage over any other forage class during this time as noted during visual observation. Herbaceous production during October increased as goat preference shifted from herbaceous forage to juniper.

According to bite count estimates, juniper consumption steadily increased as the fall of the year approached. Gas chromatograph analysis revealed lower levels of total monoterpene concentrations in ashe and redberry juniper during September and October. These results explain increased juniper consumption and agree with the observation that lower monoterpene concentrations exist in juniper in west central Texas during the fall (Owens et al. 1998).

IMPLICATIONS

Collectively, results of previous studies along with the results of this study indicate that goats should continue to be used as a cost-effective method of juniper management (Ellis et al. 2005; Dietz et al. 2008). Producers can implement strategies to increase juniper consumption by preconditioning yearling replacement nannies for 14 d at weaning along with concentrating the main breeding herd in juniper-dominated pastures without fear of a reduction in kidding percentage or lighter kid weaning weights.

Monoterpenoid concentrations in juniper are typically highest during the early spring and winter when most browse and herbaceous plants are dormant. This timeframe directly coincides with the breeding seasons of most goat ranchers in west central Texas. Concentrating goats into juniper-dominated pastures during this time period will increase browsing pressure on these plants and optimize potential management of juniper. Preceding goat browsing with prescribed fire may also increase overall juniper consumption by altering monoterpenoid composition.

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Supplements Containing Escape Protein Improve Redberry Juniper Consumption by Goats

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ABSTRACT

Redberry juniper (*Juniperus pinchotii* Sudw.) is a common invasive plant species in west central Texas. Goats will consume redberry juniper, but intake is limited by monoterpenoids found in the plant. Previous research has shown that goats will increase juniper intake through (1) preconditioning and through (2) protein supplementation. This study compared intake of juniper when goats received different protein supplements, either with or without protein sources that are high in amino acids that escape digestion in the rumen. Recently weaned Boer-cross goats (n = 47) were randomly placed into 5 treatments. Treatments 1, 2, 3 and 4 received a protein supplement and juniper for 1 hour daily for 14 days, along with a basal diet of alfalfa pellets (2% BW). Treatment 5 received only a basal diet of alfalfa pellets and juniper. All supplements were isonitrogenous (37% CP). Treatment 1 contained cottonseed meal (high CP escape value); Treatment 2 contained cottonseed meal and corn distiller's grain (higher CP escape value); Treatment 3 contained soybean meal (low CP escape value), and Treatment 4 contained soybean meal and distiller's grain (moderate CP escape value). Refusals of juniper, supplements, and alfalfa were weighed daily to determine intake. Supplementation with cottonseed meal, soybean meal or soybean meal and distillers grain did not influence juniper intake. Conversely, goats supplemented with cottonseed meal and distiller's grain ate more ($P<0.05$) juniper than goats only receiving alfalfa apparently because of increased escape of glucogenic amino acids. We contend that supplementation with protein supplements with high escape values should increase juniper intake on rangelands.

INTRODUCTION

Redberry (*Juniperus pinchotii* Sudw.) and ashe (*Juniperus asheii* Buch.) juniper are problematic woody species that have invaded millions of ha of Texas rangelands (Ansley et al. 1995, Smeins et al. 1997). Several studies have shown that goats will consume juniper, particularly after feeding juniper at weaning (Bisson et al. 2001, Ellis et al. 2005, Dunson et al. 2006, Dietz et al. 2008). Unfortunately, intake of juniper is limited because monoterpenoids found in the plant cause aversive

post-ingestive feedback (Riddle et al. 1996, Pritz et al. 1997). Indeed, most poisonous plants avoid herbivory through aversive post-ingestive feedback and the formation of conditioned food aversions (Provenza et al. 1992, Provenza 1995). However, ruminants may be able to avoid aversive feedback if toxins are metabolically altered through the processes of digestion and metabolism.

When goats consume low to moderate levels of juniper, monoterpenoids in the plant are liberated after ingestion and absorbed through the rumen wall and small intestine. These partially metabolized compounds are then transported to the liver via the portal systems for detoxification. Apparently, these compounds are then oxidized by cytochrome P-450 enzymes (Bidlack 1982, Scheline 1991). Thereafter, altered monoterpeniod oils are conjugated with endogenous cofactors, such as glucuronic acid (Bidlack et al. 1986, Scheline 1991). Toxic compounds become more hydrophilic because of oxidation/conjugation in liver allowing them to be excreted in urine (Foley et al. 1995, Nebbia 2001).

Protein sources high in glucogenic amino acids, like corn distiller's dried grains (DDG), should increase the likelihood of detoxification because they may provide the substrate (i.e. glucuronic acid) for conjugation. Preliminary research has illustrated that protein supplementation improved juniper consumption in goats. Cottonseed meal (CSM) and alfalfa supplementation increased redberry juniper intake by 40% compared to goats fed a corn supplementation and 30% for goats receiving no supplementation (Campbell et al. 2007). Protein supplementation of cows improved tolerance of broom snakeweed (*Gutierrezia sarothrae* [Pursh] Britt & Rusby) toxicosis because of increased liver capacity to conjugate and eliminate xenobiotics (Strickland et al. 1998). Supplementation with protein sources high in sulfur-containing amino acids like soybean meal has improved detoxification of some poisonous plants (Calhoun et al. 1989). Apparently, protein sources high in sulfur-containing amino acids provide a source of sulfhydral groups for toxin conjugation in the rumen.

Distiller’s dried grain is high in glucogenic amino acids (NRC 2007) while soybean meal (SBM) is high in sulfur-containing amino acids (Calhoun et al. 1989). Cottonseed meal is a common source of protein for winter supplementation of livestock in the southwestern U.S. and it also provides a source of escape proteins. Thus, we hypothesized that protein sources high in escape protein would improve juniper consumption over protein sources that are highly soluble in the rumen.

Additionally, we hypothesized that protein sources high in sulfur-containing amino acids may aid detoxification of monoterpenoids and improve juniper consumption.

MATERIALS AND METHODS

In this experiment, 47 recently-weaned, castrated Boer-cross goats (23.6±1.5 kg) were randomly placed into 5 treatments (n=9 to 10 goats/treatment). Fifty goats were purchased for this study, but 3 goats died before the feeding of juniper because of poor body condition and high loads of intestinal parasites, leaving 9 goats in three treatments. Goats were separated into individual pens (1 m by 1.5 m) and allotted 7 days for pen-adjustment. Excrement was removed weekly from pens. Alfalfa pellets (2% BW) were fed daily to meet the animals' intake requirements for maintenance. Additional supplementation was fed, according to treatment allocation, to meet requirements for growth (NRC 2007). Goats also received fresh water and calcium/phosphorous mineral with trace elements *ad libitum*.

Goats were supplemented each day before feeding juniper according to treatment group (Table 1). Treatment 1 received a supplement with CSM as the protein source; Treatment 2 received a supplement with CSM and DDG as the protein source; Treatment 3 received a supplement with SBM as the protein source; Treatment 4 received SBM and DDG supplement as the protein source; and Treatment 5 received no protein supplementation, alfalfa pellets only. All supplements were isonitrogenous (37% CP). The amount of alfalfa fed to Treatment 5 was increased so that all goats received the same amount of protein daily (4.4 g $head^{-1}day^{-1}$).

Table 1. Ingredients (%) and nutritional value (%) of protein supplements.

Ingredients	Ration			
	1	2	3	4
Cottonseed Meal	88.7	77.5	--	--
Soybean meal			78.7	63.1
Dried Distiller's Grain	--	16.2	--	26.7
Cane Molasses	3.4	3.4	3.4	3.4
Rice bran	7.5	2.5	17.5	6.5
Trace Mineral Premix	0.02	0.02	0.02	0.02
Vitamin ADE Premix	0.3	0.3	0.3	0.3
TDN	70.2	72.3	73.8	76.6
Protein	37.3	36	39.6	37.3

All percentages based on one ton (909.1 kg)

All goats were naïve to supplements prior to the initiation of the study; thus, a 7-day pretrial was used to familiarize goats with pens and the supplements. Supplements were offered during the pretrial until goats consumed all the supplement offered daily. Amount of supplement for each goat was based on providing 1.9 g kg^{-1} BW to meet CP maintenance requirements. In addition, 64 g of additional protein was fed each day to surpass daily protein requirements for growth (NRC 2007). The amount of each supplement fed was based on requirements for maintenance and growth minus the number of grams of protein provided by alfalfa pellets (17% CP).

Animals received one of four supplemented protein treatments and juniper for 14 days. Protein supplementation was offered from 0800 to 0900 to goats in each treatment. Redberry juniper leaves were offered to all animals from 0900 to 1100. Prior to initiation of the study, redberry juniper was harvested from randomly selected trees at the Texas AgriLife Research Center, Sonora, Texas. Leaves were stripped from the stems before feeding, composited, and stored at 4^0 C at the Angelo State University Management, Instruction, and Research Center until feeding. Initially, 50 g of juniper was offered to each goat. If an individual goat consumed all the juniper offered, the amount fed was increased daily until refusals were noted. Goats then received alfalfa pellets (2% BW) from 1200 to 1700 to meet maintenance requirements. Intake of supplements, juniper, and alfalfa were recorded daily for the 14 days of the study.

True *in vitro* digestibility, digestible CP, and by-pass protein potential of the supplements were determined using six cannulated goats, located at the Texas AgriLife Research and Extension Center, San Angelo, TX. Goats were fed alfalfa pellets (2% of BW) at 0800 h for 12 days. Four hours after feeding, approximately 500 ml of rumen fluid per goat was collected on days 0, 3, and 7 (3 replications) through 1 layer of cheesecloth into a pre-warmed thermos. Approximately 200 g of material left on the cheesecloth was crumbled and also added to each thermos. Thermoses were sealed and shaken (Labline, Melrose Park, IL) for 3 minutes to dislodge some particle-associated bacteria.

Rumen fluid was combined, mixed, continually flushed with CO_2, and 400 mL was filtered through 2 layers of cheesecloth and rinsed once with approximately 200 mL of a McDougal's buffer solution (1.064 g of urea per L of solution). The remaining rumen material was squeezed through

cheesecloth. The rumen fluid-buffer mixture was transferred to an incubation jar containing 1,000 mL of McDougal's buffer, purged with CO_2 for 1 min, and sealed. This procedure was repeated for the other 3 jars. A separate incubation jar for each supplement was used to ensure that one type of supplement did not influence another. Each protein supplement was ground to pass a 1-mm screen (Wiley Mill) and 0.35 g of each supplement was placed into a fiber bag (F57, Ankom) that was then heat sealed. Bags of supplement were incubated for 0, 24, or 48 hours. Bags were introduced in reverse order, removed all at once, and placed into an ice water bath for 5 minutes to arrest microbial fermentation. Zero-hour bags were not incubated; soluble, readily degradable CP was determined from three 0-hr bags that were soaked in warm water (40 °C) for 15 min and washed with the other bags.

Bags (0, 24, and 48-hr) were placed into a washing machine and subjected to 5 rinse cycles (low water level) with 1-min agitation (delicate setting) and a 2-min spin per rinse (Coblentz et al. 1997). After washing, bags were subjected to a neutral detergent solution (no Na sulfite; 4 bags per supplement per hour), dried (60 °C) for 48 hr, and weighed to determine true *in vitro* dry matter digestibility. Bags and contents were then analyzed for CP by a modified Kjeldahl procedure (Tecator Kjeltec 2400; AOAC 2001.11). Crude protein from residue remaining after the NDF procedure is the neutral detergent insoluble nitrogen (NDIN), which is also considered to be the rumen undegradable CP content, since NDF solution rinses away particle-associated bacteria (Mass et al. 1999). To determine non-digestible CP content, 3 bags per supplement were digested and washed with the other bags during the 1st digestibility run, subjected to an acid detergent solution, dried, weighed, and analyzed for CP. Acid detergent fiber and NDF procedures were performed using methods of Van Soest et al. (1991) modified for an Ankom^{2000} Fiber Analyzer (Ankom Technology Corp., Fairport, NY).

The study design was a completely randomized design. Differences between treatment means (protein supplement) was assessed using repeated measure analysis of variance. Individual goats were nested within treatments and served as replications. Treatment means were analyzed as a fixed effect, individual animals as a random effect, and days of feeding as the repeated measure. Planed orthogonal contrasts were used to assess treatment effects. Means were separated using

Least Significant Differences (LSD) when P≤0.05. Means and standard errors were calculated for UIP, IVDMD, and dCP. Data were analyzed using the statistical package JMP (SAS 2007).

RESULTS

Protein and alfalfa intake were similar (P>0.05) among treatments and across days during the 7-day pretrial. Goats typically consumed all of the alfalfa and protein supplement offered each day.

When means were compared across all treatments, juniper intake was similar (P>0.05) among treatments (Table 2), but varied across days of feeding for all treatments (Fig. 1). Initially, goats were reluctant to consume juniper (0.72±0.31 g kg^{-1} BW); however, by day 12, intake had increased to (2.67±0.31 g kg^{-1} BW). The treatment X day interaction was not significant. Treatment means for juniper intake varied from 0.88±0.55 g kg^{-1} BW for the treatment receiving no supplementation to 2.63±0.55 g kg^{-1} BW for the treatment receiving a protein supplement containing both CSM and DDG as a protein source. When planned orthogonal contrasts were used to compare treatment means, one difference was evident. Goats receiving supplements containing CSM/DDG supplement consumed more juniper than goats

Table 2. Average intake of alfalfa, protein, and juniper for treatments receiving different protein supplements. All supplements were isonitrogenious (37%).

Supplement	Intake		
	Alfalfa (g kg^{-1} BW)	Protein (g^{-1} hd^{-1}day)	Juniper (g kg^{-1} BW)
CSM	18.5±1.9	4.4±0.3	1.5±0.5
CSM/Distiller's grain	20.5±1.6	4.7±0.3	2.6±0.5
SBM	18.1±1.6	4.3±0.3	1.5±0.5
SBM/Distiller's grain	19.4±1.5	4.5±0.2	1.4±0.5
Alfalfa alone	23.7±1.5	4.0±0.2	0.9±0.5

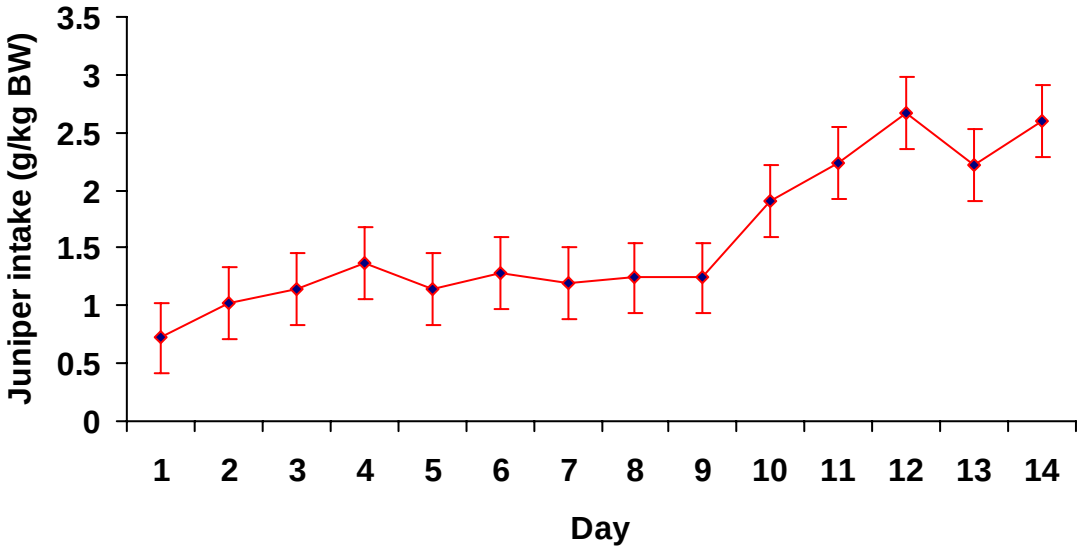

Figure 1. Juniper intake (g kg^{-1}) for the 14 days of feeding different protein supplements.

receiving alfalfa alone (Fig. 2). This was particularly evident when comparing juniper intake between goats receiving the CSM/distiller's grain supplement vs. alfalfa alone across the 14 days of feeding (Fig. 3).

Alfalfa intake (g kg^{-1} BW) and protein supplement intake (g $head^{-1}day^{-1}$) were similar among treatments (Table 2). The cottonseed meal/distiller's grain supplement resulted in more escape protein (UIP) than the other supplemental rations (Table 3). The UIP value for alfalfa was also high, suggesting a high escape value, but overall digestibility (IVDMD) was lower for alfalfa compared to the supplemental protein rations.

DISCUSSION

Results of this study illustrate that goats receiving a protein supplement consisting of CSM and DDG ate more redberry juniper than goats receiving alfalfa alone. Before this study, there was little known about how the source of protein would affect intake of juniper by goats. Other studies have illustrated that protein supplementation improves intake of some poisonous plants (Calhoun et

al. 1989, Strickland et al. 1998, Campbell et al. 2007). However, results from this study suggest that the amount of protein that escapes rumen digestion may further improve juniper intake.

Many toxins are absorbed, bio-transformed, and metabolized by mammals to form organic acids that must be buffered and excreted from the body (Foley et al. 1995). If a food is toxic, no amount of exposure is likely to increase intake beyond toxic satiation (Distel and Provenza 1991). Illius and Jessop (1995) hypothesize that animals limit consumption of toxins when nutritional stress reduces their tolerance to

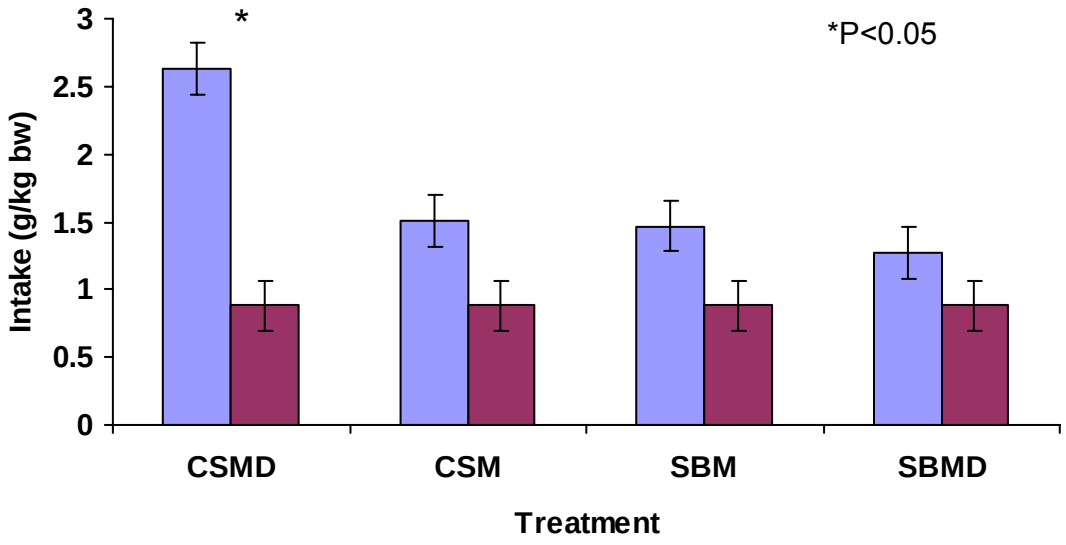

Figure 2. Comparison of juniper intake when each supplement was compared to the controld diet (alfalfa alone).

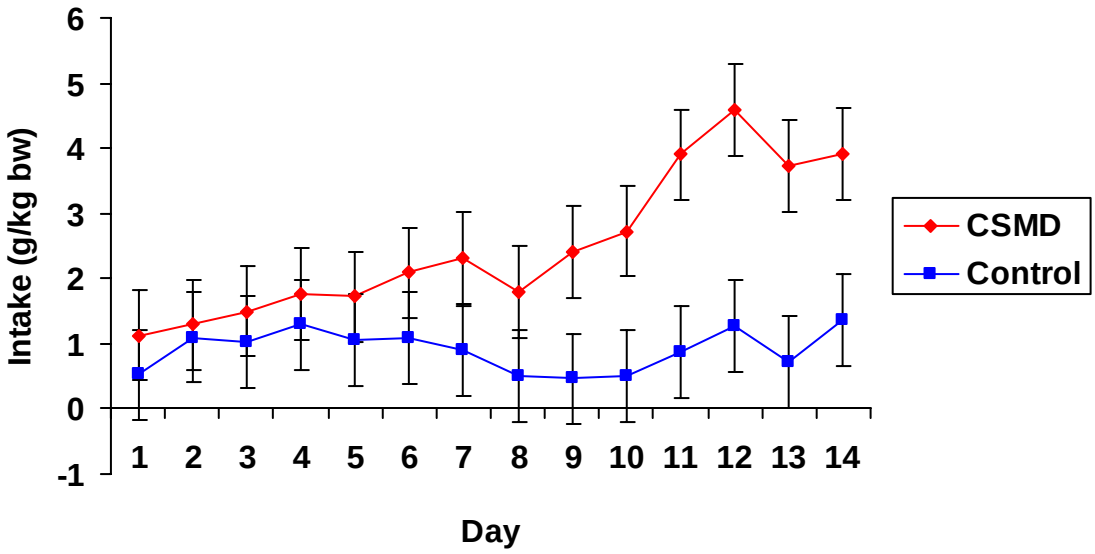

Figure 3. Juniper intake (g kg^{-1}) for the 14 days of feeding of the CSM/distiller's grain supplement versus alfalfa alone.

Table 3. True *in vitro* dry matter digestibility, potential undegradable intake protein, and acid detergent insoluble crude protein[a].

	Treatment[b]				
Item[c]	ALF	CSM	CSMD	SBM	SBMD
0-hr (wash)					
tIVDMD	26.45	30.25	30.89	39.08	40.44
UIP, % initial DM	**13.77**	**30.20**	**32.63**	**31.92**	**29.38**
dCP, % initial DM	7.03	9.50	6.97	8.68	11.02
0-hr (NDF)					
tIVDMD	49.93	76.76	74.02	86.23	81.81
UIP, % initial DM	**7.15**	**4.41**	**5.32**	**2.65**	**3.94**
dCP, % initial DM	14.00	35.29	34.79	37.95	37.21
24-hr					
tIVDMD	61.44	80.60	79.22	90.38	87.52
UIP, % initial DM	**4.45**	**2.76**	**3.65**	**1.44**	**2.22**
dCP, % initial DM	16.35	36.68	35.95	39.16	37.54
ADICP, % initial DM	2.57	3.69	6.58	1.87	2.57
ADICP, % initial CP	12.36	9.29	16.61	4.61	6.36
48-hr					
tIVDMD	69.07	83.72	84.60	94.20	92.20
UIP, % initial DM	**3.33**	**2.48**	**2.87**	**0.67**	**1.43**
dCP, % initial DM	17.47	37.22	36.73	39.93	38.98
ADICP, % initial DM	2.18	3.89	4.09	1.66	3.07
ADICP, % initial CP	10.48	9.79	10.33	4.09	7.59

[a]True *in vitro* dry matter digestibility (tIVDMD), potential undegradable intake protein (UIP), and acid detergent insoluble crude protein (ADICP).
[b] Treatment rations were fed daily.
[c] 0-hr (wash) = no digestion, soaked and washed; 0-hr (NDF) = no digestion, soaked, washed, and rinsed with neutral detergent solution (NDF); 24- and 48-hr = digested for 24 or 48 hr, washed, rinsed with neutral detergent solution.

allelochemicals. During times of starvation, the body can undergo depletion of glycogen stores, increased gluconeogenesis from degraded amino acids and fatty acid utilized for energy. This response to starvation can result in a loss of the MFO reactions and conjugation enzymes that reduce an animal's ability to handle plant toxins (Bidlack 1982). Detoxification also requires additional expenditures of amino acids and glucose to conjugate with toxins and maintain an animal's acid-base balance (Illius and Jessop 1995). Levels of cytochrome P-450 and reductase are reduced in animals fed protein-deficient diets (Owens and Zinn 1988). In addition to supplying building blocks for protein, amino acids also supply a major portion of the glucose needed by ruminant animals. Alanine, aspartate, glutamate and glutamine are the primary amino acids used as a source of carbon for glucose; alanine being the most glucogenic, accounting for 40–60% of the glucose formed from

amino acids (Fahey and Berger 1988). Thus, feeding excess amino acids or protein sources high in escape protein may provide a source of amino acids that can be used for synthesis of glucose in the liver, which may play a role in the conjugation of toxins to be secreted from the body (Illius and Jessop 1995).

Cottonseed meal feeds are generally high in escape proteins, while DDG are high in glucogenic amino acids. These may be important for xenobiotic detoxification because they can provide amino acids needed for Phase II reactions (Freeland and Jansen 1974). Soybean meal is higher in sulfur-containing amino acids and also used in toxin detoxification. This reaction, however, generally occurs in the rumen. In this study, neither SBM-based supplement affected ($P>0.05$) juniper intake. Likewise, SBM supplementation did not affect consumption of sagebrush, which also contains terpenes (Burritt et al. 2000). Dunson et al. (2007) illustrated that rumen function had no effect on the degradation of several monoterpenoids found in juniper. Thus, based on the results of this study, and findings from Dunson et al. (2007), it seems unlikely that providing substrates for rumen degradation of toxins will improve juniper consumption.

Environmental conditions such as amount of rainfall and daily temperatures can have an effect on monoterpenoid levels found in redberry juniper (Owens et al. 1998), and they tend to be higher in winter and spring (Riddle et al. 1996). However, this is when we can see a greater impact on juniper species, because most preferred dominant browse species are dormant and there is minimum forb growth during these months. In addition, livestock typically require additional protein during the winter to meet maintenance requirements.

Goats in all treatments during this study increased juniper intake daily until day 12 and this pattern of intake has been clearly illustrated in other studies (Bisson et al. 2001, Ellis et al. 2005, Dunson et al. 2007). In addition, feeding juniper at weaning can increase acceptance of that plant that continues once goats are released on pasture (Dietz et al. 2008).

IMPLICATIONS

Winter protein supplementation is often implemented by landowners throughout the southwestern U.S. Supplementation costs continue to rise as feed ingredients (e.g. corn and soybean meal) are used for biofuel production. For livestock enterprises to remain viable, alternative

supplements must be identified. Distiller's dried grains are a readily available byproduct of ethanol production. When incorporated in protein supplements, they provide a source of glucogenic amino acids that apparently improve juniper consumption. Based on the results of this study, we recommend including DDG in traditional CSM-based supplements for winter supplementation of goats foraging on juniper dominated rangelands.

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Consumption of Salt Cedar and Willow Baccharis by Boer-cross Goats

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ABSTRACT

Salt cedar (*Tamarix ramosissima*) and willow baccharis (*Baccharis salicina*) are invading rangelands throughout Texas, particularly areas with high soil moisture. Both species often dominate mesic sites throughout the southwestern U.S. Control efforts are often hampered because of cost and reduction in non-target species growing on the same site. The objective of this study was to determine if Boer-crossed goats would consume salt cedar and willow baccharis. Goats (n=35) were randomly divided into four Treatments. Treatment 1 was fed saltcedar, Treatment 2 was fed willow baccharis, Treatment 3 was fed saltcedar and willow baccharis, and Treatment 4 was fed alfalfa pellets. Goats ate more ($P<0.05$) salt cedar that willow baccharis. Intake of willow baccharis was apparently limited because of aversive postingestive feedback experienced by goats. When salt cedar was fed alone, intake was higher ($P<0.05$) than when it was fed with willow baccharis. Conversely, willow baccharis intake was higher when it was fed with salt cedar. Alfalfa and water intake were similar ($P>0.05$) among treatments. Collectively, the results of this study indicate that goats may be a viable option for reducing salt cedar cover but may have little impact on willow baccharis cover.

INTRODUCTION

The shrubs saltcedar (*Tamarix ramosissima* Ledeb.) and willow baccharis (*Baccharis salicina* Torr. & Gray) are invading rangelands throughout Texas, particularly riparian areas and lake basins. Both species out-compete native vegetation and utilize large amounts of soil moisture (Young et al. 2004). Saltcedar originated from Eurasia in Central Asia and was introduced to North America to help prevent erosion along banks of streams, lakes, and rivers (Kennedy and Hobbie 2004, Bartelt and Cossè 2005). Saltcedar was first seen on rangelands of Texas in 1877 (Everitt 1980, Brotherson and Winkel 1986) and has now invaded over 600,000 ha in Texas (DiTomaso 1998, Hart 2003). It has also expanded from the Great Plains to the Pacific and from Canada to Mexico (DeLoach and Carruthers 2005). Saltcedar can grow up to 9 m and is capable of tolerating high concentrations of

salt, drought, fire, cold, and flooding (Stevens and Walker 1998). Also, because of its competitive abilities, it significantly reduces number and quality of native vegetation (Hart 2003). Willow baccharis, much like saltcedar, grows in close proximity to water, has little to no value to wildlife, and poses a threat to our rangelands because of its ability to out-compete native vegetation especially after soil disturbance.

Various control methods have been implemented in order to control both saltcedar and willow baccharis, including; mechanical treatments (root plowing), chemical treatments (spraying), and prescribed burning. However, all of these methods are very costly and often result in limited success. For example, cost of aerial spraying saltcedar often costs in excess of $200/ac (McDaniel and Taylor 2003). A method which has not been fully explored is biological control; the use of a living organism to control unwanted plant species. With the exception of a beetle also introduced from Eurasia, there is no other living organism known to consume saltcedar because of its salinity content (Hart 2003).

Willow baccharis is typically not consumed by ruminants; deer will consume some of the plant but only in poor conditions where alternative forage availability is limited (Armstrong and Young 1991). Goats, which have been used as a means of biological control on other unwanted species of plants such as redberry juniper (*Juniperus pinchotti* Sudw.), may have the capability to consume saltcedar and willow baccharis. Other studies have shown that goats will consume some unwanted plants especially if they are first preconditioned for 10-14 days in a pen situation (Dunson et al. 2005, Ellis et al. 2005). Goats typically start by consuming little but intake increases daily until a toxic threshold is reached. Thereafter, intake levels off and usually remains high throughout the remainder of the grazing period. Previous evidence shows that once adjusted to eating a certain plant species, goats will continue to consume it when placed on pastures (Ellis 2001, Dietz 2006).

The objectives of this study were to determine if goats would consume saltcedar, and/or willow baccharis in a 14-d feeding trial, and if so, to determine which shrub was preferred. In addition, this study also looked at serum levels indicative of toxicosis, performance, and water intake to determine if salinity content in saltcedar had any adverse effects on goats' physiology.

MATERIALS AND METHODS

Thirty-six Boer-cross freshly weaned goats (27.24 ± .54 kg) were individually penned at the Angelo State University (ASU) Management, Instruction, and Research (MIR) Center, San Angelo, TX. Goats were randomly allocated to one of four treatments: Treatment 1 consisted of 9 goats fed saltcedar for 1 hour daily for 14 days, Treatment 2 consisted of 9 goats fed willow baccharis for 1 hour daily for 14 days, Treatment 3 consisted of 9 goats fed saltcedar and willow baccharis for 1 hour daily for 14 days, and Treatment 4 consisted of 9 goats fed only alfalfa pellets which served as the control group. One goat in Treatment 3 was removed because of health issues leaving only 8 goats in Treatment 3. Goats were placed in individual pens (1 m X 1.5 m) to monitor intake of both saltcedar and willow baccharis on a daily basis, where each individual animal served as an experimental unit.

Saltcedar and willow baccharis were both harvested at the ASU MIR center, and leaves were stripped off prior to feeding and stored at 4°C until feeding. Saltcedar and willow baccharis were fed in excess of consumption at the same time each day for one hour and refusals were collected and weighed to determine intake. Intake was measured in g kg^{-1} of BW to account for variations in body size. Initially, goats from Treatment 1 were offered 25 g of saltcedar, goats from Treatment 2 were offered 25 g of willow baccharis, and goats from Treatment 3 were offered 25 g of each. The amount fed was increased daily as needed.

Water intake was recorded by selecting 2 goats from Treatments 1, 2, and 3 (n=6) and providing each with 17 L of water daily. Water intake was recorded every day for 12 d at the same time. Two containers of water with the same amount of water were placed outside the pens, one in the shade and one in the sun to record evaporation. Evaporation from containers was used as a correction factor to estimate water intake. All other goats were provided fresh water ad libitum.

All goats were allowed a calcium/phosphorus mineral with trace elements throughout the pen-feeding study. Goats also received alfalfa pellets (2.0% BW) to meet daily nutritional maintenance requirements (NRC 2007). After feeding saltcedar and willow baccharis for one hour, alfalfa pellets were offered to goats for 24 hrs. Each day before feeding saltcedar or willow baccharis alfalfa pellets refusals were weighed to estimate intake.

Serum levels, indicative of soft tissue damage from toxicosis, were monitored on all goats throughout the trial. Blood samples were collected via jugular venipuncture on the first day of the study, midway through the study and at the conclusion of the study to identify any changes in the blood chemistry related to intake of saltcedar and willow baccharis. Changes in serum metabolic levels indirectly indicate toxicosis that has occurred through liver damage from toxicosis (Radostits et al. 1994). Blood samples were centrifuged; serum was harvested, frozen, and transported to the Texas Veterinary Medical Diagnostic Laboratory System, College Station, Texas for analysis. Serum samples were analyzed for creatinine levels indicative of kidney damage, blood urea nitrogen (BUN) and gamma glutamyltransferase (GGT) which elevated levels are factors affecting functionality of the liver from tissue damage. Also analyzed was the level of aminotransferase (AST). Elevated levels are also indicative of soft tissue damage due to toxicosis (Cornelius 1989, Kramer 1989, Cheeke 1998).

Individual animal performance of goats that were fed either saltcedar or willow baccharis were compared to that of the control group by weighing at the beginning and at the end of the study. Weight change (±) was used to assess differences in performance among treatments.

Statistical Analysis

Differences between treatments for intake and serum levels were assessed using repeated measures analysis of variance. Beginning and ending body weights were assessed using analysis of variance. Individual goats (random effect) were nested within treatments (fixed effect). Individual goats served as replications with days of feeding as the repeated measure. Means separated using Least Significant Difference (LSD) when $P \leq 0.05$. Data was analyzed using the statistical package JMP (SAS 1998).

RESULTS

Of the two shrubs (saltcedar and willow baccharis) that were fed to goats, saltcedar was preferred over willow baccharis (Fig. 1). When saltcedar was fed alone (Treatment 1), intake was higher ($P<0.05$) than when fed with willow baccharis (Treatment 3; Fig. 2). Saltcedar intake gradually increased throughout the 14-d feeding trial whether fed alone or with willow baccharis (Fig. 3). At the end of the study, saltcedar intake appeared to still be increasing.

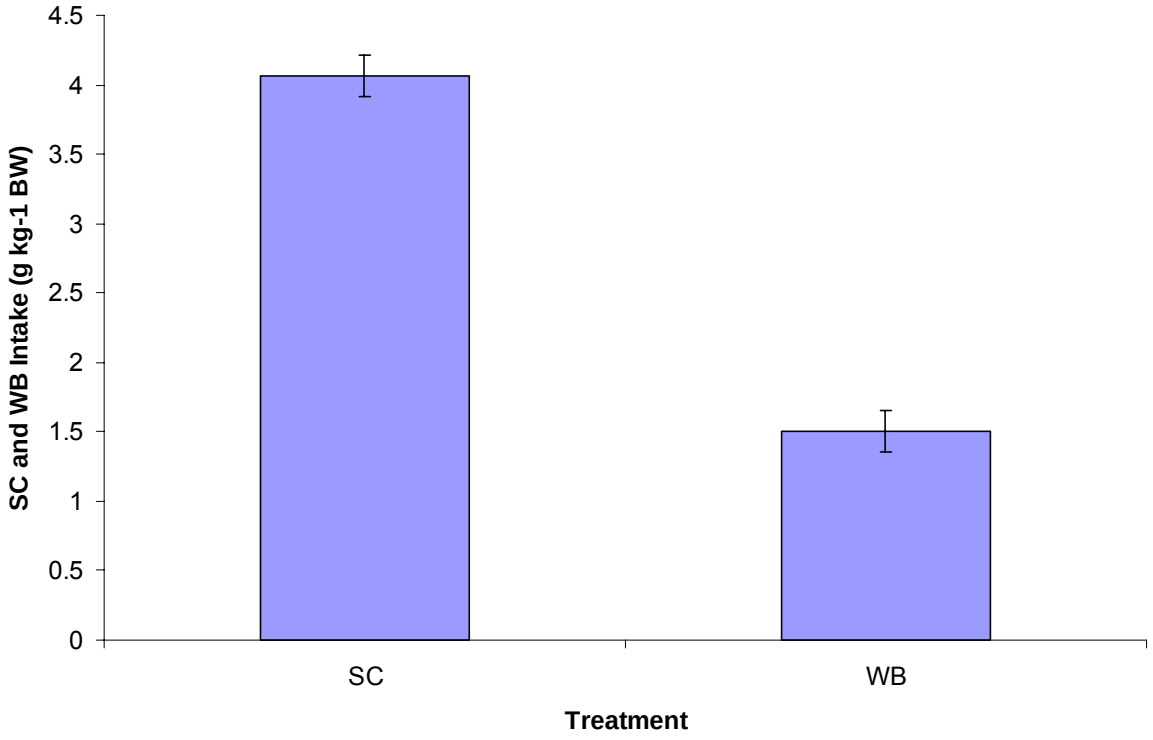

Figure 1. Intake (g kg^{-1} BW) by goats fed saltcedar or willow baccharis when offered either or both for one hour daily for 14 d.

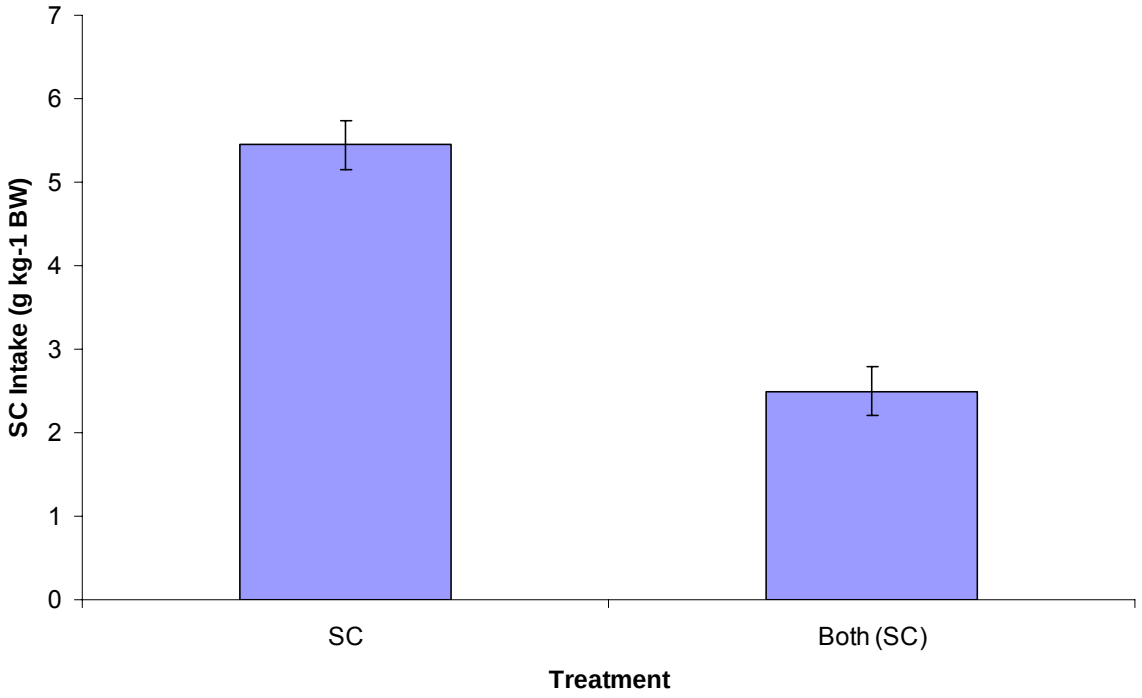

Figure 2. Intake (g kg^{-1} BW) of saltcedar by goats when offered saltcedar alone for one hour daily for 14 d versus goats that were offered saltcedar along with willow baccharis for one hour daily for 14 d.

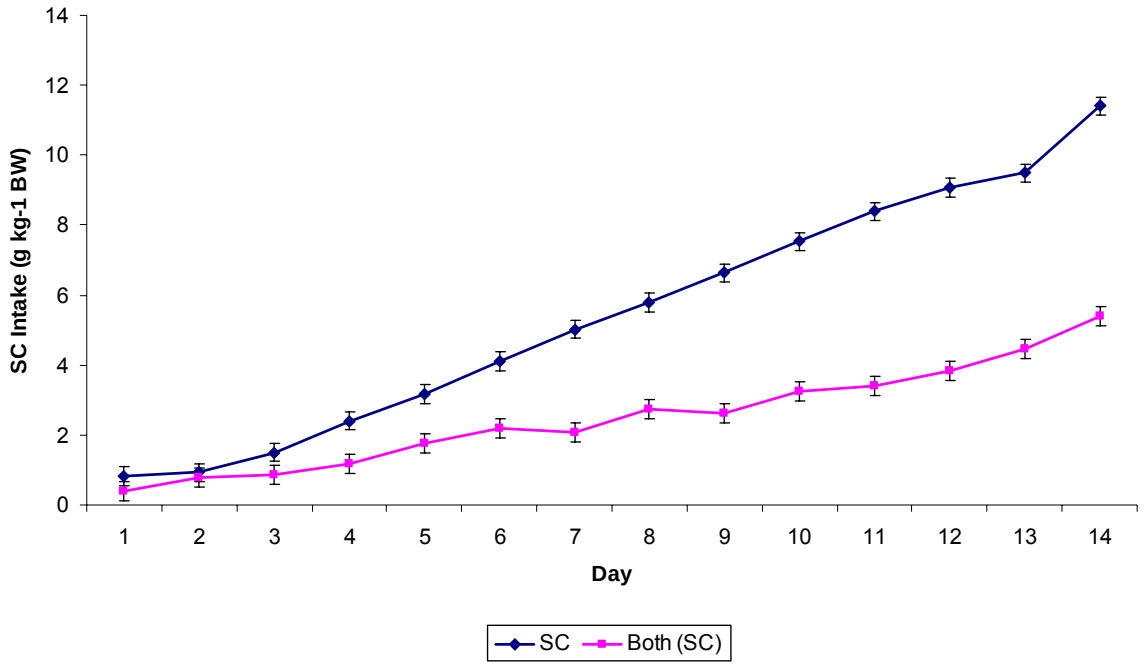

Figure 3. Average daily saltcedar intake (g kg^{-1} BW) of goats that were offered saltcedar alone one hour daily for 14 d and goats that were offered saltcedar with willow baccharis one hour daily for 14 d.

Intake differed between treatments for willow baccharis. Willow baccharis intake was greater ($P<0.05$) when fed with saltcedar (Fig. 4). Daily average intake of willow baccharis gradually increased throughout the feeding trial but intake fluctuated with repeated patterns of decreased and increased intake (Fig. 5). Intake appeared to peak on d 12 and on d 13 intake decreased.

No differences ($P>0.05$) were observed for water intake among treatments or across days (Table 1). Alfalfa intake was similar between treatments (Table 1), but intake differed ($P<0.05$) across days of feeding. All of the 4 treatments (n=35) consumed more alfalfa during the saltcedar and willow baccharis feeding trial than before it began (Fig. 6). All treatments lost weight (Table 2). Weight change was similar ($P>0.05$) among treatments. No differences ($P>0.05$) were observed for serum metabolite levels among treatments (Table 3).

DISCUSSION

Prior to this study, little was known regarding the potential impact that goats could have as a biological control aid to help control saltcedar and willow baccharis. The data herein illustrates that goats will consume both saltcedar and willow baccharis. Saltcedar was more palatable and

apparently less aversive than willow baccharis. Goats preferred saltcedar and never appeared to reach a toxic level during the feeding trial. If goats were placed on rangelands and used as a biological control, goats would probably consume saltcedar before consuming willow baccharis. Selective browsing of saltcedar would result in willow baccharis becoming the dominant shrub. Habitat degradation, erosion, forage production, and lack of biological diversity would continue. However, chemical treatment of willow baccharis is less expensive than chemical control of saltcedar. Once saltcedar densities are effectively reduced, willow baccharis could be sprayed with herbicides to reduce its coverage. In addition, in several lake basins and along several riparian zones, saltcedar may be the primary invasive plant. Goat browsing could be used as a cost-effective control method. If willow baccharis densities increased, future efforts could focus on control of willow baccharis.

Because animals regulate ingestion of food to minimize aversive feedback from toxins (Pfister et al. 1997), the decreased saltcedar intake when offered with willow baccharis could have been because of the aversive postingestive feedback from the toxins in the willow baccharis (Provenza 1995). Little is known about toxins of willow baccharis and interaction with livestock, however, when goats were presented the willow baccharis, they consumed some until they reached an apparent toxic level. Intake of toxic plants often fluctuates daily; animals often increase intake until aversive postingestive feedback is experienced and then intake decreases accordingly (Pfister et al. 1997, Wang and Provenza 1997).

Some plants cause an overall decrease in intake because of internal malaise (Provenza 1995). Aversive postingestive feedback after consuming willow baccharis may have caused a decrease in saltcedar intake as well.

In some cases, when alternative nutritious foods are available, toxic food may be completely avoided (Ralphs et al. 2001). The degree of postingestive feedback with other poisonous plants may be so severe (du Toit et al. 1991) or levels of intake when postingestive feedback is experienced may be low enough (Burritt and Provenza 2000) that poisonous plants are completely avoided. All too often, ruminants continue to consume toxic plants but maintain intake below toxic levels (Wang and Provenza 1997). This toxic wisdom is gained through increasing intake daily until aversive postingestive feedback is experienced followed by decreasing intake on subsequent days.

Table 1. Intake of water (l) and alfalfa (g kg^{-1} BW) of freshly weaned Boer-cross goats during a 14-d feeding trial when fed saltcedar (SC), willow baccharis (WB), both, or neither.

	Treatment				
	SC alone	WB alone	Both	Control	SEM
Water Intake (l)	2.1	1.7	1.5	-	.4
Alfalfa Intake (g kg^{-1} BW)	19.4	19.2	19.8	20.1	.3

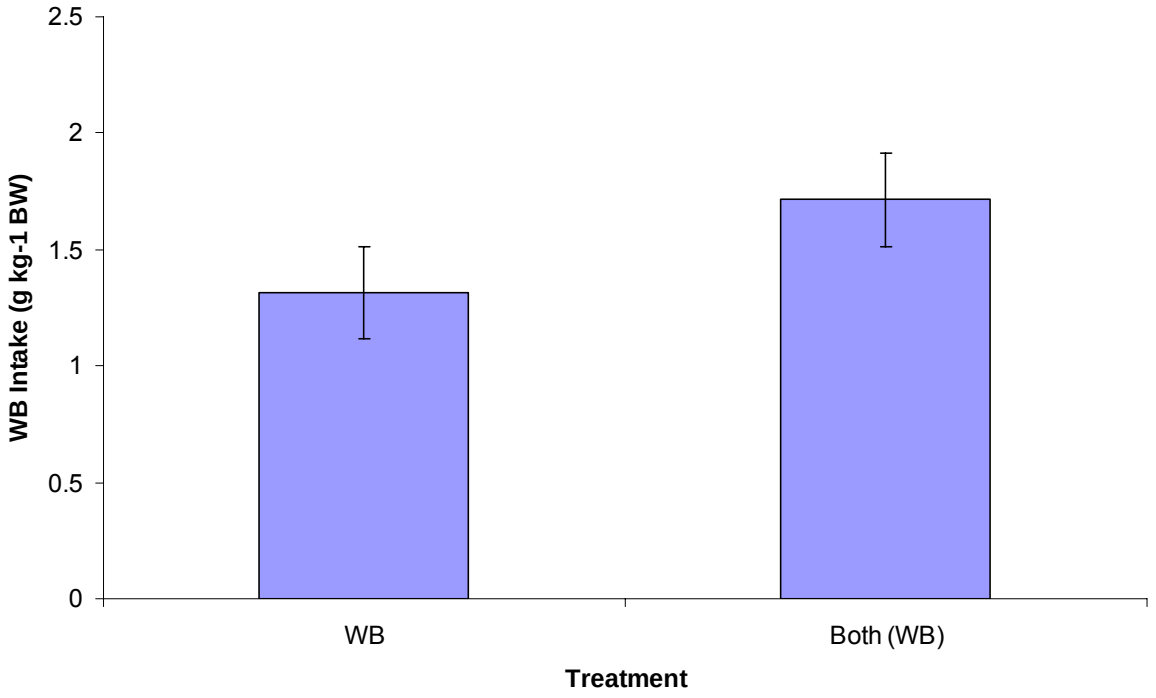

Figure 4. Intake (g kg^{-1} BW) by goats when offered willow baccharis alone for one hour daily for 14 d versus goats that were offered willow baccharis along with saltcedar for one hour daily for 14 d.

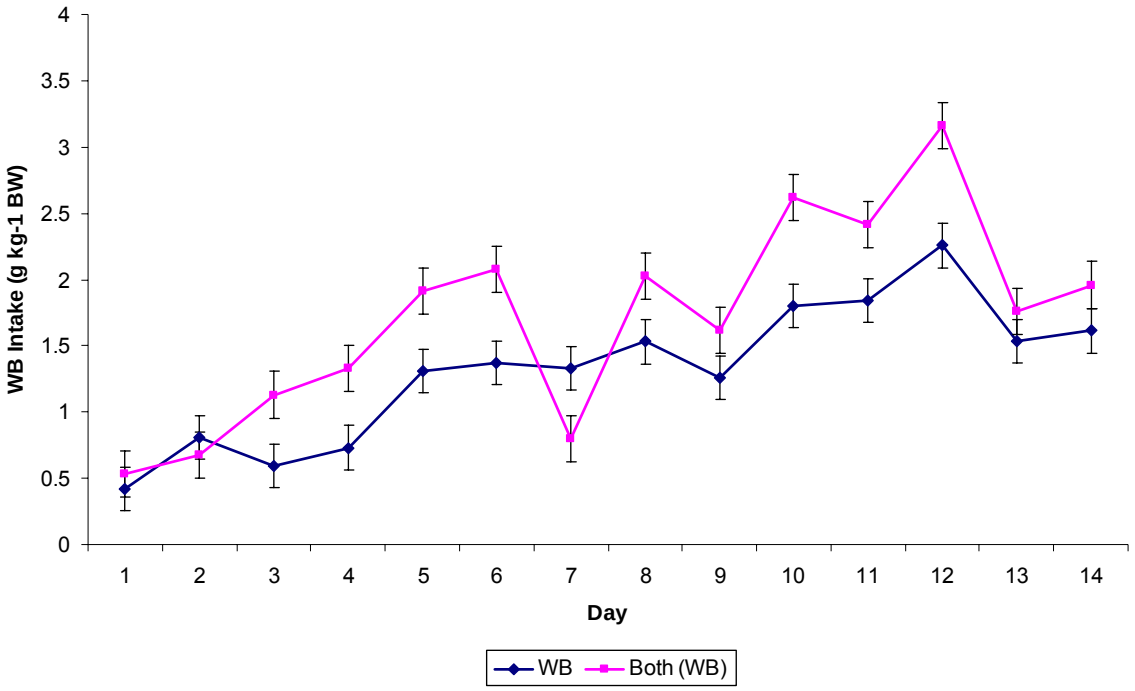

Figure 5. Average daily willow baccharis intake (g kg^{-1} BW) of goats that were offered willow baccharis alone one hour daily for 14 d and goats that were offered willow baccharis with saltcedar one hour daily for 14 d.

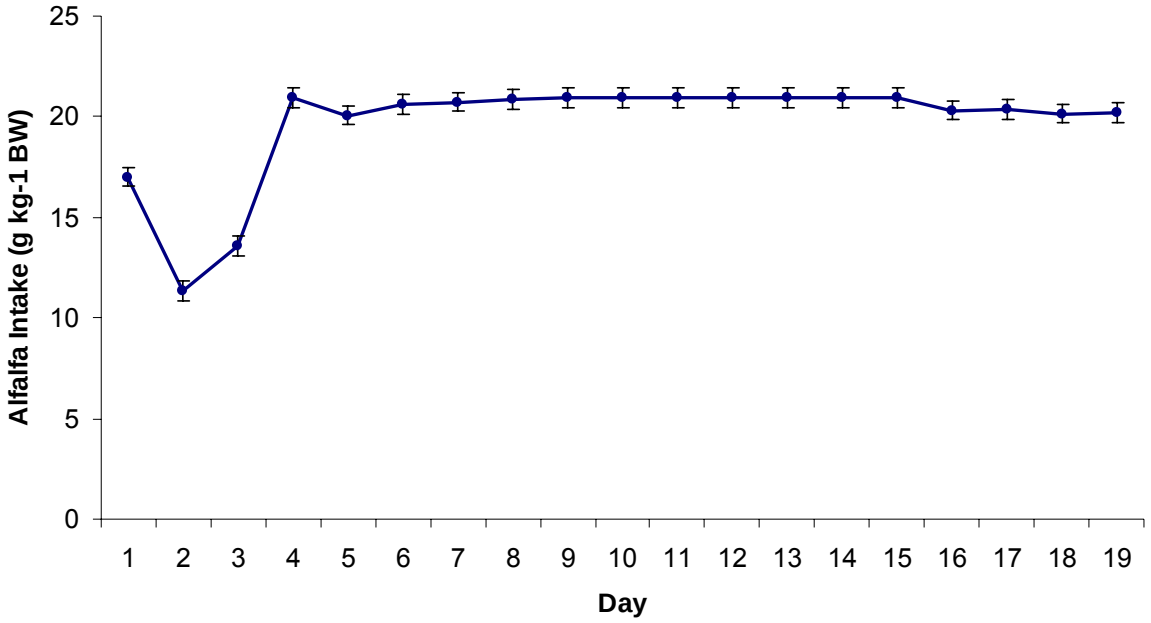

Figure 6. Average daily alfalfa intake (2% BW) of all 35 goats during a 14 d feeding trial where saltcedar, willow baccharis, and saltcedar along with willow baccharis were fed for one hour daily for 14 d.

Table 2. Weight changes of freshly weaned Boer-cross goats during a 14-d feeding trial when fed saltcedar (SC), willow baccharis (WB), both, or neither.

	Weight (kg)		
	Initial	Final	SEM
Saltcedar	26.8	24.4	1.1
Willow baccharis	27.0	24.8	1.1
Both	29.3	27.0	1.1
Control (neither)	31.0	27.8	1.0

Table 3. Serum metabolite levels when freshly weaned Boer-cross goats were fed saltcedar (SC), willow baccharis (WB), both, or neither during a 14 day feeding trial.

	Treatment				
	SC	WB	Both	Neither	SEM
AST	89.3	62.3	61.2	57.3	11.5
GGT	55.7	56.1	55.0	47.8	4.6
Creatinine	0.7	.0.8	0.8	0.8	0.04
BUN	22.3	24.5	24.4	26.3	1.1
Biliruben	0.2	0.1	0.1	0.1	0.05

Ruminants also consume a variety of foods to meet nutritional requirements, including some toxic foods (Provenza 1995). Often dietary items may be included in the diet to meet nutritional requirements that are not typically consumed. For example, protein deficient goats consumed woodrat houses in southern Utah, while phosphorus-deficient steers in Spain consumed rabbits (Provenza 1995). For ruminants to meet nutritional requirements (CP, energy, Ca, P, trace minerals) a variety of foods are often required. In many cases, some of the most nutritious foods are also toxic (Deeds 2004). Thus, ruminants may consume some level of toxic foods like willow baccharis even when alternative foods are available to meet their nutritional requirements.

When willow baccharis was fed with saltcedar, the pattern of increased and decreased intake was more profound than the intake when it was offered alone. There is some evidence that intake of toxic plants will be greater when multiple plants are offered over intake when only a single plant is offered (Freeland and Janzen 1974). A varied diet enhances the animal's ability to meet its nutritional requirements when feeding on plants with secondary compounds provided that the toxins consist of different physiological effects and that they are detoxified by different metabolic pathways, not interacting with one another to become more toxic to the animal (Burritt and Provenza 2000, Deeds 2004). Offering animals a variety of toxic plants may cause ruminants to consume more than just one plant to increase overall food intake and to avoid toxicosis. There is some evidence that when animals consume more than one toxic plant, intake of both may be increased. For example, Freeland and Janzen (1974) suggested that saponins and tannins may compete for the same metabolic pathway and chelate in the digestive tract. Once toxins are bound, they are indigestible and are excreted. Deeds (2004) illustrated that feeding shrubs containing saponins with shrubs with tannins may increase intake in some cases. However, there is insufficient evidence to suggest that a similar situation is occurring with saltcedar and willow baccharis.

IMPLICATIONS

The results of this study indicate that goats could be a potential biological aid to help control these shrubs especially saltcedar because of the amount consumed. Land managers should consider utilizing goats to reduce the amount of saltcedar cover. Goats will be most effective in controlling saltcedar before the plant reaches a mature size. Levels of several lakes in west central Texas vary

from year to year. As water levels recede, saltcedar typically germinates and dominates surrounding vegetation. Goats could be concentrated in these areas to reduce cover and dominance.

Successful control of both saltcedar and willow baccharis will require an integrated approach. Biological control mechanisms such as goat and the leaf beetle could be introduced to control the rate of invasion, and herbicides could be used to reduce cover of dense mature stands of saltcedar and willow baccharis.

This feeding project was conducted in late summer when saltcedar and willow baccharis were both in full bloom. Plant toxins can vary from one season to another or during different growing stages. For example, Pfister et al. (1994) illustrated that toxic alkaloid levels of tall larkspur differed at times. Because, the current project was only conducted for 14 d and in a pen situation, future research should focus on saltcedar and willow baccharis intake during other seasons of the year to see if intake is similar and to see if goats would significantly help as a biological control agent for these shrubs. In addition, there is some evidence that supplementation may improve intake of some toxic forages (Banner et al. 2000). Future studies should examine the effect of supplementation in saltcedar and willow baccharis intake.

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Effects of Tasco-EX on Meat Quality in Feeder Lambs

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ABSTRACT

The objective of this study was to determine effects of Tasco-EX supplementation on shelf-life and sensory characteristics of fresh lamb meat. Lambs (n = 20; 38 ± 3 kg) were divided into a control group (Control; n = 10) fed a concentrate diet and treatment group (Tasco; n = 10) received similar concentrate diet with 0.1% Tasco-EX on a dry matter basis. Animals received *ad libitum* diet until 57 kg live weight was reached. Rib chops from each carcass were used for retail display, lipid oxidation determination, and trained sensory evaluation. Tasco had greater leg circumference ($P < 0.001$). No differences ($P > 0.05$) were found for sensory characteristics or lipid oxidation. Tasco chops had higher ($P < 0.05$) CIE L* values. A Tasco supplementation × retail display day interaction was noted for rib CIE a* values, rib uniformity, discoloration and browning ($P < 0.01$). Leg CIE a* values were higher ($P < 0.05$) for Tasco on d 3, d 4, and d 5, and leg visual discoloration scores were lower on d 5 ($P < 0.05$). Visual leg color score were higher Control on d 0, d 1, and d 2 ($P < 0.04$), and visual uniformity scores were lower on d1.

INTRODUCTION

Per capita consumption of lamb has decreased 73.6% in the past 44 yr to 0.54 kg/person annually on a retail weight basis, while total red meat consumption has declined only 8.9% to 54.5 kg/person (CattleFax, 2005). Although slight increases in consumption have been seen in the past year, the trend for lamb consumption is still static. Also, lamb harvest facilities are concentrated in specific regions of the United States, primarily in Colorado and Iowa (USDA, 2006), while consumption is highest on the east and west coasts. This leads to potential problems in marketing fresh lamb meat, requiring extended retail display periods to disperse the product.

Various methods for extending shelf-life in fresh lamb have been studied with the most pronounced effects coming from the dietary supplementation of vitamin E. Wulf et al. (1995) proved supplementing lambs with 500 IU vitamin E·lamb^{-1}·day^{-1} effectively increased α-tocopherol, which significantly increased shelf-life by delaying oxidation of oxymyoglobin. However, no significant

differences were found during visual color appraisal in a 6 d retail display of loin chops and semimembranosus steaks completed by Turner et al. (2002b).

Significant developments for extending shelf-life have been made in beef with the use of an extract of the seaweed *Ascophyllum nodosum* (ANOD). The extract is manufactured either as Tasco-Forage, which is applied to pastures to be grazed by livestock, or as Tasco-EX, which is fed directly to livestock as a feed additive. In a review by Allen et al. (2001b), meat from steers grazing Tasco-treated fescue had a longer shelf-life, as did Tasco-EX supplemented steers in the final 14 d of feedlot finishing. Also, Braden (2003) found that steaks from Tasco-supplemented steers were more uniform and had less discoloration and browning than control steaks. Galipalli et al. (2004) indicated meat from Tasco- supplemented Boer goat bucks has significantly less metmyoglobin formation than control over a 7 d retail display. Since the response has been consistent across species, it can be hypothesized that the same effects could be obtained in lamb. The objective of this study was to determine the effects of Tasco-EX supplementation on the shelf-life of fresh lamb, bone-in rib chops, bone-in and boneless leg chops, and trained sensory characteristics of bone-in rib chops.

MATERIALS AND METHODS

Feeder lambs (n = 20; 38 ± 3 kg) were obtained and divided into two treatment groups. The control (Control) received a concentrate diet containing 73% grain sorghum, 13% soybean hulls, 2% soybean meal, 6.5% alfalfa pellets, 3% molasses, and 2.5% sheep mineral premix. The second group received the same concentrate diet with the addition of Tasco-EX® (Tasco) at 0.1% per dry matter basis. Animals received *ad libitum* diet until a target market weight of 57 kg was reached.

Animals were harvested at the Angelo State University Food Safety and Product Development Laboratory following a 24 h withdrawal from feed. Carcasses were cooled for 24 h at 3º C. Yield and quality grades were determined in accordance with the American Meat Science Association (AMSA, 2001).

Sensory Evaluation

Rib chops fabricated at 2.5 cm with 2 cm tails and trimmed to 0.3 cm from the left half of the carcass were frozen at -4º C until evaluated by a trained sensory panel. At this time, chops were thawed at 2º C for 24 h prior to cooking in a George Forman grill (Saltan Model GR38WHT; Lake

Forest, IL) to an internal temperature of 71º C. Chops were then cut into 1 cm × 1 cm × 2.5 cm pieces and placed in serving pans to keep them warm. Samples were served to an eight-member panel trained according to AMSA (1995). Panelists were asked to evaluate initial and sustained juiciness, initial and sustained tenderness, characteristic lamb flavor, and overall acceptability, using an 8-point hedonic scale (8 = extremely juicy, tender, characteristic lamb flavor, and like extremely; 1 = extremely dry, tough, uncharacteristic lamb flavor, and dislike extremely), and off-flavor using a 5-point hedonic scale (5 = extreme off-flavor; 1 = no off-flavor). Trained sensory panels were conducted under red light to mask color differences. Panelists were given apple juice and water to cleanse their palates between samples. Results from these panels were used to determine the effects of Tasco supplementation on palatability. Also, 1.3 cm cores were cut parallel to the muscle fiber orientation and sheared once to determine Warner-Bratzler shear force (WBSF).

Lipid Oxidation

Lipid oxidation was measured in duplicate from rib chops (n = 4/carcass) fabricated at 2.5 cm and displayed using the same methods described above on d 1, 3, 5, and 7. After display time had elapsed, samples were frozen, and all samples were analyzed in one week to allow for the greatest sample uniformity. Lipid oxidation was determined by measuring thiobarbituric acid reacting substances (TBARS), using the method as modified from Buege and Aust (1978). TBARS was expressed as mg malonaldehyde/kg muscle.

Retail Display

Each carcass was fabricated into wholesale cuts 48 h postmortem with the rack cut into 2.5 cm chops with 2 cm tails, and subcutaneous fat was trimmed to 0.3 cm. Two 2.5 cm chops were then taken from the right leg with the first slice originating 0.5 cm posterior to the aitch bone. The bone was removed from the most posterior chop, and both were trimmed to 0.3 cm of subcutaneous fat. The first three rib chops, starting between the 12^{th} and 13^{th} rib and moving anteriorly from the right half of the carcass, and two leg chops from each carcass were placed on Styrofoam trays, covered with polyvinyl chloride film (PVC), and placed in a retail display case (Model NM8, Tyler Refrigeration Corp., Niles, MI) at 2º C for 7 d. During the 7 d period, surface meat color Commission Internationale de l'Eclairage (CIE) L* (muscle lightness), a* (muscle redness), b* (muscle yellowness) values were

measured daily using a Minolta Chromameter (Model CR-410, Konica Minolta Sensing, Inc., Ramsey, NJ). These measurements were taken through the packaging material using methods consistent with AMSA (1991). Also, chops were evaluated daily by a trained panel, consisting of at least six members, for lamb color (8 = extremely bright red; 1 = extremely dark red), color uniformity (5 = extreme two-toning; 1 = uniform), surface discoloration (7 = 100%; 1 = 0%), and lean browning (6 = dark brown; 1 = no evidence of browning), according to AMSA (1991) color guidelines.

Statistical Analysis

The sensory characteristics (juiciness, tenderness, flavor, off-flavor, and overall liking) and WBSF were analyzed using the GLM procedure of SAS (SAS Institute, Inc., 1995), with animal being the experimental unit. Least square means were generated and separated using pairwise t-tests (PDIFF option) at an $\alpha = 0.05$. Instrumental measurements and trained color panel were analyzed using repeated measure. The GLM procedure of SAS (SAS Institute, Inc., 1995) was used to generate least square means and separated using pairwise t-tests (PDIFF option) at an $\alpha = 0.05$, with animal being the experimental unit.

RESULTS AND DISCUSSION

Carcass Characteristics

Carcasses from lambs supplemented with Tasco had greater leg circumference (69.25 vs. 65.25) than the Control group ($P < 0.001$; Table 1). Tasco supplementation had no effect ($P > 0.05$) on final live weight, hot carcass weight (HCW), leg score, back fat, adjusted back fat, yield grade, quality grade, or flank streakings; however, the CONTROL group had higher numerical flank streaking scores than the Tasco group (154 vs. 127). This is converse to other studies that show higher marbling scores for cattle supplemented with Tasco (Allen et al., 2001a; Braden, 2003).

Table 1. Carcass quality and yield characteristics of feeder lamb (n = 20) fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg

Trait	Tasco	Control	SE[a]
Final live weight, kg	54.04	51.14	1.32
Hot carcass weight, kg	30.36	28.67	0.76
Leg score[b]	11.0	11.3	0.24
Leg circumference, cm	69.25[f]	65.25[g]	0.61
Back fat, cm	0.84	0.83	0.05
Adjusted back fat (ABF), cm	0.86	0.91	0.04
Yield grade[c]	3.4	3.5	0.17
Flank streakings[d]	127	154	19.3
Quality grade[e]	20	21	2.2

[a]Standard error of the mean, n = 10 for each mean.
[b]Leg Score: 10 = Choice$^-$, 11 = Choice^0, 12 = Choice$^+$.
[c]Yield Grade = 10*ABF + 0.4.
[d]Flank streaking scores: 100 = slight^0, 200 = small^0.
[e]Quality grade: 10 = Choice$^-$, 20 = Choice^0, 30 = Choice$^+$.
[f,g]Means within a row with different superscripts differ ($P < 0.05$).

Increased leg circumference could be due to slightly higher HCW, but it does result in a significant economic impact because of increased total saleable product. Similar back fat, adjusted back fat, and yield grade measurements concur with Allen et al. (2001a) and Braden (2003) who found no statistical differences in HCW or yield grade, and no real biologically meaningful differences in back fat.

Sensory Characteristics

Tasco supplementation did not affect ($P > 0.05$) on any sensory characteristics or Warner-Bratzler shear force values (Table 2). Therefore, no adverse palatability effect was found for Tasco supplementation. Fike et al. (2001) reported no differences for meat sensory characteristics of Tasco supplemented wether lambs when compared to animals fed hays containing endophyte-infected fescue or control. A study by Montgomery et al. (2001) of steers that grazed tall fescue treated with Tasco-EX, found no differences in WBSF, beef flavor, overall mouthfeel, or off-flavor. Also, Braden (2003) stated no differences in sensory characteristics for strip loin steaks.

Lipid Oxidation

No differences were found between treatments or by retail display day for TBARS analysis (Table 3). Conversely, significant retail display day and treatment differences were found after d 3 in vitamin E supplemented lambs (Guidera et al., 1997; Macit et al., 2003).

Table 2. Sensory characteristics of lamb rib chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg

Trait	Tasco	Control	SE[a]
Warner Bratzler shear, kg	2.4	2.6	0.15
Initial juiciness[b]	5.6	5.5	0.23
Sustained juiciness[b]	5.8	5.5	0.24
Initial tenderness[b]	5.6	5.3	0.26
Sustained tenderness[b]	5.9	5.6	0.26
Lamb flavor[b]	5.1	5.1	0.19
Off-flavor[c]	1.0	1.0	0.02
Overall acceptability[b]	5.5	5.2	0.30

[a]Standard error of the mean, n = 10 for each mean.
[b]Eight-point scale; 8 = extremely juicy, tender, characteristic lamb flavor, and like extremely; 1 = extremely dry, tough, uncharacteristic lamb flavor, and dislike extremely.
[c]Five-point scale; 5 = extreme off-flavor, 1 = no off-flavor.

Table 3. Thiobarbituric acid reacting substances (TBARS) as mg malonaldehyde/kg meat of lamb rib chops under simulated retail display from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg

Trait	Tasco	Control	SE[a]
TBARS, mg/kg			
D1	0.103	0.107	0.003
D3	0.105	0.102	0.003
D5	0.104	0.102	0.003
D7	0.106	0.103	0.003

[a]Standard error of the mean, n = 10 for each mean.

Retail Display

As expected, all instrumental and visual lean color traits measured, with the exception of CIE L* values for rib chops, decreased with time on retail display. However, the rate of decline over retail display day varied for several instrumental and visual measures of lean shelf life attributes due to effects of Tasco supplementation and/or the interaction of Tasco supplementation with retail display day.

Rib Chops. CIE L* values of rib chops were influenced by Tasco supplementation, as chops from the Tasco group were significantly lighter ($P < 0.03$, Table 4) compared to the Control group. CIE L* values were consistently higher ($P < 0.03$) for rib chops from Tasco supplemented lambs than from the Control group. CIE a* value decline was dependent upon a Tasco supplementation × retail display day interaction ($P = 0.001$; Figure 1). This interaction was evident by d 7 (45.83 vs. 40.57; $P = 0.007$). Tasco supplementation resulted in chops from the Control group being redder ($P < 0.001$) than the Tasco group. Conversely, studies in beef have stated higher CIE a* values for Tasco

Table 4. Effects of Tasco on lean color traits of rib and leg chops from feeder lamb (n = 20) fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg

	Rib			Leg		
Trait	Control	Tasco	SE[a]	Control	Tasco	SE[a]
CIE L*[b]	27.41[w]	29.37[x]	0.88	20.96[y]	22.31[z]	0.43
CIE a*[c]	45.99[w]	44.79[x]	0.47	45.24[y]	47.64[z]	0.54
CIE b*[d]	23.75	23.96	0.48	19.91[y]	21.08[z]	0.44
Color scores[e]	3.97	3.98	0.10	4.38[y]	3.94[z]	0.08
Lean uniformity[f]	1.58[w]	1.50[x]	0.02	2.33	2.38	0.07
Lean discoloration[g]	1.91[w]	1.84[x]	0.03	2.59	2.61	0.09
Lean browning[h]	1.94[w]	1.84[x]	0.04	2.39	2.44	0.08

[a]Standard error of the mean, n = 10 for each mean.
[b]Lean L* value (lightness).
[c]Lean a* value (positive = red, 0 = neutral, negative = green).
[d]Lean b* value (positive = yellow, 0 = neutral, negative = blue).
[e]Lamb color (8 = extremely bright red; 1 = extremely dark red).
[f]Color uniformity (5 = extreme two-toning; 1 = uniform).
[g]Lean discoloration (7 = 100%; 1 = 0%).
[h]Lean browning (6 = dark brown; 1 = no evidence of browning).
[w,x]Means within a row with different superscripts differ ($P < 0.05$).
[y,z] Means within a row with different superscripts differ ($P < 0.05$).

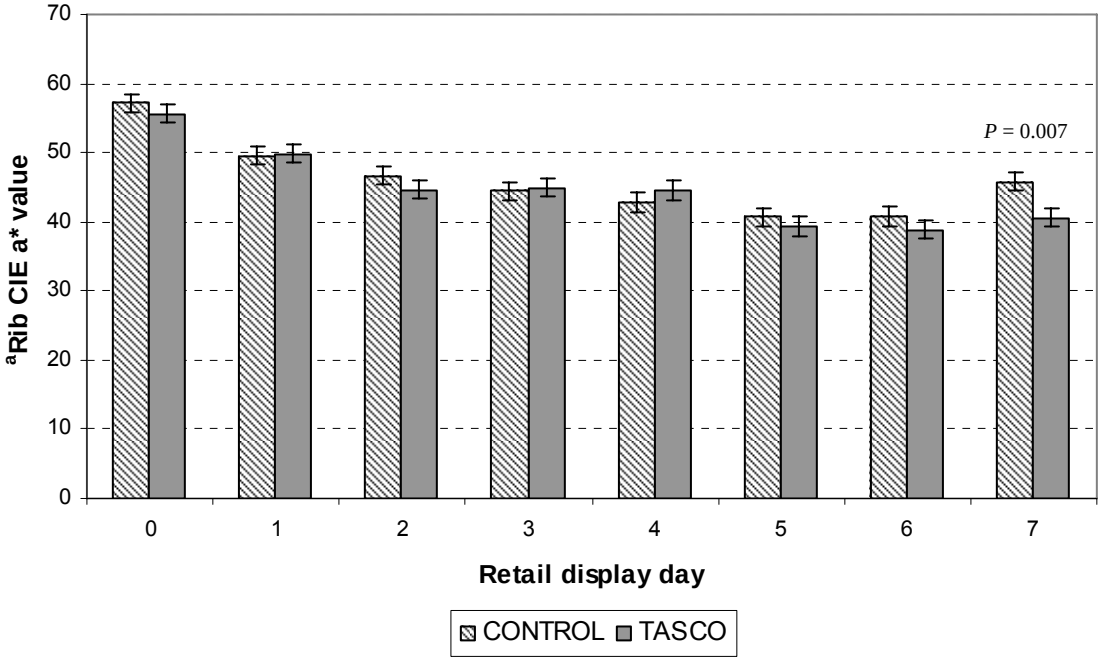

Figure 1. Effect of retail display day × Tasco supplementation interaction on instrumental CIE a* value of rib chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Lean a* value (positive = red, 0 = neutral, negative = green); n = 10 for each mean.

supplemented animals over non-Tasco fed animals (Allen et al., 2001a; Braden, 2003); however, this study concurs with astudy of Boer goat bucks supplemented with Tasco that showed little to no

change in CIE a* values after d 5 (Galipalli et al., 2004). Furthermore, dietary supplementation of vitamin E in lambs has shown little or no change of CIE a* values between d 4 and d 7 during retail display (Macit et al., 2003). The decline in CIE b* values was dependent on retail display day (P < 0.001; data not shown).

Visual color scores decreased over simulated retail display, regardless of treatment (P < 0.68; Table 4). Visual lean uniformity scores were dependent on a retail display day × Tasco supplementation interaction (P < 0.004; Figure 2). Tasco supplemented chops had significantly lower uniformity scores on d5 and d6 when compared with the Control group. Rib chops from both treatments were similar during the first 4 d of simulated retail display, but on d 5 and d 6 the chops from Tasco supplement lambs were noticeably more uniform (P < 0.03; Figure 2). This concurs with Braden (2003) who found lower uniformity scores on d 4 and d 5 of retail display for Tasco supplemented beef animals over the non-supplemented control and with Montgomery et al. (2001) who found Tasco improved lean uniformity scores throughout a 3 d simulated retail display.

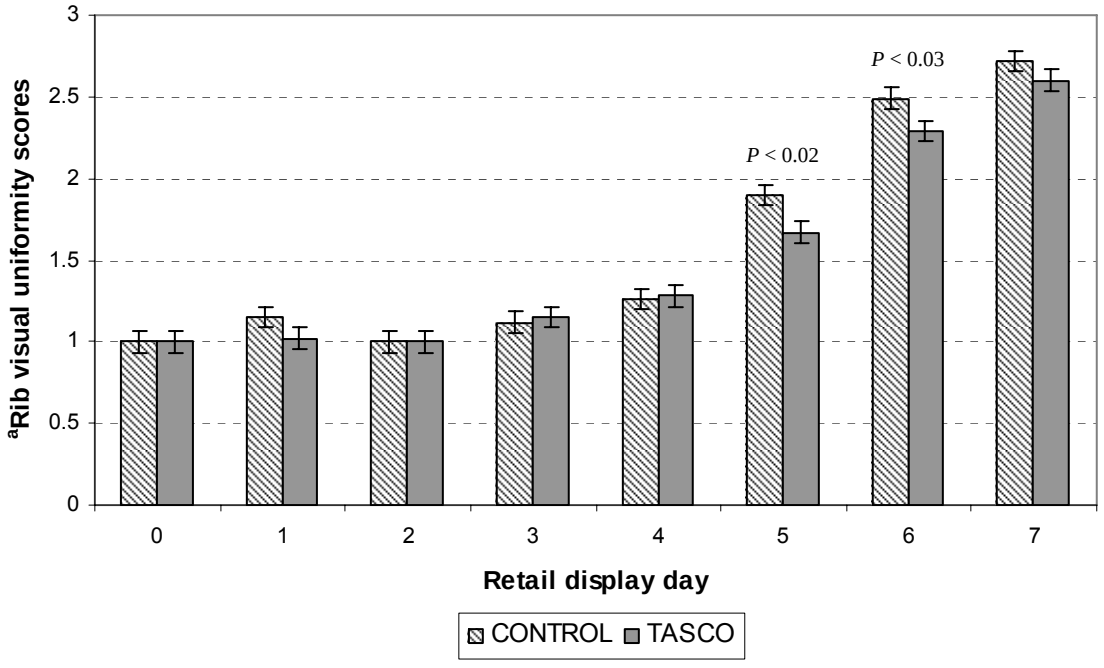

Figure 2. Effect of retail display day × Tasco supplementation interaction on visual lean uniformity scores of rib chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Color uniformity (5 = extreme two-toning; 1 = uniform); n = 10 for each mean.

Visual lean discoloration and browning scores were affected by a Tasco supplementation × retail display day interaction ($P < 0.001$). Tasco supplemented animals had lower lean discoloration scores after d 4. Lower scores were especially evident on d 6 ($P < 0.001$; Figure 3), and on d 7 of retail display, lean discoloration scores tended to be lower ($P < 0.10$). Similar effects were found for visual browning scores with the Tasco group having significantly lower browning scores on d 6 and d 7; however, the Control group showed lower ($P < 0.02$) values on d 4 (Figure 4). Chops from Tasco supplemented animals remained more uniform with less discoloration and browning than chops from the Control group after d 5 resulting in increased marketability due to extended shelf-life.

Leg Chops. CIE L* values of leg chops were influenced by Tasco supplementation ($P < 0.001$, Table 4), as chops from the Tasco group were significantly lighter compared to the Control group, resulting in CIE L* values that were consistently higher for Tasco supplemented lambs than from the Control group. These values are concurrent with results from rib chops in this study.

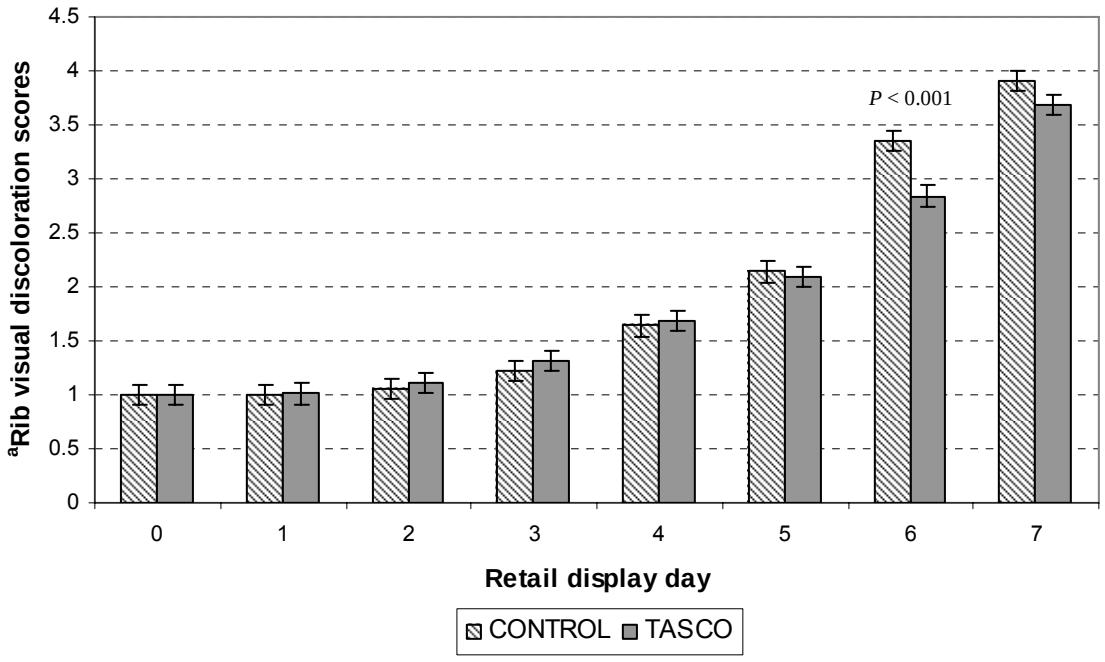

Figure 3. Effect of retail display day × Tasco supplementation interaction on visual lean discoloration scores of rib chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Lean discoloration (7 = 100%; 1 = 0%); n = 10 for each mean.

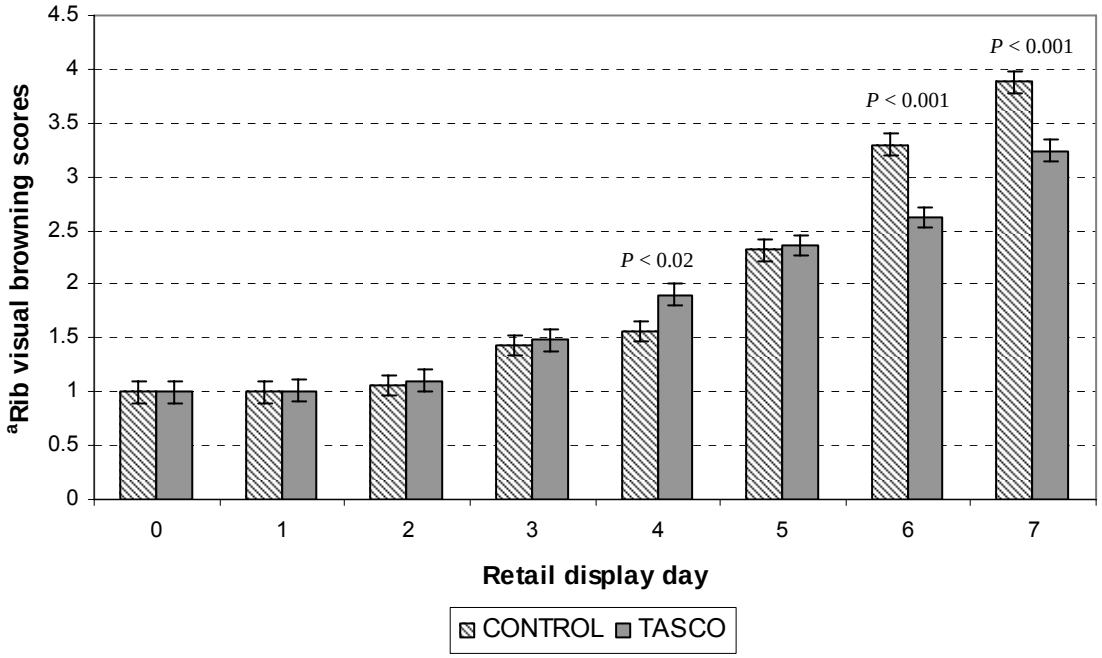

Figure 4. Effect of retail display day × Tasco supplementation interaction on visual lean browning scores of rib chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Lean browning (6 = dark brown; 1 = no evidence of browning); n = 10 for each mean.

The decline in CIE a* was dependent on a Tasco supplementation × retail display day interaction. Values were higher ($P < 0.05$; Figure 5) for the Tasco group over the Control after d 3, and there was a trend ($P < 0.07$) on d 3. Leg chops from Tasco supplemented lambs were redder ($P < 0.001$; Table 4) throughout the simulated retail display when compared to the Control. The decline in b* was affected by Tasco supplementation ($P < 0.001$; Table 4), resulting in chops that were more yellow when compared to the Control group. No differences were found between bone-in and boneless leg chops (data not shown).

Visual color score decline was affected by a Tasco supplementation × retail display day interaction ($P < 0.001$; Figure 6). Control lambs had significantly higher visual color scores for d 0, d 1, and d 2 over the Tasco group. Therefore, leg chops from Control lambs showed a brighter red color than chops from Tasco supplemented lambs during the initial three days of simulated retail display.

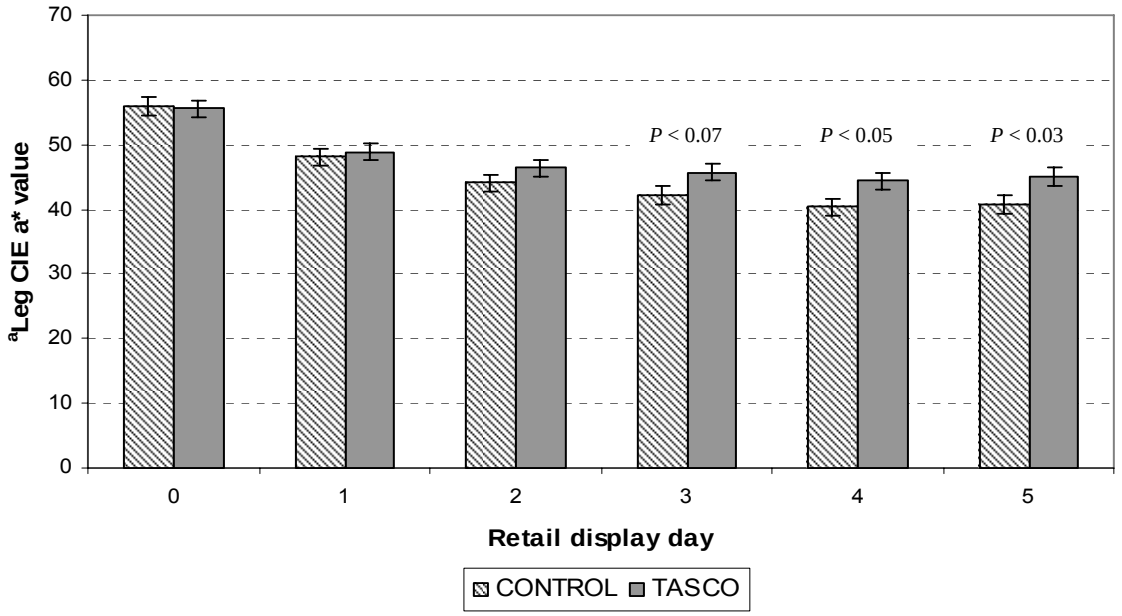

Figure 5. Effect of retail display day × Tasco supplementation interaction on instrumental CIE a* value of leg chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Lean a* value (positive = red, 0 = neutral, negative = green); n = 10 for each mean.

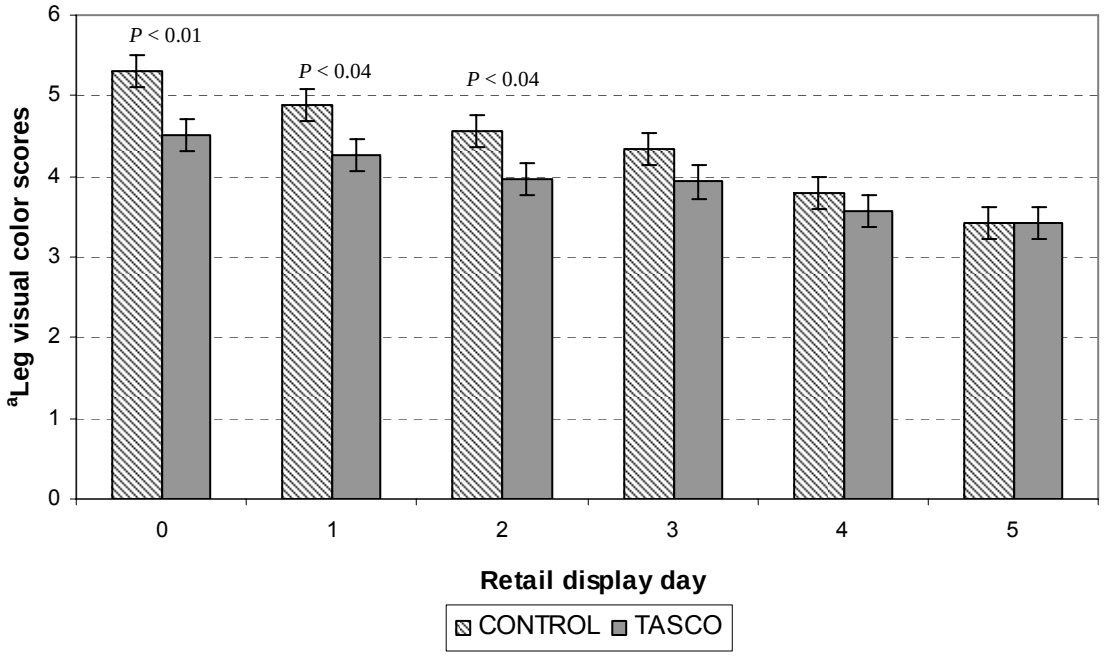

Figure 6. Effect of retail display day × Tasco supplementation interaction on visual lean color scores of leg chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Lamb color (8 = extremely bright red; 1 = extremely dark red); n = 10 for each mean.

Visual lean uniformity scores were affected by a Tasco supplementation × retail display day interaction ($P < 0.001$; Figure 7). Chops from the Control group were significantly more uniform on d 1 when compared to Tasco supplemented animals, but this effect had reversed by d 4. Both visual lean discoloration and browning values increased with retail display day. However, the progression of lean discoloration was affected by a Tasco supplementation × retail display day interaction ($P < 0.001$; Figure 8). Chops from Tasco supplemented animals contained significantly less discoloration than chops from the Control group on d 5; conversely, a trend ($P < 0.11$) was observed on d 1 showing lower discoloration scores for the Control group. No treatment effects were found for lean browning values of leg chops (Table 4).

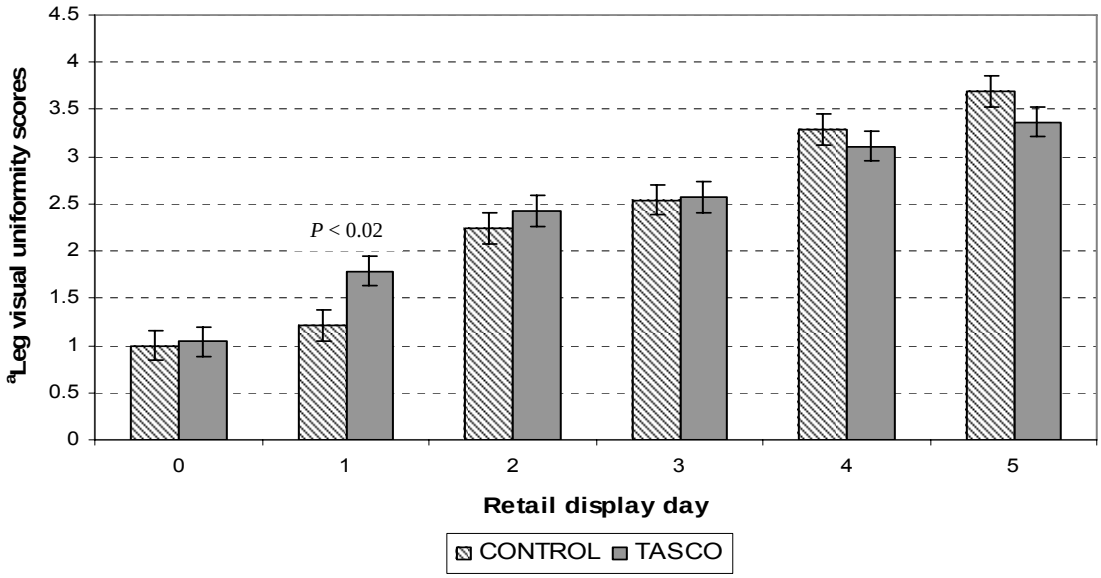

Figure 7. Effects of retail display day × Tasco supplementation interaction on visual lean uniformity scores of leg chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Color uniformity (5 = extreme two-toning; 1 = uniform); n = 10 for each mean.

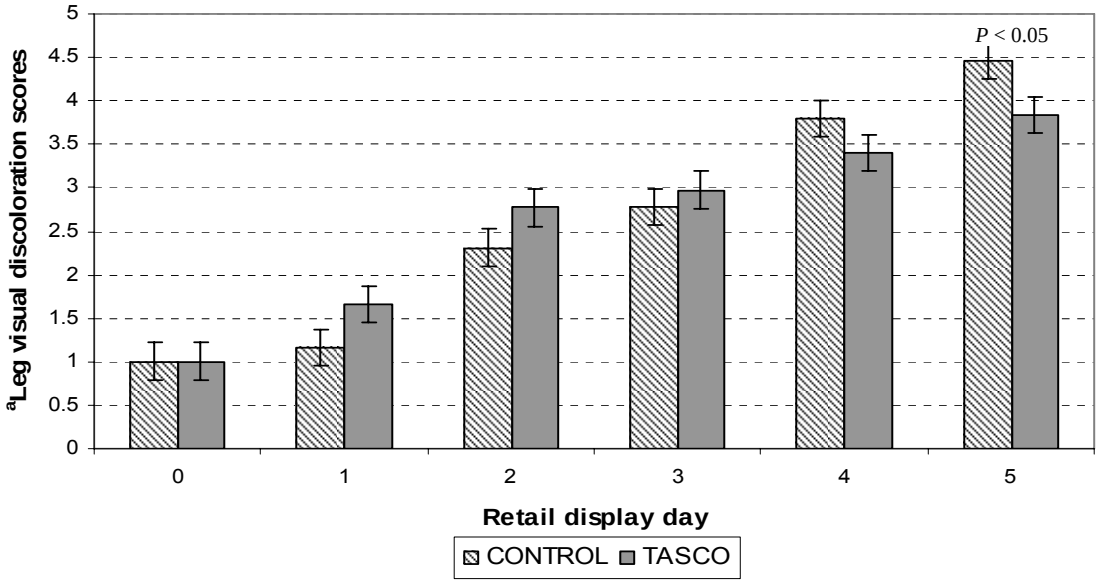

Figure 8. Effect of retail display day × Tasco supplementation interaction on visual lean discoloration scores of leg chops from feeder lambs fed an *ad libitum* concentrate ration with 0.1% Tasco-EX (Tasco) or without (Control), to a target weight of 57 kg (least squares means ± SEM). [a]Lean discoloration (7 = 100%; 1 = 0%); n = 10 for each mean.

IMPLICATIONS

Tasco supplementation may extend shelf-life of lamb rib and leg chops during extended retail display over 4d. Also, Tasco supplementation may increase CIE a* values (redness) in leg chops. No negative effects of Tasco on sensory characteristics or lipid oxidation were found; therefore, using Tasco to extend shelf-life could greatly reduce product loss due to discoloration and browning in fresh lamb meat. However, further study is needed, possibly with a corn-based concentrate diet, to conclude if Tasco supplementation would work in all regions and still be cost effective.

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Effects of Supplementation of Tasco-EX on Heat-Stress Induced Infertility in Young Male Goats

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ABSTRACT

A study was conducted at the Angelo State University Research Center to determine the effects of supplementation of the kelp extract product, Tasco-EX, on physical and fertility traits in young male goats challenged by heat stress. Twenty genetically similar Boer bucks averaging 100 days of age and 21 days post-weaning were randomly divided into two equal experimental groups. Individuals assigned to the first group received tri-weekly oral dosage of Tasco-EX so that the total weekly supplementation for each goat was 35g. The second group received no Tasco-EX supplementation and served as the control. All goats were maintained under feedlot-type conditions and received identical high-energy diets offered *ad libitum*. Supplementation spanned an 84-d period during which weekly average high temperatures ranged from 32.1-38.2° C. Data was collected for scrotal circumference growth, ADG, live-animal REA, and rectal temperature as well as actual and visual sperm-cell concentration and motility score. No effects of the supplementation protocol were observed for scrotal circumference (P = 0.22) or final REA (*P* = 0.75). Average daily gain was affected neither on a periodic (*P* = 0.72; *P* = 0.32) nor total (*P* = 0.75) basis. Rectal temperatures were surprisingly higher (*P* = 0.01) for the supplemented group than the control by an average of almost 0.2° C. Although no statistically significant differences were observed for sperm-motility score (*P* = 0.23) or for visual concentration score (*P* = 0.41), actual sperm-cell concentration data revealed a 1.2 billion cells/ml average increase in the supplemented group over the control (*P* = 0.10). Based on the data collected in this study, supplementation of Tasco-EX to young male Boer goats can reduce infertility related to heat stress by maintaining sperm cell concentrations despite the slight increase in body temperature associated with such supplementation.

INTRODUCTION

Heat stress is a major limiting factor of goat production in Texas and the Southwestern U.S. During the hot summer months, goats exhibit reduced physical performance (McDaniel and Parker, 2004), and reproductive capability drops drastically (Rockett et al., 2001). The latter is of significance because it limits producers to a single kid crop each year despite the relatively short gestation period of goats. Without hyperthermically-induced infertility, does could conceivably give birth twice each year, doubling output at only slightly higher costs to the producer.

A major factor in the inability of goats to successfully reproduce during the summer season is a decline in spermatogenic activity in males. This is caused in part by heat-activated enzymes that destroy developing germ cells (Vera et al., 2004a), and by increased internal body temperature, which prevents proper function of testicular tissue. Heat stress also causes an increase in respiratory frequency and intensity, leading to elevated free radical production; an occurrence that is detrimental to both fertility and immune function (Allen et al., 2001). These physiological changes occur in direct response to extreme ambient temperature and most likely function interactively to the impairment of reproductive ability.

Tasco-EX is an extract of *Ascophyllum nodosum*, a species of kelp or brown seaweed, and has been shown to reduce certain symptoms of heat stress in livestock, specifically elevated body temperature and increased respiratory rate (Evans et al., 2002; Leonard et al., 2001). It has also been proven to increase immune system vigor and performance (Saker et al., 1998), and is a rich source of free radical-neutralizing antioxidants such as α-tocopherol
and glutathione (Ayad et al., 1998; Allen et al., 2001). Because of its proven effects on heatstress in livestock, seaweed extract could increase fertility of goats during the hot summer months in Texas and the Southwestern U.S. This study will determine if seaweed extract positively affects young male goat fertility enough to support the practice of summer breeding. The basis for this determination will be number, viability, and motility of sperm collected at the end of the experimental period, as well as scrotal circumference growth during the experimental period. In addition, this study will provide an opportunity to monitor average daily gain and ribeye area growth in response to supplementation of brown seaweed extract in male goats held in feedlot-type conditions.

MATERIALS AND METHODS

Pure-bred, intact male Boer goats (n = 20) of Angelo State University stock, 100 days of age and 21 days post-weaning, were gathered in late May. The goats were grouped according to size to eliminate social dominance and confined five per pen at the Angelo State University Management, Instruction, and Research Center on May 26, 2006. All goats used in the study were visually inspected to ensure proper health and physical soundness. After an 11-day adjustment period during which the goats were acclimated to the experimental environment, all goats began an identical 84-day *ad libitum* feeding regimen that was designed to simulate a high-energy feedlot-style diet (Table 1). This feeding regimen was initiated on June 6, 2006. At this time, 10 randomly selected goats were designated to serve as the control group and received no experimental treatment. The remaining 10 goats received a dose of Tasco-EX seaweed (kelp) extract three times weekly for the duration of the 84 day feeding period. Ten-gram doses of the extract were administered on Mondays and Wednesdays, and 15-gram doses were given on Fridays to allow for the weekend. The extract was in paste form and administered orally from a 100-gram tube to the back of the throat.

Effects of the treatment were defined by physical traits as well as semen quality traits. Physical considerations consisted of scrotal circumference growth, average daily gain, ribeye area and internal body temperature. Ribeye area measurements were conducted on the live animal using an ALOKA 500 (ALOKA, Inc., Wallingford, CT) ultrasound machine. Internal body temperatures were obtained rectally on a bi-weekly basis for eight weeks.

Semen quality was defined by visual semen concentration, actual sperm cell concentration and comparative motility score. Initial measurements for all physical traits were recorded on day 0 (June 5, 2006), one day before the first oral administration, and final measurements were recorded on day 85 (August 29, 2006), one day after the conclusion of the experimental period. Periodic measurements for growth traits were recorded throughout the 84-day period in order to augment data. A determination of the practicality of summer breeding was based on comparisons of the experimental data collected in this study against the normal values reported by Coffey et al. (2004).

Table 1. Analysis of Surefed 16% Boer and Show Goat Ration (RM) Medicated Feed

Ingredient	
Crude protein	16.00%
Crude fat	2.50%
Crude fiber	17.00%
Ca	1.00%
P	0.30%
K	1.00%
NaCl	1.25%
Cu	25.00 ppm
Se	0.30 ppm
Vitamin A	4545.45 IU/kg
Vitamin E	9.09 IU/kg
Monensin	4.55 IU/kg

fed *ad libitum*.

STATISTICAL ANALYSIS

Goats (n = 20) were assigned to the treatment or control group (n = 10/ group) on a random basis. Because of spatial restrictions, goats were confined in pens of five. However, each goat represented an individual experimental unit. Scrotal circumference growth, average daily gain, ribeye area growth, and internal temperature measurements as well as visual semen concentration score, actual sperm cell concentration, and comparative motility score were analyzed using the greatest linear means (GLM) function of SAS (SAS Institute, Cary, NC). Due to the conservative sample size used in the study, differences of ($P \leq 0.10$) among data were considered significant. Data was examined for interactions involving sire and shared birth (single, twin, or triplet).

RESULTS AND DISCUSSION

Effects of Tasco-EX on physical growth traits

Values for periodic and overall average daily gains (Table 2) were not significantly different between the goats administered Tasco-EX and the control group. This suggests that supplementing Tasco-EX to goats under feedlot conditions does not improve weight gain. The findings contradict results reported for the meal form of the product (Turner et al., 2002; Allen et al., 2001), as well as for seaweed extract administered under pasture conditions (Fike et al., 2005; Leupp et al., 2005). However, the results of the previous studies may be products of factors absent in the current study. Tasco-14, the meal version of the seaweed product, has been compared to medium quality alfalfa hay in its protein and energy content (Ventura and Castañón, 1997). Because much of this digestible

organic material is removed during the extraction process, it is not available to animals receiving the extracted product, resulting in less growth.

Two hypotheses can be offered as explanations for the success of seaweed extract under pasture conditions. Leupp et al. (2005) stated that Tasco-EX increased the digestibility of poor quality roughage, allowing supplemented animals more efficient use of available forage, and consequently, higher rates of gain. This effect was not an issue in the present study because no poor quality roughage was offered. The small amount of roughage contained in the high-energy diet was of good quality. The second element of increased pasture gains is the immunological properties of the extract and its interaction with microbial life present on grazed pastureland. Spiers et al. (2005) found that certain microbes commonly present on growing forage during warm-weather months can cause a decrease in intake and, thus, rate of gain. Specifically, Spiers used the model of endophyte toxicity in

Table 2. Average daily gain in kg/d of adolescent Boer goats administered Tasco-EX and their control counterparts

	Treatment			
Time period	Control	Tasco-EX	SE	*P*-value
Jun 6- Jul 5	0.34	0.28	+/-0.04	0.32
Jun 6- Aug 1	0.30	0.32	+/-0.33	0.72
Jun 6- Aug 29	0.29	0.28	+/-0.02	0.75

fescue to illustrate the medicinal effects of seaweed extract supplemented to livestock grazing in the presence of toxin-producing microbes. Because the goats in the present study were given a processed feed, microbial toxicity was not a factor. Nothing was found in the study to indicate weight gain can be improved in feedlot goats through the supplementation of Tasco-EX.

Averages for size of ribeye area (Table 3) were also similar for the treatment and control groups. The administration of seaweed extract did not effect ribeye muscle growth for reasons similar to those described for daily weight gain. Although Ventura and Castañón (1997) found that protein availability was improved by supplementing seaweed extract, the goats in the current study received adequate amounts of dietary protein, and any additional protein was most likely lost through excretion.

Goats administered Tasco-EX averaged a 9.90 cm scrotal circumference (Table 3), while their control counterparts averaged 7.65 cm. Due to high variance, these values were not significant

(*P* = 0.22). Replication of the trial on a larger scale is needed to verify the tendencies of the values for scrotal growth recorded in this study.

Effects of Tasco-EX on internal temperature

Average rectal temperatures (Table 4) were unexpectedly higher for the experimental group than the control (*P* = 0.01) in the presence of elevated ambient temperatures (Table 5). This contradicts findings by Allen et al. (2001b), Leonard et al. (2001), and Evans et al. (2002), but supports those of Allen et al. (2001a). As with weight gain, the contrast in rectal temperature values of the current and previous studies may be explained by immunological function, rather than direct stress reduction.

Table 3. Average measurements for scrotal circumference growth in cm and ribeye area in in^2 for adolescent Boer goats administered Tasco-EX and their control counterparts

	Treatment			
	Control	Tasco-EX	SE	*P*-value
Scrotal circumference growth	7.65	9.90	+/-1.27	0.22
Initial scrotal circumference	21.60	20.60		
Final scrotal circumference	29.20	30.50		
Ribeye area	1.98	2.01	+/-0.08	0.75

Table 4. Average rectal temperature readings in °C for adolescent Boer goats administered Tasco-EX and their control counterparts

	Treatment			
Date of reading[a]	Control	Tasco-EX	SE	*P*-value
Jun 16	39.13	39.29	+/-0.14	0.44
Jun30	39.48	39.71	+/-0.12	0.20
Jul 14	39.22	39.46	+/-0.08	0.04
Jul 28	39.16	39.26	+/-0.12	0.54
Overall average	39.25	39.43	+/-0.04	0.01

[a]readings taken between 0800 and 0930.

Table 5. Weekly averages for high ambient temperature in San Angelo, TX

Week	°C
June 2-12	38.0
June 13-19	37.5
June 20-26	34.7
June 27-July 3	32.1
July 4-10	34.0
July 11-17	38.2
July 18-24	37.7
July 25-31	36.7
August 1-7	36.3
August 8-14	36.9
August 15-21	37.8
August 22-28	35.4

National Weather Service, San Angelo, TX

The reduction of temperature observed in previous work was in livestock exposed to endophyte toxicity, which has been shown to elevate internal temperature (Spiers et al., 2005), independent of ambient conditions. Because Tasco-EX greatly reduces the toxicity of endophyte-infected forage, it provides a peripheral reduction of body temperature through long-term sedation of immunological activity. This indirect temperature reduction is greater than the direct physiological increase in temperature caused by the product, resulting in a net decrease in body temperature. The absence of microbial toxicity and its resulting temperature spike in control goats allowed the physiological temperature spike to be noticed in the experimental group. It is important to note that, with one exception, all average temperatures for both groups fell within the 38.6°-39.7° C range that is considered normal (Gasparotto, 2005) and below critical levels for fertility.

Effects of Tasco-EX on semen quality

Average comparative motility score (Table 6) for goats administered Tasco-EX was 1.80 and 2.70 for the control group. Standard error prevented statistical significance of this difference (P = 0.23). The experimental group did exhibit more consistency, with 80% of the animals scoring in the top 28th percentile of the scale. Only 50% of the control group scored as well. Heat stress has been reported to effect semen motility by damaging germ cell DNA during early spermatogenesis (Banks et al., 2005; Rockett et al., 2001), but the results of this study fail to support previous accounts that suggest high levels of antioxidants such as Vitamin E and glutathione found in seaweed extract reduce detriment to immature sperm cells and testicular tissue (Brezezinsha-Slebodzinska et al., 1995; Galipalli et al. 2004a; Galipalli et al. 2004b; Allen et al., 2001b).

Table 6. Average measurements for semen quality traits of adolescent Boer goats administered Tasco-Ex and their control counterparts

	Treatment			
Semen trait	Control	Tasco-EX	SE	*P*-value
Motility[a]	2.70	1.80	+/-0.51	0.23
Visual concentration[b]	1.90	1.70	+/-0.17	0.41
Actual concentration[c]	3.01	4.22	+/-0.50	0.10

[a]1 = extreme movement; 7 = no movement.
[b]1 = cloudy; 3 = clear.
[c]actual concentration is value x 10^9 sperm cells/ml.

Average concentration of spermatozoa (Table 6) was 24% higher for the experimental group than for the control, a significant difference (P = 0.10). Average concentrations for both groups were above the 2 to 3 billion cells per ml average reported by Coffey et al. (2004), although some individual goats in the control group fell well below the minimal value for proper breeding soundness. This data indicates that supplementation of seaweed extract hinders the detrimental effect heat stress exhibits on fertility (Cameron and Blackshaw, 1980; Rocket et al., 2001).

Based on the data collected in this and other studies, the hypothesized mechanism for the improvement of fertility under heat stress conditions is a disruption in the stepwise apoptotic pathway described by Vera et al. (2004a) rather than a physiological reduction in internal temperature, as suggested in some reports (Allen et al., 2001b; Leonard et al., 2001). Certain studies of the apoptotic process have shown it to be increased by heat stress (Rockett et al., 2001), specifically through the increased production of dangerous free radicals during elevated respiration rates (Allen et al., 2001b; Evans et al., 2002). Administering Tasco-EX provides a boost in available antioxidants in the system, which neutralizes a higher number of free radicals, thus protecting vulnerable immature spermatocytes and testicular tissue.

Practicality of summer breeding with Tasco-EX supplementation

In order to determine practicality of summer breeding using supplementation of seaweed extract, fertility data collected for supplemented goats in this study must be compared to values expected during the cooler fall months, when breeding traditionally occurs. Coffey et al. (2004) reported ideal scrotal circumferences of 34 to 36 cm for fully mature bucks during normal breeding seasons. These values, however, can shrink by as much as 50% in response to heat stress (Rockett

et al., 2001). The average scrotal circumference for goats administered Tasco-EX in the current study was 30.5 cm. This slight difference in size is likely as much a product of youth as heat factors. The experimental bucks produced an average sperm cell concentration of 4.22 billion cells per ml of semen, well above the average range of 2 to 3 billion cells per ml considered adequate for successful breeding (Coffey et al., 2004). Sperm cell concentration appeared to be the fertility trait most influenced by heat stress, as evidenced by the significant reduction in concentration values for goats not administered seaweed extract. These goats were presumably left exposed to heat stress effects. Although the average for these goats fell above the minimum acceptable concentration, several individual goats registered extremely low concentrations, a potentially disastrous condition during breeding. Motility is considered acceptable at no less than 70% motile cells (Coffey et al., 2004). Although numerical measurements of motility were not recorded, the high average comparative motility score for bucks receiving the treatment suggested that sperm cell-motility was satisfactory. Based on the male fertility traits examined in this study and ignoring factors related to female fertility and embryonic survival, supplementation of seaweed extract to adolescent male goats under heat stress conditions improved spermatogenesis and reproductive capacity to levels comparable to those reported for traditional breeding seasons, as average values for all measured fertility traits were at or near values expected during traditional fall breeding seasons, as reported by Coffey et al. (2004).

No interactions were found among any of the data for sire or shared birth. Additional research on an expanded scale is needed to verify data for traits that approached significance in this study, and to evaluate the effects of the product on female fertility.

SUMMARY

Supplementation of seaweed extract, specifically Tasco-EX, improved sperm cell concentration in semen samples from adolescent Boer goats facing heat stress. Motility score and scrotal circumference were also improved, though not significantly. Ignoring female fertility and embryonic survival, supplementation of seaweed extract during high ambient temperatures may provide summer breeding opportunities in some production scenarios. Disruption of the apoptotic pathway appears to be the mechanism behind reduction of heat stress-induced infertility by seaweed extract and not decreased body temperature, as internal temperature was actually increased by the

product. Supplementation of seaweed extract does not improve average daily weight gain or size of ribeye area in goats under feedlot conditions.

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Effect of Tasco® on Feedlot Performance and Carcass Characteristics of Rambouillet and Rambouillet X Suffolk Cross Feeder Lambs

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ABSTRACT

This study evaluated the effects of Tasco-EX® in feedlot diets on performance and carcass characteristics of Rambouillet and Rambouillet-cross feeder lambs. Lambs were (n = 60) separated by weight, sex, and breed into pens of three and randomly assigned to treatments: CON (No Tasco-EX / Control) and Tasco-EX, 0.1% of diet. Lambs were weighed on d 0, 28, 45, 56, 70, and 84 and harvested when pen average weight reached 59 kg. Differences ($P < 0.10$) within diets were evaluated for average daily gain (ADG) and days on feed (DOF). Differences ($P < 0.10$) within breed type were found for ADG, DOF, final weight, hot carcass weight, leg circumference, fat thickness, adjusted fat thickness, flank streaking, USDA Quality Grade, and USDA Yield Grade. Differences ($P < 0.10$) within sex type were seen for DOF, flank streaking, and USDA Quality Grade.

INTRODUCTION

Seaweeds have been researched for years in relation to composting and plant growth (Szmidt., 1997). In recent years *Ascophyllum nodosum,* a seaweed species, has been studied for use in agriculture (Allen et al., 2001b). A majority of the research related to *Ascophyllum nodosum* has been completed on feedlot steers, rodents, and pigs (Turner et al., 2002; Montgomery et al., 2001; Jones et al., 1979). Research about seaweeds with respect to feedlot sheep and goats has been minimal.

Tasco-EX™ is a brown seaweed extract from the seaweed *Ascophyllum nodosum*. Tasco-Forage has been used in many different research projects including feedlot performance and carcass characteristics of steers (Allen et al., 2001a), which looked at average daily gain (ADG), days on feed (DOF), and feed efficiency and found no improvements in these areas. Carcass characteristics studied included marbling scores, USDA yield grade (YG), quality grades (QG), flank streaking, and overall meat quality. The shelf-life of meat products from steers fed Tasco-Forage prior to harvest has shown extended shelf-life (Montgomery et al., 2001).

As the feedlot industries continue to develop and search for new ways of improving feed efficiency without profit loss, the use of new feed additives such as seaweed extracts are promising. Seaweed is rich in antioxidants, minerals, and vitamins and may have promising effects on feedlot performance and carcass characteristics in cattle and sheep.

The objectives of this study were to: (1) to determine the effect of Tasco-EX™ in feedlot diets on feedlot performance of Rambouillet and Rambouillet X Suffolk-cross lambs, and (2) to determine the effect of Tasco-EX™ in feedlot diets on carcass characteristics of Rambouillet and Rambouillet X Suffolk-cross lambs.

MATERIAL AND METHODS

This study was conducted at the Angelo State University Management, Instruction and Research Center, near San Angelo, TX. Feeder lambs were purchased from Producers Livestock Auction in San Angelo, TX.

Animals and Feeding

Rambouillet and Rambouillet x Suffolk cross feeder lambs (n = 60), averaging 41 kg, were randomly assigned to one of two treatments. Treatment 1 served as the control (CON), which consisted of lambs receiving a normal feedlot industry diet series (Table 1). Lamb diets consisted of increasing grain for an average of 5 d on each diet until the final ration was reached. Treatment 2 (Tasco-EX) received the same diet as CON, with Tasco-EX™ added to the diet at 0.1%. Prior to entering the feedlot experiment, lambs were each treated with anthelmintic (8 ml; Prohibit® Soluble Drench Powder; Agri Laboratories, Ltd., St. Joseph, MO) and vaccinated against enterotoxemia (2 ml; Bar Vac® CD/T Clostridium Perfrigens Types C and D- Tetanus toxoid; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO).

Lambs were blocked by weight, sex, and breed and fed in pens of three lambs each. Lambs had *ad libitum* access to the diets, clean fresh water, and were kept in 20 pens with 3 lambs per pen and 10 pens per treatment. Each pen measured 3.0 m by 9.1 m. Lambs were weighed at the initiation of the trial and d 28, 45, 56, 70, and 84 to monitor gains. Once the pen average weight reached 59 kg, the entire pen was harvested. Feed was weighed prior to being placed in feeders and reweighed

Table 1. Dietary composition of diets of feeder lambs on two different finishing diets (as fed basis)

Ingredients	Ration #1	Ration #2	Ration #3	Ration #4
Milo, %	36.00	50.00	62.00	73.00
Soybean hulls, %	22.00	10.50	19.00	13.00
Soybean meal, %	6.50	4.50	3.00	2.00
Alfalfa pellets, %	30.00	29.50	10.50	6.50
Molasses, %	3.00	3.00	3.00	3.00
Sheep Mineral Premix, %	2.50	2.50	2.50	2.50

once lambs reached harvest weight to calculate days on feed (DOF) and feed efficiency (per pen of three lambs).

Carcass Characteristics

Forty lambs were harvested at Producers' Lamb and Goat, L.P., a commercial harvest facility in San Angelo, TX. Twenty lambs were randomly selected, 10 from each treatment, and harvested at the Angelo State University Food Safety and Product Development Laboratory, for participation in a companion research trial. After spray chilling approximately 24 h post-mortem, carcass data was collected by university meat scientists at both facilities, on all lambs for USDA Yield Grade (USDA YG) and Quality Grade (USDA QG), along with leg score (LS), flank streaking, fat thickness at the 12^{th} rib, adjusted fat thickness (ADJFT), and leg circumference (AMSA, 2001).

Statistical Analysis

Lamb performance, DOF, and carcass characteristics were analyzed using the GLM procedures of SAS (SAS Inst., Inc., Cary, NC), with individual lambs serving as the experimental unit. Preplanned contrasts were used to compare 1) CON vs. Tasco-EX, 2) Fine wool vs. crossbred, 3) male vs. female, 4) diet x breed interaction, 5) diet x sex interaction, and 6) diet x breed x sex interaction. Feed efficiency was analyzed using pen of three lambs as the experimental unit. Least square means were separated by pair-wise t-test (PDIFF) option with a predetermined $\alpha = 0.10$.

RESULTS AND DISCUSSION

Feed Analysis

Chemical analysis of Ration 4 feed treatment was conducted by Dairy One Inc., Ithaca, NY (Table 2). Results revealed elevated levels of acid detergent fiber (ADF) and neutral detergent fiber (NDF) in CON. Consistent levels between moisture, dry matter (DM), crude protein (CP), adjusted crude protein, and total digestible nutrients (TDN) were also found.

Table 2. Chemical composition of Ration 4 of experimental diet of feeder lambs on two different finishing diets (as fed basis)

	Treatment	
Parameter	CON	Tasco-EX
DM, %	89.8	89.3
CP, %	13.2	13.8
NDF, %	24.7	15.6
ADF, %	17.4	11.5
TDN, %	70.0	72.0

Performance of Lambs

Feedlot performance of feeder lambs on two different finishing diets was compared within breed, sex, and diet types (Table 3). No differences ($P > 0.10$) among breed, sex, and diet type were observed for initial weight as expected since lambs were blocked by weight at the initiation of the trial. Within diet type, lambs fed Tasco-EX revealed increased ($P < 0.10$) ADG over those on CON diet. As stated in Allen et al. (2001b), swine supplemented with either Tasco-EX or Tasco-14 gained

Table 3. Effects with standard errors of the mean (SEM) of breed, sex, and diet on performance of feeder lambs on two different finishing diets

	CON				**Tasco-EX**									
	Fine-wool		Crossbred		Fine-wool		Crossbred		Orthogonal contrasts[a]					
Item	Male	Female	Male	Female	Male	Female	Male	Female	1	2	3	4	5	6
Initial Wt, kg	39.54[b] ±1.74	38.72[b] ±1.56	41.93[b] ±2.46	37.61[b] ±1.74	39.20[b] ±1.74	38.36[b] ±1.56	39.77[b] ±2.46	38.97[b] ±1.74	0.783	0.650	0.214	0.986	0.519	0.513
Final Wt, kg	53.35[de] ±2.01	55.40[cde] ±1.79	59.88[bc] ±2.83	57.95[be] ±2.01	53.97[de] ±2.01	56.04[cde] ±1.79	58.06[bd] ±2.84	60.79[b] ±2.01	0.715	0.006	0.432	0.969	0.456	0.458
ADG, kg	0.17[c] ±0.17	0.20[c] ±0.02	0.34[b] ±0.04	0.33[b] ±0.03	0.21[c] ±0.03	0.23[c] ±0.02	0.39[b] ±0.04	0.34[b] ±0.03	0.088	<0.0001	0.912	0.988	0.599	0.620
DOF[g]	84.00[b]	84.00[b]	52.00[ef]	61.00[de]	72.75[c]	75.30[c]	46.00[f]	64.00[d]	0.04	<0.001	0.01	0.13	0.30	0.56

[a]Probability of significant orthogonal contrasts. Effects tested using orthogonal contrasts were 1) control vs. Tasco-EX addition, 2) Fine wool vs. crossbred, 3) male vs. female, 4) diet x breed interaction, 5) diet x sex interaction, and 6) diet x breed x sex interaction.
[b,c,d,e,f]Least square means within a row with different superscripts differ ($P < 0.10$).
[g]Days on feed.

more ($P < 0.05$) body weight than control pigs (K. Pond, V. Allen, and C. Melton, unpublished data). In contrast, Turner et al. (2002) found no differences ($P > 0.05$) in ADG of pigs treated at different levels of *Ascophyllum nodosum*. Fike et al. (2001) reported a linear increase ($P < 0.05$) in daily gain in

lambs influenced by Tasco-Forage during the summer grazing period. In the current study, a difference ($P < 0.10$) within breed type was revealed between crossbred and fine-wool lambs with crossbred lambs gaining better than fine-wool lambs in both treatments similar to sheep feedlot industry standards.

Days on feed for lambs within diet type were observed to be lower ($P < 0.10$) for lambs fed Tasco-EX than CON. Within breed type, fine-wool lambs within both treatments were on feed a greater ($P < 0.10$) amount of days than crossbred lambs. Within sex types male lambs were lower ($P < 0.10$) in DOF than female lambs. No differences ($P > 0.10$) between diet types were found for feed efficiency (Table 4). Allen et al. (2001a) found similar results for feed efficiency of steers grazing pastures treated with Tasco.

Table 4. Least square means (SEM) for feed efficiency within each treatment group of lambs on two different finishing diets

	Treatment	
Trait	CON	Tasco-EX
Efficiency[a], kg	7.11 (0.41)	7.14 (0.41)

[a]Efficiency = (Total kg of feed consumed by pen)/(Total gain of pen).
Least square means with no superscripts do not differ ($P < 0.10$).

Within breed type, crossbred lambs in either treatment were observed to have higher ($P < 0.10$) final weights than fine-wool lambs. Allen et al. (2001a) observed no effect on final pasture weight or performance during the feedlot finishing phase for steers grazing Tasco-Forage treated pastures, but a difference ($P < 0.05$) in final weight influenced by endophyte. Saker et al. (2001) revealed similar results in final weights of steers grazing Tasco treated pastures and Cu supplementation.

Carcass Traits

Carcass traits of feeder lambs on two different finishing diets were compared within breed, sex, and diet type (Table 5). Within breed type, crossbred lambs had higher ($P < 0.10$) hot carcass weights (HCW) than fine-wool lambs. No differences ($P > 0.10$) in HCW within sex and diet type were observed. Similarly, hot carcass weights of steers were not affected by the application of Tasco-Forage to pastures (Allen et al., 2001a).

Table 5. Effects with standard errors of the mean (SEM) of breed, sex, and diet on carcass traits of feeder lambs on two different finishing diets

	CON				Tasco-EX									
	Fine-wool		Crossbred		Fine-wool		Crossbred		Orthogonal contrasts[a]					
Trait	Male	Female	Male	Female	Male	Female	Male	Female	1	2	3	4	5	6
HCW[n], kg	27.58^{deg}	27.22^{fg}	32.36^{a}	30.46^{bc}	28.15^{cdef}	29.69^{be}	30.37^{b}	32.09^{b}	0.4	0.001	0.778	0.3	0.1	0.6
Leg Score[i]	10.88^{b}	11.40^{b}	10.75^{b}	11.50^{b}	11.13^{b}	10.90^{b}	11.00^{b}	11.25^{b}	0.777	0.820	0.144	0.7	0.1	0.7
LegC[J], cm	65.88^{fg}	65.95^{g}	72.63^{bc}	72.50^{bd}	68.13^{ef}	69.00^{e}	70.25^{bc}	73.94^{b}	0.152	<0.01	0.139	0.0	0.1	0.3
FT[k], cm	0.68^{ef}	0.73^{cde}	0.97^{b}	0.92^{b}	0.71^{cd}	0.82^{bd}	0.92^{b}	0.83^{bc}	0.9	0.000	0.881	0.1	0.8	0.6
AFT[l], cm	0.78^{cde}	0.82^{be}	0.94^{b}	0.91^{b}	0.74^{cde}	0.84^{bd}	0.95^{b}	0.86^{bc}	0.7	0.004	0.914	0.8	0.9	0.4
FS[m]	230.00^{cd}	260.00^{bd}	265.00^{bc}	307.50^{b}	220.00^{c}	224.00^{c}	212.00^{b}	307.50^{b}	0.1	0.025	0.016	0.9	0.7	0.2
DP[n], %	0.52^{b}	0.51^{b}	0.53^{b}	0.53^{b}	0.52^{b}	0.52^{b}	0.51^{b}	0.53^{b}	0.5	0.465	0.720	0.5	0.4	0.9
USDA QG[o]	5.25^{b}	4.80^{bc}	4.50^{bd}	4.38^{cd}	5.25^{b}	5.00^{b}	5.25^{bd}	4.00^{d}	0.4	0.012	0.016	0.8	0.2	0.1
USDA YG[p]	3.25^{cd}	3.30^{cd}	3.93^{bc}	3.79^{b}	3.09^{cd}	3.51^{bd}	3.95^{bc}	3.59^{a}	0.8	0.003	0.9	0.7	0.8	0.3

[a]Probability of significant orthogonal contrasts. Effects tested using orthogonal contrasts were 1) control vs. Tasco-EX addition, 2) Fine wool vs. crossbred, 3) male vs. female, 4) diet x breed interaction, 5) diet x sex interaction, and 6) diet x breed x sex interaction.
[b,c,d,e,f,g]Least square means within a row with different superscripts differ ($P < 0.10$).
[h]Hot Carcass Weight, kg.
[i] Leg Conformation Score (15 = High Prime, 14 = Average Prime, 13 = Low Prime, 12 = High Choice, 11 = Average Choice, 10 = Low Choice, 9 = High Good).
[j]Leg Circumference, cm.
[k]12th rib Fat Thickness, cm.
[l]Adjusted Fat Thickness, cm.
[m]Flank Streaking (800 = Abundant, 700 = Moderately Abundant, 600 = Slightly Abundant, 500 = Moderate, 400 = Modest, 300 = Small, 200 = Slight, 100 = Traces, 0 = Practically Devoid).
[n]Dressing Percentage
[o]USDA Quality Grade (1 = High Prime, 2 = Average Prime, 3 = Low Prime, 4 = High Choice, 5 = Average Choice, 6 = Low Choice, 7 = High Good). [p]USDA Yield Grade = ((12th rib fat thickness x 10)

Leg circumference within breed type revealed crossbred lambs to be higher ($P < 0.10$) than fine-wool lambs. A diet x breed effect ($P < 0.10$) was also observed for leg circumference. No differences ($P > 0.10$) were observed within breed, sex, and diet type for leg conformation score and dressing percent. Fat thickness (FT) of crossbred lambs was higher ($P < 0.10$) than fine-wool lambs within breed type. Adjusted fat thickness (AFT) was also higher ($P < 0.10$) for crossbred lambs than fine-wool lambs within the respected breed type, similar to feedlot industry standards.

Flank streaking (FS) was observed to be greater ($P < 0.10$) in crossbred lambs than fine-wool lambs within breed type. Within sex type, female lambs were observed to have increased ($P < 0.10$)

flank streaking compared to male lambs. Allen et al. (2001b) observed increased ($P < 0.05$) marbling scores with the application of Tasco-Forage to pastures regardless of endophyte status. Stated in Allen et al. (2001b), higher ($P < 0.05$) marbling scores were observed in steers supplemented with Tasco-EX at 2% of the diet during the first 10 d in the feedlot in comparison to steers unsupplemented (J.W. Johnson, K. Pond, V. Allen, unpublished data). As stated in Allen et al. (2001b), Tasco-EX fed at 0, 1, and 2% of the diet to steers during the final 14 d in the feedlot, revealed no effect on marbling scores (D. Messer, K. Pond, V. Allen, unpublished data).

Crossbred lambs had higher ($P < 0.10$) USDA Quality Grades (USDA QG) than fine-wool lambs within breed type. Within sex type, female lambs were observed to have higher ($P < 0.10$) USDA QG than male lambs. Allen et al. (2001a) stated steers grazing Tasco-Forage treated pastures prior to entering feedlot graded no lower than Choice-, with steers grazing untreated pastures grading Select+. Within breed type, fine-wool lambs had lower ($P < 0.10$) USDA Yield Grades (USDA YG) than crossbred lambs.

IMPLICATIONS

This study indicates that the addition of Tasco-EX at 0.1% of the diet revealed increases in ADG and a decrease in DOF. An increase in ADG, with a decrease in DOF for feeder lambs, has the prospective for lambs to reach harvest weight more promptly while not receiving a mature grade at harvest. Data from this project indicates males had a shorter DOF compared to females. However, the addition of Tasco-EX at 0.1% did not improve carcass traits. Thus, this data indicates the need for further research in determining adequate levels of Tasco-EX when fed to feeder lambs.

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Estrus Synchronization with Adjusted Time Artificial Insemination in Cows and Heifers

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ABSTRACT

Single and multiparous registered Angus cows and heifers were synchronized and artificially inseminated at a set time (Timed Artificial Insemination, TAI) to determine the effects of TAI and estrus synchronization protocols on actual estrus and to determine the effect of insemination time on conception following TAI. Trial 1 was a project to adjust times in Trial 2 using crossbred multiparous cows. Trial 2 consisted of Angus heifers (n=19) and Angus cows (n=54). Treatments were a synchronization protocol in addition to adjusted insemination times by several hours between treatments. Results of the heifers and cows were similar. Heifers and cows data showed differences in conception on first TAI *(P < .08)*. Treatment 3 in the heifers and treatment 1 in the cows may be the ideal time to artificially inseminate heifers and cows, respectively. Some results were somewhat unexplainable which could be due to a number of outlying factors.

INTRODUCTION

Synchronizing the estrous cycle and applying timed artificial insemination (TAI) among a group of cows or heifers can be very beneficial and economical to a beef cattle producer (Anderson et al., 2002). Synchronization is especially beneficial when artificially inseminating (AI). Synchronization and TAI require extensive management practices and may be costly, but provide the potential for many benefits to the producer.

Heat or estrus synchronization has a number of potential benefits when performed correctly. Estrus synchronization allows for earlier calf weaning, less need for bulls, potential for shortened breeding seasons, and more efficient use of labor and management (Deutscher, 2005). A number of synchronization protocols exist for beef cattle. A producer should research the protocols to determine which one is sufficient for his or her operation. Any program should be well planned, implemented, and suited to the needs of the operation.

Timed AI also has many benefits. Timed AI can increase herd efficiency by selecting for better traits, improve genetics by selecting sires and dams with superior genetics, and increase cattle

production (Williams, 2005). It is important that insemination coincide with ovulation. For insemination to be effective cows should be in proper body condition, at least 45 d postpartum, stress should be limited, and proper breeding techniques should be incorporated.

There are many products approved for estrus synchronization, but there is variation among conception rates. The main reproductive objective for a beef cattle producer is high pregnancy conception rates. This study will evaluate conception rates resulting from an estrus synchronization program with adjusted TAI.

MATERIALS AND METHODS

This study was conducted at the Angelo State University Management, Instruction, and Research Center located about 7 miles north of San Angelo in Tom Green County. Two trials were conducted for this study. Trial 1 was a pilot project for Trial 2 to determine the approximate times of estrus following the selected estrus synchronization protocol. The time of AI following estrus for cows and heifers in Trial 2 was determined using the results from Trial 1.

Trial 1 consisted of 18 crossbred (Hereford X Angus) cows of 7 to 10 yrs of age. The cows were managed in one group and fed free choice haygrazer hay and a feed supplement consisting of alfalfa pellets, milo, soybean hulls, soybean meal, molasses, and a mineral premix. Estrus was synchronized using a two injection system of GnRH and $PGF_{2\alpha}$ with EAZI-BREED™ CIDR® insertion (Co-Synch + CIDR protocol). On January 19, 2006 (d 0), a 2 ml GnRH (Cystorelin®/gonadorelin diacetate tetrahydrate) injection was administered and a CIDR inserted into the cow's vagina; this was designated as treatment (trt) 1. On January 26, 2006 (d 7) a 5 ml $PGF_{2\alpha}$ (ProstaMate®/dinoprost tromethamine) injection was administered and the CIDR removed. Heat was then detected from d 7 to 10 (72 to 84 h) using the HeatWatch® (DDx, Denver, CO) transmitter system. CIDR removal, $PGF_{2\alpha}$ injection, and fitting of HeatWatch® transmitters was designated as trt 2. The actual time from CIDR removal and prostaglandin injection to estrus was determined and recorded. Data from this trial was used to adjust times in Trial 2.

Trial 2 consisted of 19 registered Angus heifers, 11 registered Angus 2 yr old single parous cows, and 42 registered Angus 3 to 10 yr old multiparous cows all 36 to 60 d postpartum. Treatment (trt) in this trial was based on Trial 1. The cows and heifers were managed separately (split into

heifers and cows) and were maintained on grass pasture. The 19 heifers (Table 1) and 21 of the cows (Table 2) formed Group 1. Group 2 consisted of the remaining 32 cows (Table 3). Cows were assigned to groups randomly and all cows were at least 36 d postpartum prior to beginning of the study.

Treatment effect for both groups was time of AI following CIDR removal. Treatment 1 was 56 h, trt 2 was 60 h, and trt 3 was 66 h for all of the heifers in this trial. Treatment 1 was 50 h, trt 2 was 56 h, and trt 3 was 59 h for all of the cows in this trial. Each cow and/or heifer was given a two injection system of GnRH and $PGF_{2\alpha}$ with CIDR insertion (Co-Synch + CIDR protocol). On d 0 a 2 ml GnRH (Cystorelin®/gonadorelin diacetate tetrahydrate) injection was administered and an EAZI-BREED™ CIDR® inserted into the cow's vagina. On d 7 a 5 ml $PGF_{2\alpha}$ (ProstaMate®/dinoprost tromethamine) injection was administered, CIDR removed, and HeatWatch transmitters were applied to detect estrus or heat. All heifers and cows were heat detected (using the HeatWatch detection system) a second time three weeks after TAI; any cows or heifers exhibiting estrus were then re-inseminated 10 to 12 h following estrus detection. All cows and heifers were then turned out with registered Angus bulls on grass pasture to allow the females that did not get bred by TAI to be bred by the bulls.

Table 1. Dates of procedures performed per treatment group of Angus heifers in Group 1.

	Procedure 1[a]	Procedure 2[b]	n
Trt 1[c]	March 22 (12:00)	March 24 (pm)	6
Trt 2[d]	March 21 (20:00)	March 24 (pm)	6
Trt 3[e]	March 21 (14:00)	March 24 (pm)	7

[a]2 ml GnRH injection + CIDR
[b]CIDR removal + $PGF_{2\alpha}$ injection + fitted with HeatWatch® transmitters
[c]56 h TAI post estrus + 2 ml GnRH injection
[d]60 h TAI post estrus + 2 ml GnRH injection
[e]66 h TAI post estrus + 2 ml GnRH injection

Table 2. Dates of procedures performed per treatment group of Angus cows in Group 1.

	Procedure 1[a]	Procedure 2[b]	n
Trt 1[c]	March 22 (11:00)	March 24 (pm)	7
Trt 2[d]	March 22 (05:00)	March 24 (pm)	7
Trt 3[e]	March 22 (02:00)	March 24 (pm)	7

[a]2 ml GnRH injection + CIDR
[b]CIDR removal + $PGF_{2\alpha}$ injection + fitted with HeatWatch® transmitters
[c]50 h TAI post estrus + 2 ml GnRH injection
[d]56 h TAI post estrus + 2 ml GnRH injection
[e]59 h TAI post estrus + 2 ml GnRH injection

Table 3. Dates of procedures performed per treatment group of Angus cows in 3Group 2.

	Procedure 1[a]	Procedure 2[b]	n
Trt 1[c]	March 22 (11:00)	March 31 (pm)	10
Trt 2[d]	March 22 (05:00)	March 31 (pm)	11
Trt 3[e]	March 22 (02:00)	March 31 (pm)	11

[a]2 ml GnRH injection + CIDR
[b]CIDR removal + $PGF_{2\alpha}$ injection + fitted with HeatWatch® transmitters
[c]50 h TAI post estrus + 2 ml GnRH injection
[d]56 h TAI post estrus + 2 ml GnRH injection
[e]59 h TAI post estrus + 2 ml GnRH injection

Cows and heifers in both groups were sonogrammed approximately 3 mos after the first AI date to determine pregnancy. Ultrasound (Aloka SSD-500V, Aloka Co., ltd., Wallingford, CT, 1991) was used opposed to palpation due to the fetal size. An image of the top of the fetus's head was taken by using the ultrasound machine. Each image was then measured for crown width to determine the fetus's age. Fetal age determined which breeding the fetus was conceived on, such as the first AI, second AI, or by a bull.

STATISTICAL ANALYSIS

No statistics were analyzed for Trial 1 of the study. Treatment effect for trial 2 was h of TAI following CIDR removal and estrus synchronization. Trial 2 was a randomized complete block design with the heifer or cow serving as the experimental unit and parity or age being used as the blocking factor. Data from this trial was analyzed using the CATMOD Procedure of SAS (SAS Inst. Inc., Cary, NC, 1989). Chi square was used to analyze treatment differences which were predetermined at $\alpha = 0.10$.

RESULTS AND DISCUSSION

Trial 1

All of the crossbred cows (n=20) were palpated prior to the trial to determine pregnancy. Two of the cows were determined pregnant prior to synchronization and were eliminated from the trial. Some of the cows that were originally determined open, about two weeks later were determined to be pregnant. This is the reason for no estrus detection on those particular cows. The majority of the crossbred cows (n=18) in Trial 1 exhibited heat or estrus after synchronization. Eight out of the eighteen cows exhibited estrus from 42 to 78 h following synchronization. The cows not exhibiting

estrus may be due to any of the following: poor body condition, stress, reproductive disease, other disease, age, weather, or environmental conditions.

Trial 2

Table 4 shows results from the data of the registered Angus heifers (n=19). The heifers were categorized by trt to compare the number of animals per trt, how many heifers conceived on the first AI, and the percent conception on the first AI. There were differences in conception on the first AI among the group of heifers *(P < .08)*. Statistically, trt 3, 66 h from estrus to AI, shows to be the best time for AI. These results suggest 66 h post CIDR removal, following estrus synchronization, may be the ideal time to AI heifers. And 60 h post CIDR removal, following estrus synchronization, may be the least successful time to AI heifers. The expected results of this study were for the ideal AI times to fall somewhere in between the three treatments (56 h, 60 h, 66h). The outcome of the results are unexplainable since 66 h post CIDR was the best with 56 h falling intermediate and the middle time (60 h) having the poorest results. The varying results among the heifers could be due to the limited number (n=19) used in the study. It would have been beneficial to have had a greater number of heifers for this part of the research.

Table 4. Number of heifers, number of heifers that conceived, and percent of heifers that conceived in Angus heifers by treatment.

Treatment[a]	1	2	3
n	6	6	7
No. Conceived	3[b]	2[c]	5[d]
% Conceived	50.0[b]	33.33[c]	71.4[d]
No. in Estrus 2nd Cycle[e]	2	3	0
% in Estrus 2nd Cycle[f]	33.3	50.0	0

[a] Treatment 1 = 56 h post estrus, treatment 2 = 60 h post estrus, treatment 3 = 66 h post estrus
[bcd] Means within a row with common superscripts differ at *P < .08*
[e] Number of heifers in heat on 2nd estrous cycle within treatment
[f] Percent of heifers in heat on 2nd estrous cycle within treatment

The number of heifers exhibiting estrus on their 2nd estrous cycle is displayed in Table 4 (these results were not analyzed statistically). Treatment 3 (n=7) had no animals showing heat on the 2nd cycle. This suggests that the majority of heifers in the group were successfully artificially inseminated. Treatment 2 (n=6) had 50% of the animals showing heat on the 2nd cycle and trt 1 (n=6) had 33.3% showing heat on the 2nd cycle. Results show trt 3, 1, and 2, respectively, to be the most successful estrus synchronization among the heifers in this trial.

The Angus cows were also categorized by trt to compare the number of animals per treatment, the mean of days postpartum for each treatment, how many cows conceived on the first AI, and the percent conception on the first AI among each treatment group. As shown in Table 5, statistical differences existed among each trt group of cows with respect to number of cows to conceive and percent conception ($P < .08$). Treatment 1 had the highest conception with treatment 2 having the lowest. This suggests 50 h following estrus may be the optimal time to AI single and multiparous cows, and 56 h may be an unfavorable time to AI cows. And 56 h post estrus, following estrus synchronization, may be the least successful time to AI single and multiparous cows. The expected results of this study were for the ideal AI times to fall somewhere in between the three treatments (50 h, 56 h, 59h). The results are similar to the heifer results since there is not a trend for increased or decreased conception with hours post CIDR removal.

Table 5. Number of cows, days postpartum, number of cows that conceived, and percent of cows that conceived in Angus cows by treatment.

Treatment[a]	1	2	3
n	17	18	18
Days Postpartum	65	64	65
No. Conceived	7[b]	2[c]	5[d]
% Conceived	41.2[b]	11.1[c]	27.8[d]
No. in Estrus 2nd Cycle[e]	5	8	6
% in Estrus 2nd Cycle[f]	29.4	44.4	33.3

[a] Treatment 1 = AI 50 h post estrus, treatment 2 = AI 56 h post estrus, treatment 3 = AI 59 h post estrus
[bcd] Means within a row with common superscripts differ at $P < .08$
[e] Number of cows in heat on 2nd estrous cycle within treatment
[f] Percent of cows in heat on 2nd estrous cycle within treatment

The number of cows exhibiting estrus on their 2nd estrous cycle is displayed in Table 5 (these results were not analyzed statistically). Treatment 1 (n=17) had 5 animals showing heat on the 2nd cycle. This suggests that the majority of cows (12 out of 17) in the group were successfully synchronized and artificially inseminated. Treatment 3 (n=18) had 33.3% of the animals showing heat on the 2nd cycle and trt 2 (n=18) had 44.4% showing heat on the 2nd cycle. Results show trt 1, 3, and 2, respectively, to be the most successful estrus synchronization among the cows in this trial.

Days postpartum and sex of last year's calves of all the cows were analyzed in this study. There were no interactions found between d postpartum and/or calf sex and percent conception or

conception among trt. This suggests d postpartum and sex of calf have no effect on conception or treatment times.

DISCUSSION

A total of 11 Angus cows and/or heifers among the herd from trial 2 initially were determined open (not pregnant) when sonogrammed. Five cows were determined open several weeks after the ultrasound dates. Although this was determined beyond the end of this study, it suggests some type of issue that caused abortions. Each of the 5 cows were sonogrammed on the scheduled date and at that time had a modest sized fetus. The abortions could be due to a number of factors such as environmental conditions, stress, body condition, weather, and/or infectious diseases. The 5 cows and one of the bulls were blood sampled and tested for the reproductive disease known as Vibriosis. All test results were determined to be negative, however the blood samples were not evaluated for the other reproductive diseases or other infectious diseases. These observations imply that a similar problem could have occurred with the initial 11 cows that were determined open or not pregnant. Results from the present study raise questions as to the validity of the results since so few females exhibited return to estrus following TAI, but were later determined to have conceived to the bull. Therefore, it can be speculated the initial conception rates were higher than reported, but some unknown factor caused early embryonic loss, thereby allowing the females enough time to return to estrus and conceive during the breeding period.

IMPLICATIONS

This study found 50 h following estrus, after estrous synchronization, to be the most suitable time to AI single and multiparous cows. Also, 66 h following estrus, after estrous synchronization, is the best time to AI heifers. Due to the limited number of heifers in the trial, more research needs to be performed with a greater number of animals. It would be beneficial to experiment with times beyond 66 h on heifers to determine conception rates. Also, more research in general, in respect to estrus synchronization and TAI in cows and heifers, needs to be performed to explain the variation in ideal AI times. Additional research would also be beneficial to justify the number of open cows detected and the reason for the loss of pregnancy in several of the cows. Results of this study will be verified at

calving, thus indicating a need for additional research. If it is determined, at calving, that a problem existed with the herd sire DNA tests can be performed.

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Parasite Resistence Determined by Genetics and Species Variation in Rambouillet and Dorper Sheep

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ABSTRACT

Blood and fecal samples from 185 ewes were analyzed to estimate differences between Rambouillet and Dorper ewes for parasite burden (*Haemonchus contortus*). Rambouillet ewes (n=94) originated from 13 Texas flocks and Dorper ewes (n=91) originated from 20 flocks from 10 states. Ewes of both breeds were managed together and exposed to a natural parasite infection over a 16-month period. Fecal egg counts (FEC) and packed cell volume (PCV) were measured in April, August, and December of 2006 and April and August of 2007. Data were analyzed with a mixed linear model that included fixed effects for breed and year of birth, a covariate for body weight of the ewe and a random effect for flock origin. No significant breed differences ($P > 0.05$) were found in April, August, and December of 2006 for FEC. Dorper ewes had significantly lower FEC ($P < 0.01$) in April 2007 (533 eggs/g vs. 943 eggs/g) and August 2007 (135 eggs/g vs. 456 eggs/g). The 2007 collections were preceded by higher than usual rainfall. Dorper ewes had higher PCV ($P< 0.05$) in August (38.9 vs. 36.3) and December (38.5 vs. 36.7) 2006, which were the collections with the lowest mean FEC. No significant breed differences in PCV were observed at other collections when mean FEC was higher. Corrleations between log-transformed fecal egg counts (LFEC) and PCV were computed for all ewes together and for each breed separately. Significant negative correlations between LFEC and PCV were observed in April 2007 (-0.25; $P < 0.01$) and in August 2007 (-0.29; $P < 0.01$). Similar results were observed when estimates were calculated within breed. Flock of origin variance for FEC accounted for 0% of the variance for the three collections where there was no significant breed difference. However, in the April and August 2007 collections, 13% of the variation in FEC was due to the flock of origin. Flock of origin variance for PCV accounted for 5% or less of the variation for the first four collections. The August 2007 collection was characterized by an unusually low total variance and an unusually high flock of origin variance. Flock of origin variance accounted for 19% of the variation for the August 2007 collection. These results suggest that Dorper ewes have fewer internal parasites than Rambouillet when environmental conditions result in substantial parasite

burdens. No breed difference was observed when mean FEC was lower. Dorper vs Rambouillet differences in FEC are dependent on the environment.

INTRODUCTION

In today's research of livestock management a primary focus has been parasite resistance. Internal parasites increase costs of management and treatment, reduce production, and may cause deaths (Barger and Cox, 1984; Larsen et al., 1995). Therefore it is imperative that we better understand the relationship between livestock species/genetics and resistance to varying levels of parasite loads.

There have been numerous studies on the effects of different species and their corresponding levels of parasite resistance; however, few reports examine the relationship between genetics within and among species and parasite resistance. With hair sheep gaining popularity exponentially, one of the speculations is that some hair sheep breeds offer greater parasite resistance than their wool counterparts. There are indications of increased resistance to internal parasites in hair sheep (Wildeus, 1997). This statement could offer some degree of truthful merit due to the fact that some of the hair sheep breeds did originate in humid sub-tropical climates of West Africa in which the ability to withstand parasites, which thrive in moist climates, could be considered a surviving factor. This study was designed to: 1) evaluate ovine breed and genetic differences to see if they prove to be a determining factor in resistance to the barber pole worm (*Haemonchus contortus)* in both wool and hair sheep breeds, and 2) to distinguish if any genetic differences in parasite resistance can be found between differing genetic lineages within the same breed. The third portion of this study will incorporate the use of packed cell volume (PCV) analysis to determine if a correlation can be determined between fecal egg counts (FEC) and parasite resilience or the level of parasite burden being experienced by the individual. The hair sheep breed chosen for comparison with the known Rambouillet breed in this study will be the Dorper which originated in semi-arid desert region of South Africa.

MATERIAL AND METHODS

Flock Management

The test flock consisted of N = 185 ewes, distributed between 94 Rambouillet and 91 Dorper (7/8 or greater) ewes. From 2003-2006, Dorper ewes were acquired from 20 flocks from 10 different states and Rambouillet ewes were acquired from 13 Texas flocks for a research project designed to evaluate lifetime lamb production. The ewes were mated to USDA-MARC Composite (Leymaster, 1991) rams in single-sire breeding pastures starting in August in each of the production years from 2004 to 2007. Both breeds were maintained in the same location on the Texas A&M Experiment Station ranch facility in Tom Green County of west central Texas prior to lambing in January-February until weaning occurred (April). The ewes were held in a drylot during lambing and provided feed supplementation. One month post-lambing, the ewes were moved to small grain fields. Once the lambs were weaned (approximately 90 d of age) the ewes were relocated to the Hill Ranch lease, adjacent to the Texas A&M Experiment Station ranch facility in Edwards County in south central Texas. The pasture land in Edwards County exhibits an over story consisting primarily of live oak and ash juniper, a plant under story dominated by three awn, curly mesquite, Texas cupgrass, Texas wintergrass, and other scattered brush i.e. persimmon, algirita, and lote bush. The ewes were maintained on pasture from April until January. Parasitism was evaluated from April 2006 through August 2007 (Table 1). Ewes that had been in the flock for less than 8 months were excluded from analysis for the 2006 collections. This is because they were introduced from April to August of 2006 and we were unable to account for their previous production records and/or parasite loads.

Experimental Method

Parasite concentrations were measured in the ewes through means of fecal analysis. Fecal collections of both breeds occurred in April, August, and November of 2006 and also in April and August of 2007. Between collection dates, monitor samples were collected monthly from ten randomly assigned ewes from each breed so that if parasite levels reached critically high levels, athelmintics could be administered to prevent harm to the ewes. Fecal samples, 2 grams minimum, were collected from each ewe. Fecal samples were refrigerated with ice packs until all necessary samples were collected and were analyzed in their entirety within 48 hours. The procedure

Table 1. Sample collection schedule of (FFEC) fecal egg count of all ewes, (FPCV) packed cell volume analysis of entire population, (SSFEC) fecal egg count of a representative sample of sheep population.

Date	Sample collected[1]
April, 2006	FFEC, FPCV
May, 2006	SSFEC
June, 2006	SSFEC
July, 2006	SSFEC
August, 2006	FFEC, FPCV
September, 2006	SSFEC
October, 2006	SSFEC
November, 2006	SSFEC
December, 2006	FFEC, FPCV
January, 2007	SSFEC
February, 2007	SSFEC
March, 2007	SSFEC
April, 2007	FFEC, FPCV
May, 2007	SSFEC
June, 2007	SSFEC
July, 2007	SSFEC
August, 2007	FFEC, FPCV

[1] FFEC = fecal egg count of all ewes, FPCV = packed cell volume analysis of entire population, SSFEC = fecal egg count of representative sample of sheep population.

was conducted per the guidelines outlined by Machen et al. (2006). The specific protocol includes mixing the 2 grams of feces with 28 ml of sodium nitrate fecal float solution into a conical vial. A pipette was used to extract the solution from the middle of the vial and transfer it to a McMaster's slide. A McMaster's slide is a two chambered slide in which the fecal solution is placed, thus allowing for the microscopic examination of the parasite eggs to occur. The slide was given time to sit thus allowing the eggs to float to the top of the slide for viewing under a microscope. The slide was analyzed using a microscope at a 100X setting, the eggs were then counted on both sides of the slide. The total number of eggs was divided by two and then multiplied by 100 to give eggs per gram. Items used to conduct this study were a 100X microscope, McMaster's slide, 50 ml vials, and saline fecal float solution. A summary consisting of the number of observations, means, variances, maximum values, and minimum values of each complete fecal egg count analysis is displayed in (Table 2). Because fecal egg counts were not normally distributed, a logarithmic transformation was applied to FEC. The transformation chosen was LFEC = ln(FEC + 100), which aided in normalizing

the distribution of the results. A summary table of these findings including the same measurements as the previous table is found in Table 3.

Table 2. Total number of observations (N), mean (egg/g), variance, maximum value (Max egg/g), minimum value (Min egg/g) for fecal egg count analysis (FEC) of all ewes.

	Collection[1]				
Measurement	1	2	3	4	5
N	135	134	137	170	169
Mean, egg/g	1593.70	156.07	447.16	1043.82	776.92
Variance	3205127.97	262419.34	138934.74	724562.22	724562.22
Max, egg/g	9950	4400	1800	5450	7100
Min, egg/g	0	0	0	0	0

[1] 1 = April 2006 collection, 2 = August 2006, 3 = December 2006, 4 = April 2007, 5 = August 2007

Table 3. Total number of observations (N), mean, variance, maximum value, minimum value for log-transformed fecal egg count analysis (LFEC) of all ewes.

	Collection[1]				
Measurement	1	2	3	4	5
N	135	134	137	170	169
Mean	6.86	5.00	6.04	6.72	5.97
Variance	1.39	0.16	0.56	0.80	1.55
Max	9.22	6.11	7.55	8.62	8.88
Min	4.61	4.61	4.61	4.61	4.61

[1] 1 = April 2006 collection, 2 = August 2006, 3 = December 2006, 4 = April 2007, 5 = August 2007

Whole blood samples were collected via jugular puncture in blood collection tubes containing ethylene diamine tetraacetic acid (EDTA) to prevent coagulation. Samples were then analyzed to determine packed cell volume (PCV, %) using the micro-hematocrit centrifuge method as described by Sabine and Nickolai, (1952). This process involves drawing the blood from the collection tubes into microhematocrit capillary tubes. The capillary tubes are then sealed at the open end with hematocrit clay. Once the tubes have been sealed, the tubes are placed in a small clinical centrifuge at top speed for five minutes allowing for maximal separation between the cells and plasma. The cell and plasma levels were read against the millimeter measurement ruler affixed to the backdrop of the centrifuge. A summary consisting of the number of observations, means, variances, maximum values, and minimum values of each complete packed cell volume analysis is displayed in Table 4.

Table 4. Total number of observations (N), mean (%), variance, maximum value (Max %), minimum value (Min %) for packed cell volume analysis (PCV) of all ewes.

	Collection[1]				
Measurement	1	2	3	4	5
N	136	134	135	171	171
Mean, %	36.84	37.46	37.22	33.75	34.74
Variance	21.29	18.88	21.29	25.39	16.17
Max, %	53	48	48	46	45
Min, %	25	23	20	20	24

[1]1 = April 2006 collection, 2 = August 2006, 3 = December 2006, 4 = April 2007, 5 = August 2007

Statistical Analysis

Fecal egg count and PCV were analyzed using a mixed linear model in SAS (SAS Institute; Cary, North Carolina). Individual ewes were considered the experimental unit. The statistical model used included fixed effects for breed (Dorper & Rambouillet), and year of birth (2003, 2004, & 2005), a linear covariate for bodyweight, and a random effect for flock of origin (33 different breeders). Sheep were added to the test flock after the first three collections, therefore only 29 breeders were represented in the first three collections. In addition, when analyzing the April 2006 collection there was also a contemporary group added as the ewes had either weaned their lambs or were still lactating. The distribution of Fecal egg count was not Normal, therefore the values were transformed as LFEC = ln(FEC + 100). Correlations between FEC and PCV were estimated with PROC CORR of SAS. Correlations were estimated for the complete flock and separated by breed.

RESULTS AND DISCUSSION

No significant differences were found between breeds during the first two collections (April & August 2006; $P > 0.05$; Table 5). The single winter (December) collection showed a near significant difference ($P = 0.07$) between breeds for LFEC. Differences between Dorper and Rambouillet ewes in mean LFEC were significant during the last two collections occurring in April and August of 2007, respectively ($P < 0.01$; Table 5). Dorper ewes had lower values for parasite concentration than the Rambouillets. Parasite concentrations were noticeably higher in both breeds during the April collections of both years. The April collections were an average of 71 days after partuition in 2006 and 77 days in 2007, with the lambs' age ranging from 12 – 92d in 2006 and 35 – 97d in 2007. During lactation the ewes were grazing small-grain fields, whereas the other collections were from when the

ewes were on pasture, which had a variety of grasses and brush. Therefore, the higher FECs could be a result of denser animal populations while grazing a monoculture of small grain forage with no available browse plants and thus more conducive to a greater parasite burden. Another possible reason for higher FEC is that the ewes were lactating and the periparturient rise could be having an effect. The periparturient rise is associated with immunosuppression induced by parturition and lactation as a result of increased prolactin hormone levels. The immunosuppression resulting in a greater susceptibility to internal parasites can occur in ewes from 2 weeks prior to lambing to 4 weeks after weaning (Johnstone, 1998). The April collections fell within this time frame resulting in higher FEC for both breeds.

Table 5. Least squares breed means and standard errors and probability value for log transformed fecal egg count (LFEC) of a representative sample of Dorper and Rambouillet ewes.

	Collection[1]				
Breed	1	2	3	4	5
Dorper	6.73[a]±0.16 737.15[b]	5.05[a]±0.07 56.02[b]	5.94[a]±0.10 279.93[b]	6.45[a]±0.12 532.70[b]	5.46[a]±0.16 135.10[b]
Rambouillet	6.79[a]±0.16 788.91[b]	4.98[a]±0.07 45.47[b]	6.17[a]±0.10 378.19[b]	6.95[a]±0.13 943.15[b]	6.32[a]±0.17 455.57[b]
Pr > p	0.78	0.42	0.07	0.0047	0.0002

[1] 1 = April 2006 collection, 2 = August 2006, 3 = December 2006, 4 = April 2007, 5 = August 2007. [a] logarithmic mean Ln (FEC +100) ± Standard error, [b] backtransformed mean fecal egg count (eggs/g)

The April 2007 and August 2007 collections both showed significant differences between the Dorper and Rambouillet ewes for LFEC. These collection dates were preceded by a period of greater rainfall than the previous collections. Table 6 shows rainfall amounts in the two months prior to collection. Results suggest that observed breed differences are influenced by the environment. The August 2006 collection and the August 2007 collection were both during a time when the ewes were grazing on the Hill Ranch and were not lactating. However, the greater rainfall of 2007 resulted in a different environment.

Several studies have compared FEC in Dorpers with other breeds. Environmental conditions likely influence the results, so that inferences may not extend to substantially different environments. Matika et al. (2003) reported no significant differences (P > 0.05) for LFEC between Sabi and Dorper

ewes grazing Savannah type forage under natural parasite infection in Zimbabwe two-months post lambing, both breeds are hair sheep. These Dorper sheep were reported to be less-selective grazers, compared to Merino-type breeds (Brand, 2000). Dorpers utilized browse plants such as shrubs and bushes to a greater extent and grass to a lesser extent in relation to Merino sheep (Brand, 2000). The most heavily populated (browse) plant species located in the ewes' grazing area is Oak (*Quercus*). Oak contains a compound known as tannin, more specifically condensed tannins which can act as a natural athelmintic and thereby reduce parasite concentrations within the host (Min and Hart, 2003). Furthermore, condensed tannin levels increase within the plant as the growing season continues, for example concentrations are higher in August than in April (Forkner et. al., 2004). This could have led to the substantial decrease in parasite load for the Dorper ewes from the April 2007 to August 2007 collections versus the decrease seen by the Rambouillet ewes.

Table 6. Combined two month rainfall amounts prior to each collection in the study area.

	Collection[1]				
Amounts	1	2	3	4	5
Rainfall, cm	5.46	9.40	6.96	10.29	25.04

[1]1 = April 2006 collection, 2 = August 2006, 3 = December 2006, 4 = April 2007, 5 = August 2007

Mugambi et al. (1997) found that under a natural field study Dorpers had greater FEC than Red Maasai sheep (708 eggs/g vs 275 eggs/g). Vanimisetti el al., (2004b) found that after artificial infection with *Haemonchus contortus,* Dorper-cross ewes consistently had higher FEC than Katahdin ewes ($P < 0.01$ to $P < 0.05$). Burke and Miller, (2004) found that Dorper crossbred lambs exhibited higher FEC than St. Croix lambs ($P < 0.04$) under winter grazing conditions in south-central United States. Mugambi et al. (2005) found that under natural pasture infection straight bred Red Maasai and Red Maasai cross-bred sheep exhibited lower FEC than straight bred Dorper and Dorper-crossbred sheep ($P < 0.001$) over four collections in Kenya, Africa. Baker et al. (2003) found that straight bred Dorper lambs had higher LFEC than straight-bred Red Maasai lambs ($P < 0.05$) from 4 to 12 months post initiation of the study conducted in the sub-humid coastal portion of Kenya, Africa. While the Dorper, Red Maasai, Katahdin, and St. Croix are considered to be hair breeds of sheep this

study found no significant difference (P > 0.05) between the Dorper (hair) ewes and the Rambouillet (wool) ewes during the 2006 collections of this study. There were, however, significant differences seen between breeds during the April and August 2007 collections (P < 0.01).

This study confirms and extends the study of Notter et al. (2003), which showed that hair sheep were more resistant to *H. contortus* than wool sheep. The hair breed in that study was a Barbados Blackbelly-cross and the wool breed was a Dorset-cross, respectively, which obviously differs from the breeds used in this study. Notter et al. (2003) reported that Barbados-cross (hair) lambs exhibited lower FEC than Dorset-cross (wool) lambs (P < 0.001) located in Virginia when artificially infected with 10,000 third-stage larvae of *H. contortus* during the month of August. This result is comparable to the significant difference (P < 0.0002) between the Dorper (hair) ewes and the Rambouillett (wool) ewes with the Dorper having lower FEC than Rambouillet during the month of August in the current study. The east coast of the United States does receive substantially higher amounts of rainfall in comparison to south-central Texas, however the study location did receive above average amounts of rainfall during the two months prior to the collection date (Table 6).

Amarante et al. (1999) reported that under a 1 year natural parasite infection field study that fecal cultures collected from Rambouillet ewes revealed the highest percentages of *Haemonchus contortus (*>64%) and lowest percentages in Florida Native ewes. Florida Native and Florida Native X Rambouillet cross ewes were more resistant to gastrointestinal nematode infections than were Rambouillet ewes. Zajac et al. (1990), found that Dorset X Rambouillet cross sheep showed higher FEC and PCV compared to Florida Native and St. Croix sheep under an artificial infection of *Haemonchus contortus.* Breed comparison studies must be interpreted in the context of the environment.

No significant differences were reported between breeds for PCV during the first collection (April 2006; P > 0.05) in which there was also no significant difference found between breeds for LFEC (P > 0.05; Table 7). Differences between Dorper and Rambouillet ewes in mean PCV were significant during the second and third collections occurring in August and December of 2006, respectively (Table 7). These collections resulted in the Dorper ewes exhibiting a greater percentage of red blood cells to total blood volume. These significant differences were seen in collections where

FEC was relatively low. When the parasite concentrations were higher, PCV in both breeds was lower and there was no longer a significant breed difference. This indicates that in the absence of parasites the packed cell volume of the Dorper ewes was higher than the Rambouillet ewes. The last two PCV collections (April & August 2007) reported no significant differences between breeds ($P > 0.05$) which were the two collections in which there were significant differences ($P < 0.01$) between breeds for LFEC.

Table 7. Least squares breed means and standard errors and probability value for each packed cell volume analysis (PCV) of a representative sample of Dorper and Rambouillet ewes.

			Collection[1]		
Breed	PCV1	PCV2	PCV3	PCV4	PCV5
Dorper, %	36.73±0.62	38.86±0.63	38.50±0.64	33.92±0.65	35.73±0.61
Ramb., %	35.80±0.63	36.32±0.62	36.68±0.64	33.50±0.64	34.34±0.62
	0.26	0.0016	0.03	0.63	0.11

[1]PCV1 = April 2006 collection, PCV2 = August 2006, PCV3 = December 2006, PCV4 = April 2007, PCV5 = August 2007

Notter et al. (2003) reported no significant difference ($P > 0.05$) in PCV and a significant difference ($P < 0.05$) in mean FEC for Dorper-cross (hair) lambs and Dorset-cross (wool) lambs through week 4 post artificial infection of 10,000 third-stage larvae of *H. contortus* during the month of August on the east coast of the United States. The results of Notter et al. (2003) study are similar to the result from the August 2007 collection where the Dorper ewes had lower FEC and no difference in PCV was observed.

Matika et al. (2003) found Sabi ewes to have a significantly lower PCV than Dorper ewes ($P < 0.01$) two months post lambing under natural parasite infection, grazing Savannah type vegetation in Zimbabwe exhibiting an average annual rainfall of 62.4 cm during the study period which was conducted over a 5 year period. During the comparable time of two-month post lambing (April) collections for Rambouillet and Dorper ewes there was no significant difference ($P > 0.05$) for PCV, realizing the differing breed comparisons and environments.

Mugambi et al. (2005) found that under natural pasture infection a significant difference was found with Red Maasai lambs having higher PCV than Dorper sheep ($P < 0.05$) in Kenya, Africa.

During this same period there was also a significant difference between breeds in LFEC ($P < 0.01$) with substantial parasite loads (Dorper 1,673 eggs/g vs Red Maasai 683 eggs/g). There were no differences, however, ($P > 0.05$) between the Dorper and Rambouillet ewes in this study in regards to PCV under the two collections with the highest FEC figures.

Baker et al. (2003) found that under natural infection of *Haemonchus contortus,* Red Maasai lambs had higher PCV than Dorper lambs 2 to 12 ($P < 0.05$) months post-initiation of the study conducted in the sub-humid coastal region of Kenya. Amarante et al. (1999) reported that over a 1 year natural parasite infection field study the highest mean PCV values were recorded in Florida Native ewes, followed in decreasing order by F1 Florida Native X Rambouillet cross ewes, and finally straight-bred Rambouillet ewes.

Yadav et al. (1993) found that 14d-28d post artificial infection of *Haemonchus contortus* Hisardale lambs had significantly lower PCV ($P < 0.01$) than Munjal lambs which was also the period with both breeds experiencing the highest FEC levels. The two collections in this study that reported the highest FEC (April 2006 & April 2007) for the Dorper and Rambouillet ewes did not correspondingly have significant differences ($P > 0.05$) between breeds for PCV.

Correlations among collection data are shown in Table 8. PCV was negatively correlated with corresponding FEC throughout the study with the second collection being the only exception and not significant. There were two significant negative correlations, in the April 2007 collection (-0.25; $P < 0.01$) and in the August 2007 collection (-0.29; $P < 0.01$). These collections correspond with the instances where there was a significant difference between breeds in terms of FEC or parasite load. The Dorper and Rambouillet ewes separately exhibited significant negative correlations during the April 2007 collection, Dorper (-0.26; $P < 0.05$) & Rambouillet (-0.22; $P < 0.05$) and the August 2007 collection, Dorper (-0.27; $P < 0.05$) & Rambouillet (-0.27; $P < 0.05$). Amarante et al. (1999) reported under a 1 year natural parasite infection field study that there were high negative correlation coefficients (-0.78) between FEC and PCV which coincided with peaks in mean FEC of Rambouillet, Florida Native, and F1 Florida Native X Rambouillet cross ewes which agree with the findings of this study.

Vanimisetti et al. (2004b), reported a negative residual correlation (-0.46; P < 0.01) between LFEC and PCV in crossbred Dorset, crossbred Dorper, and straightbred Katahdin ewe lambs after artificial infection of 10,000 infective stage larvae.

Table 8. Correlations among log-transformed fecal egg counts (LFEC), packed cell volume (PCV) collections of both Rambouillet and Dorper ewes facing a natural *Haemonchus contortus* challenge.

	Traits[1]				
Measurement	1	2	3	4	5
Dorper & Rambouillet	-0.09[a] 0.31[b] 135[c]	0.02[a] 0.83[b] 133[c]	-0.09[a] 0.31[b] 134[c]	-0.25[a] 0.0013[b] 167[c]	-0.29[a] 0.0001[b] 168[c]
Dorper	-0.17[a] 0.16[b] 68[c]	0.16[a] 0.21[b] 65[c]	0.12[a] 0.34[b] 67[c]	-0.26[a] 0.02[b] 81[c]	-0.27[a] 0.02[b] 82[c]
Rambouillet	0.04 0.72 67	-0.15 0.22 68	0.22 0.08 67	-0.22 0.04 86	-0.27 0.01 86

[1]PCV1 LFEC1 = April 2006 collection, PCV2 LFEC2 = August 2006, PCV3 LFEC3 = December 2006, PCV4 LFEC4 = April 2007, PCV5 = August 2007
[a] Correlation (r) value, [b] Probability estimate (Pr), [c] Sample Size (N)

A second objective of this study was to estimate the amount of variation in FEC and PCV due to flock of origin. Other studies Morris et al. (2000) and Pollot et al. (2004) have used pedigree data to estimate genetic variation or heritability for FEC. Because many of the Rambouillet ewes in this study were obtained from commercial flocks, no pedigree information was available. Therefore, flock of origin was used in the statistical model to account for correlation among ewes from the same flock. Variance component estimates for flock or origin and residual are shown in (Table 9).

Flock of origin variance for FEC accounted for 0% of the variation for the three collections where there was also no significant breed difference. However, in the April and August 2007 collections, 13% of the variation was due to the flock of origin. This suggests that the conditions during which FEC is measured influences the proportion of variation attributed to flock of origin. In this analysis, flock or origin is used as a means to account for non-independence of ewes from the same flock. These ewes shared a common environment before they became a part of the research flock, but in many cases they also share common sires or other relatives. Therefore, the flock or origin

variance component contains genetic as well as environmental variance. The low amount of flock or origin variation for the first three collections suggests that the environmental may be negligible.

Heritability estimates were determined to be 0.3 for fecal egg count and 0.4 for hematocrit post-infection (Albers et al., 1987). Flock of origin variance for PCV accounted for 5% or less of the variation for the first four collections. The August 2007 collection was characterized by an unusually low total variance and an unusually high flock of origin variance. Flock of origin variance accounted for 19% of the variation for the August 2007 collection. The relative importance of the flock of origin variance for the August collection suggests that the environment in which PCV was measured (recent high rainfall when the ewes were not lactating) may influence the outcome.

Table 9. Variance component estimates for flock of origin and residual for LFEC and PCV.

	Traits[1]				
Measurement	1	2	3	4	5
LFEC[2]	0	0.01	0	0.10	0.17
Residual	1.29	0.16	0.55	0.68	1.19
PCV[2]	0.43	0.62	0.51	1.36	3.11
Residual	16.79	16.81	19.03	24.46	13.06

[1]1 = April 2006 collection, 2 = August 2006, 3 = December 2006, 4 = April 2007, 5 = August 2007. [2] = Flock of Origin Variance

Because the flock of origin variance can contain both environmental and genetic effects, a definitive interpretation would only be speculative. These results suggest that studies which are designed to estimate genetic variances, must document the environmental conditions because the large differences in % of variation accounted for may be functions of the large differences in environmental conditions observed in this study.

CONCLUSION

Significant differences were seen between breeds for the April and August 2007 collections which correspond with higher rainfall amounts and thus environments that were more conducive to higher parasite populations. These results suggest that Dorper ewes have fewer internal parasites than Rambuouillet when environmental conditions result in substantial parasite burdens. No breed

difference was observed when mean FEC was lower. Dorper vs Rambouillet differences in FEC are dependent on the environment. When parasite infestation levels are low, Dorper ewes possessed a naturally higher PCV than Rambouillet ewes. Because 13% of the variance for FEC was attributed to flock of origin during the April and August 2007 collections which was also in an environment that exhibited higher than normal rainfall amounts and thus higher parasite infestation levels, flock of origin does play a role when certain environmental conditions are present. The relative importance of the flock of origin variance for the August collection suggests that the environment in which PCV was measured (recent high rainfall when the ewes were not lactating) may influence the outcome. PCV is negatively correlated with FEC when parasites are present in greater quantities. Breed differences and correlations are specific to environmental conditions. Studies conducted when parasite infestation levels are low can result in outcomes considerably different from studies conducted when parasite infestation levels are high.

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Changes in Performance of Traits Measured in Performance Tests on Rambouillet Rams

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ABSTRACT

The objectives of this study were to estimate time trends in performance and time trends in variation in performance of Rambouillet rams on the Texas A&M performance test in Sonora, Texas at the Texas A&M Research Center. Traits that were analyzed were average daily gain, initial and final weight, staple length, average fiber diameter, clean fleece weight, and yield. Performance records from all years (over 10,000 Rambouillet rams) were used to estimate trends in performance and variation on performance. Regressions were estimated using the Mixed Procedure of SAS. SAS PROC MEANS was used to estimate within-year variances and SAS PROC REG was used to estimate the regression on year. The regressions of performance on year indicate significant responses in all traits except yield and fiber diameter. The trend in variances suggest that sufficient variation exists within the population to continue improvement into the future.

INTRODUCTION

Central ram performance tests are conducted to identify genetically superior sires for outstanding wool and growth characteristics, and are usually conducted in favorable nutrition environments. The purpose of central performance testing is to allow for valid comparisons of performance of animals from different locations. Performance differences observed on different ranches can be due to genetic differences as well as environmental differences. The practice of measuring performance of animals from several different ranches at one central location has been employed to remove environmental differences that can skew or bias data that is collected on the animals. If the performance of rams during the test is not influenced by pretest environment, the differences observed are genetic differences (Waldron et al., 1996). The traits observed in a central performance test for sheep include weight gain, body weight, fleece weight, fleece yield, average staple length, and average wool fiber diameter (Salisbury et al., 1999). Positive heritability estimates for gain, staple length, face cover score, and skin folds were reported by Shelton (1959), using data from the early years of the Texas A&M central ram performance test. Selection for improvement of

heritable traits would be expected to result in a change in the population over time. Shelton (1979) estimated genetic change in selected flocks from the start of the central testing program through the spring of 1976.

There is a need to document changes in performance and the variation in performance over time from the central test that was conducted at the Texas A&M Research Station in Sonora, Texas from 1948 through 2006.

MATERIALS AND METHODS

The data used in this study were collected at the Central Performance Test in Sonora, Texas at the Texas A&M Research Center. The main purpose of the central performance test is to collect and analyze data and suggest implications for future reference (Shelton, 1986). The majority of the sheep flocks in the state of Texas are Rambouillet finewool sheep and the test is more suited for testing finewool type sheep (Shelton, 1986). The first test was conducted in 1948-1949. The last data included in this study were from the test that finished in 2006. Each test started in the late summer or fall and finished the following spring. Throughout this paper a test will be referenced by the year in which the test finished. (i.e. The test that started in 1985 and finished in 1986 will be referenced as the 1986 test.)

Test Procedures

The rams that are to be tested are chosen by and remain the property of the contributing breeders, and constitute a selected population from the outset (Shelton 1979). Rams submitted for testing are all subject to pre-conditioning, which involves feeding the sheep in the testing pens the same ration that is used during the test. The animals are subject to pre-conditioning for approximately 2 wk, and all sheep experience the same environmental influences so that results from the testing are not skewed (Shelton, 1986).

The test management and calendar have had several changes over the years. The starting date of the test was chosen to closely follow the usual weaning date for lambs under typical management practices in the region. However, flocks vary in lambing time and weaning time, which results in variation in age at the start of the test. Except for the initial two years of the central test, the starting date has been in September or October. The length of the first test was 308 days. The length

of the second test was 277 days. The tests of 1951 through 1957 were 224 days long. The tests of 1958 through 1971 were 168 days long (with the exception of 1969 which was 154 days long). The standard length changed to 140 days for the 1972 test and has remained the standard through 2006.

Rams are pen-fed during the performance test. The term pen-fed indicates that rams are kept in pens rather than on pasture and there is no grazing, but the rams are fed a complete feed. Nutrition directly affects growth characteristics, and feeding regimens are conducted in a manner where nutrition is not limited. Changes in the diet of the rams on test are kept to a minimum in an effort to compare performance across the years (Waldron et al., 1996). In the early years of the test, rams were fed alfalfa (50%) and oats(50%) . In 1958 rams were fed a pelleted feed, consisting of 45% cottonseed hulls, 15% dehydrated alfalfa meal, 28% ground milo, and 12% cottonseed meal. However, the following year the test returned to alfalfa (50%) and oats (50%) because of a higher incidence of urinary calculi during the previous year's test when a pelleted feed was used. From 1960 through 1968, the ration was 70% alfalfa and 30% oats. In 1969 the test used a pelleted feed consisting of 55% alfalfa, 37% milo, 5% molasses, 2% masonex, and 1% salt. The feed formulation was changed in 1986 to 39% alfalfa, 24% cottonseed hulls, 10.25% ground milo, 10.25% ground corn, 10% cottonseed meal, 5% molasses, 1% salt, .5% ammonium chloride, .5% calcium carbonate, and a Vitamin A supplement (2000 I.U. per lb). The trace mineral salt mixture was formulated for use in complete sheep feeds, as it adds a minimum of 20 ppm of both manganese and zinc, but contains no copper. The Vitamin A premix provides a minimum of 1,000 IU of Vitamin A per pound of feed. The ration was changed in 1993 to increase protein content (Table 1). The ration was not changed from 1993 through 2006.

Rams are shorn at the test station on the day before the initial weight is recorded. Intermediate body weights are recorded approximately every 7 wk. Side and britch fleece samples are obtained in January, which is after the rams have been in the test ration for approximately 3 months. Since 1972, when 140 days became the standard test length, the final weight is recorded in mid-February. Staple length is measured on the rams and scores for face cover and belly wool are assigned by a committee of three. The committee members are either breeders or Texas A&M

Table 1. Ingredient composition for diet for rams on central performance test 1993-2006.

Ration Ingredients:	Percent (as fed)
Cottonseed hulls	23.37
Alfalfa, dehy., 17%	28.24
Grain Sorghum	24.34
Cottonseed Meal	7.30
Soybean Meal, 44%	7.30
Molasses, cane	4.87
Binder	2.43
Trace Mineral Salt	0.97
Calcium Carbonate	0.49
Ammonium Chloride	0.49
Aurofac 10	0.15
Vitamin A	0.05
Total Mix	100.00

University staff. Belly wool scores are assigned, ranging from 1 to 4, with 1 being the most desirable score and 4 being the least desirable score. Belly wool is evaluated by observing the amount of belly wool that is present on the side of the animal, and low values are desired in this category. Rams with no belly wool on their side are given a score of 1. Rams with belly wool on most of their side are given a score of 4. Face cover scores also ranged from 1 to 4. A score of 1 represents an open face with no wool from the eyes and below. A score of 4 represents a face with substantial wool below the eyes, which could result in wool blindness, which is an undesirable trait (Shelton and Campbell, 1960). The final weight is recorded at the end of the test period. The day after the final weight is recorded, the rams are shorn. In years when there were large numbers of rams, the shearing was spread over two days. Final fleeces are weighed. Fleece weights and staple length are converted to a 365 day equivalent by extrapolation based on the length of time since the on-test shearing. Core samples are extracted from the entire fleece to determine the percentage yield of the fleece. To calculate percentage yield, subsamples of the core samples were washed by using the appropriate methods in

the Annual Book of ASTM Standards (ASTM, 2005c). Grease fleece weight and yield percentage were utilized to calculate clean fleece weight.

Fold scores are assigned several days after the final shearing. Fold scores range from 1 to 4, similar to the belly wool and face cover scores. A fold score of 1 represents a ram with no skin folds. A fold score of 4 indicates a ram with moderate to heavy folds on the neck and body (Shelton et. al., 1960).

Methods Used for Fiber Diameter Measurements

The side sample was used as the primary measure of fiber diameter through 1999. Starting with the 2000 test, the primary measure of fiber diameter was calculated from a core sample of the fleece (Lupton et.al., 1997), although side and britch samples were still measured and reported.

Because of advances in fiber testing, the test has used different methods over the years. No fiber diameter values were reported in 1949 and 1950. From 1951 through 1958, spinning counts, but no fiber diameter measurements, were reported. A micronaire measurement (ASTM, 2005a) was used in 1959, 1961, and 1962. The rapid count method (Von Bergen & Mauersberger, 1948) was used in 1960. From 1963 to 1985, a projection microscope was used to measure fibers with the wedge method (ASTM, 2005b). From 1986 to 1993, a Peyer Texlab FDA 200 (Peyer Electronics, Wollereau, Switzerland) was used for the fiber diameter measurements (Lynch & Michie, 1976). Starting in 1994, an OFDA 100 (BSC Electronics, Ardross, Western Australia) was used for fiber diameter measurements (ASTM 2006).

Participation in Texas A&M Performance Test

The dataset includes records on more than 10,000 rams. Although other breeds have participated in its test, only records on Rambouillet rams were used in this study. When analyzing time trends in performance, test length and ration fed are factors that influence the performance of the animals. Length of performance testing becomes a concern, as extended test lengths can lead to increased costs for feed and labor, as well as increased fat deposition and overall body condition score of the animals tested. In the earlier years of the test, carcass conformation scores were recorded and assigned, however this evaluation of carcass merit was terminated. The main reason that carcass values are discounted in the performance test is that desirable carcass characteristics

and specifications of earlier years do not coincide with present day specifications and values (Shelton, 1979).

Flock participation through from 1949 to 2006 is shown in Figure 1. Flock participation began to increase in the late 1970s when the ram sale at the conclusion of the test was originated. Flock participation decreased during the 1990s. The decline in flock participation can be attributed to several factors, such as the 1993 phase out of the Wool Act, environmental conditions such as lack of rain, increased cost of testing, and the overall state of the sheep industry. Also, in the late 1980's wool prices dropped dramatically due to Australia's efforts to sell the stockpile of wool that the country had in reserve. This event caused wool prices to dramatically decrease, and greatly affected the sheep industry. This major event influenced flock participation numbers in the Texas A& M performance test.

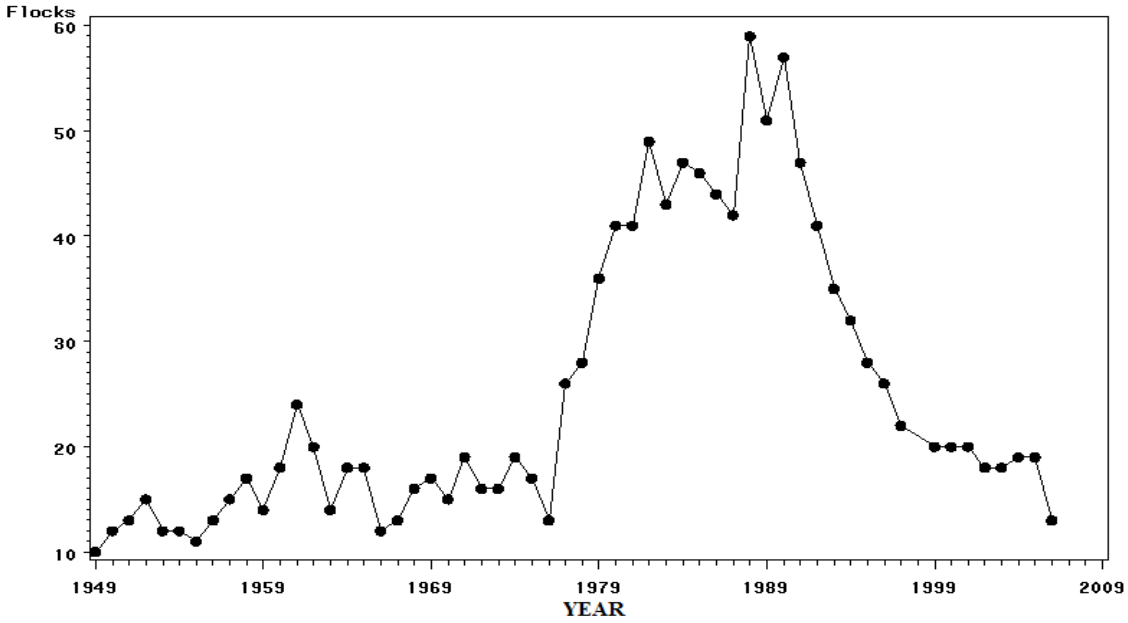

Figure 1. Flock Participation by Year for the Texas A&M Ram Test

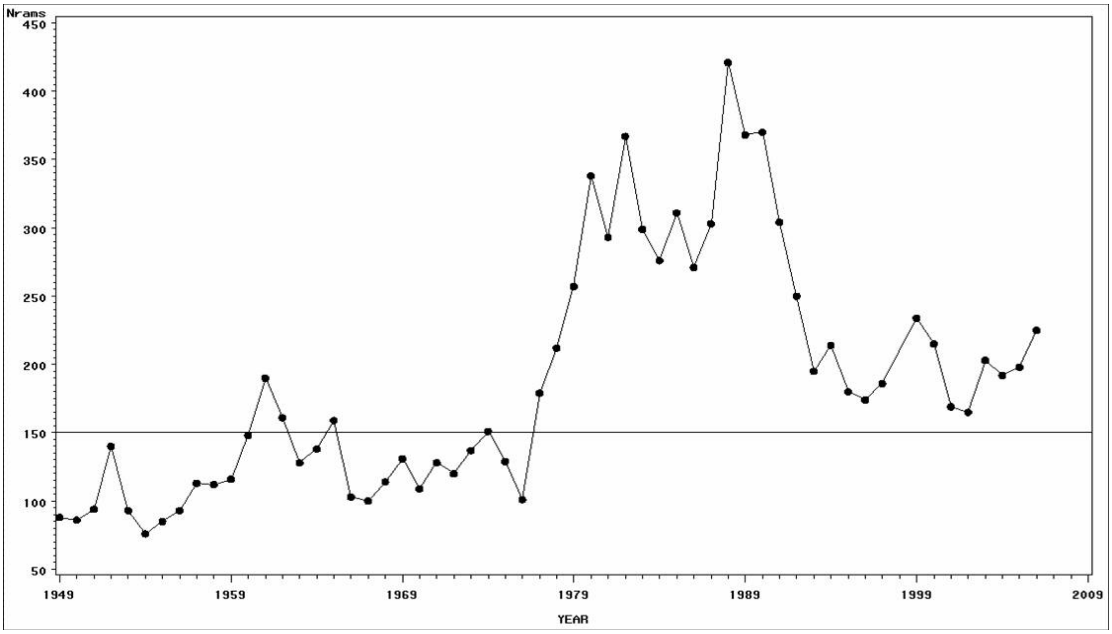

Figure 2. Ram Participation by Year for the Texas A&M Ram Test

Number of rams tested by year (Figure 2) followed a similar pattern to number of flocks participating. Ram participation has also declined during the 1990s. However, ram participation numbers over the last few years have remained relatively constant. Although flock participation has decreased over the past few years, the flocks that have submitted rams for testing submitted a larger number of rams for testing. This in turn allows ram participation numbers to stay at a steady rate.

Statistical Analysis

Performance records from all years of the test were used to estimate trends over time in performance and variation on performance. The regression of performance on year was used as the estimate of the time trend. The regression was estimated using the Mixed Procedure of SAS with a model that included fixed effects for age group (either Fall-born or Spring-born, with January 1 being the dividing date), and the test length by feed interaction, a linear covariate for year, and random effects for flock of origin and residual.

To estimate the time trend in variance of performance, within year variances were regressed on year. SAS PROC MEANS was used to estimate within-year variances and SAS PROC REG was used to estimate the regression on year.

RESULTS AND DISCUSSION

Performance Time Trends

The regression of performance on year using all available records from rams on the Texas A&M performance test in Sonora, Texas are shown in Table 2. The numbers of records varies because some rams did not have complete records for all traits. The number of rams with fiber diameter measurement from the side sample is substantially lower than other traits primarily because fiber diameter measurements were not reported from 1949 through 1957. The regressions of performance on year indicate significant favorable responses in all traits except yield and fiber diameter (AFD).

Table 2. Regression of Phenotypic Mean Values for the Total Population

Trait	N	Regression	SE	P Value
Average Daily Gain	10,549	.003 kg/yr	0.0001	<.0001
Initial Weight	10,712	.36 kg/yr	0.0130	<.0001
Final Weight	10,549	.77 kg/yr	0.0170	<.0001
Staple Length	10,554	.03 cm/yr	0.0008	<.0001
Clean Fleece Weight	10,549	.04 kg/yr	0.0030	<.0001
Average Fiber Diamater	9,701	0.04 microns/yr	0.0030	<.0001
Yield	10,540	-0.16%	0.0080	<.0001
Face Cover	10,554	-0.03	0.0010	<.0001
Belly Wool	10,465	-0.02	0.0090	<.0001
Folds	10,436	-0.01	0.0010	<.0001

Initial Weight

A steady increase in average initial weight (.36 kg/yr), ($p<0.05$) has occurred in response to selection for bigger sheep. Physical attributes of sheep entering the test in 1948 are drastically different than those of sheep entering present day testing. Body size and carcass quality differences are some of the physical attributes that have changed as a result from selection for bigger sheep. Initial weights and final weights are recorded and used to calculate average daily gain of each animal. Initial weights of rams entering testing in 1948 are dramatically different than rams entering present day testing. Average initial weight by year from 1949 to 2006 is shown in Figure 3. Year to year variation is likely due to environmental conditions such as pasture conditions on the ranches where the rams are prior to coming to the test station.

Final weight

Average final weight over the years has steadily increased (.77 kg/ yr). Averages of final weight by year from 1949 to 2006 are shown in Figure 4. Even though rams are fed in the same pens each year and few ration changes have been made over the years, environmental effects specific to each year influence final weight. The environmental effects could be pretest environment in which the animals are subject to prior to testing. Average final weight has increased due to an increase in initial weight, which can be attributed primarily to selection for bigger sheep.

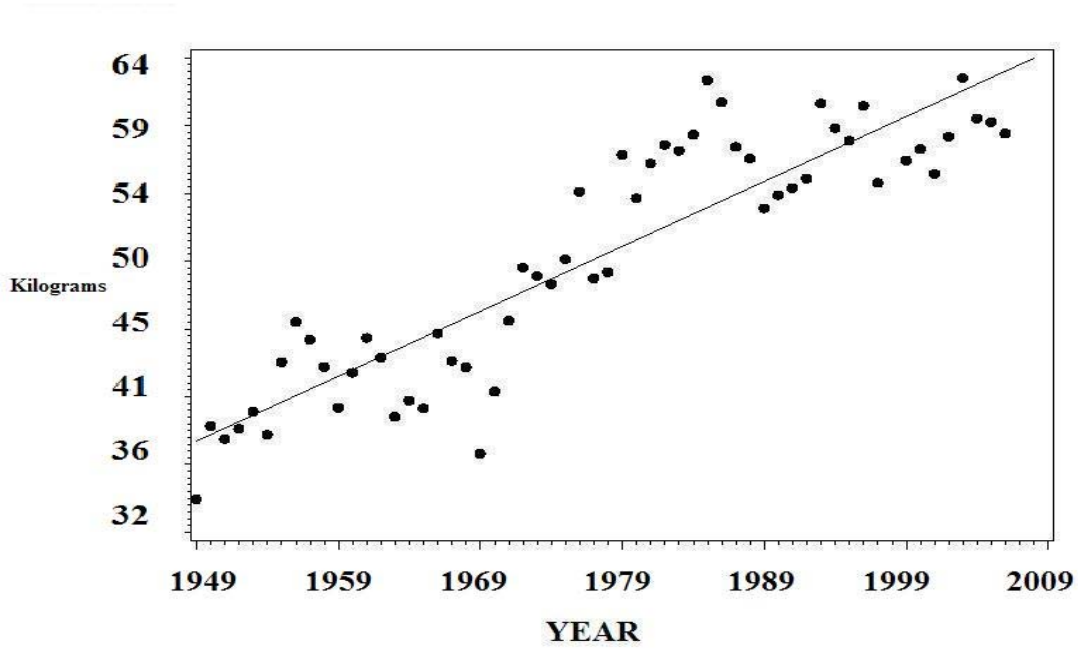

Figure 3. Average Initial Weight by Year for the Texas A&M Ram Test

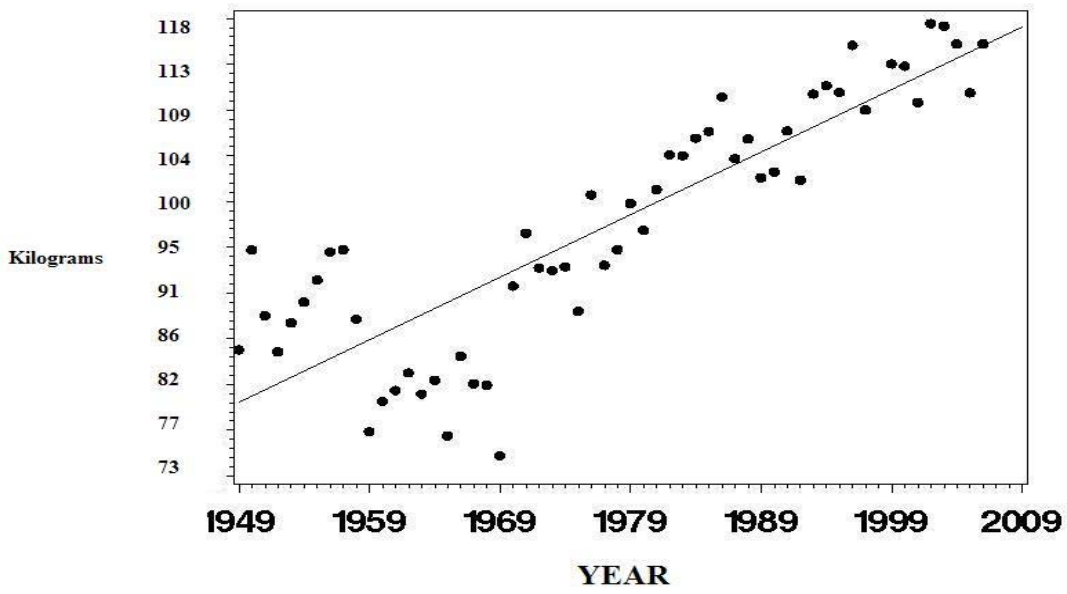

Figure 4. Average Final Weight by Year for the Texas A&M Ram Test

Average Daily Gain

Average daily gain (ADG) has increased throughout the testing tenure. Average daily gain is one of the traits that has received the most emphasis by breeders in their selection decisions. The annual increase of .003 kg/yr ($p<0.05$) over a 57 year period indicates substantial cumulative change (Figure 5). The values shown in Table 2 are estimated from a model which included fixed effects for test length, ration, and age group of the ram (Fall-or-Spring born), while the regression line shown in Figure 5 does not account for these effects. The regression of ADG on year was 4.4 g/yr (Shelton, 1979) from the data from 1949 to 1976, whereas regression analysis from 1949 to 2006 for ADG was .003 kg/yr. These trends in Rambouillet sheep are lower than those reported for Suffolk rams (8 g/yr) in central test in the Midwest (Waldron et al., 1989). This result is not unexpected because selection emphasis in Rambouillet is typically spread across several wool and growth traits whereas there is no selection emphasis on wool traits in Suffolk sheep, which are known for superior growth rate and carcass composition.

The rate of gain is a significant factor and is of great economic importance in the sheep industry. Increased average daily gain will allow the animal to reach their end point at a faster rate,

which in turn decreases the amount of time spent on feed, which then increases monetary profits for the producer (Snowder, 2002).

Clean Fleece Weight and Staple Length

Staple length and clean fleece weight have steadily increased since 1948. Averages of clean fleece weight by year from 1949 to 2006 are shown in Figure 6.

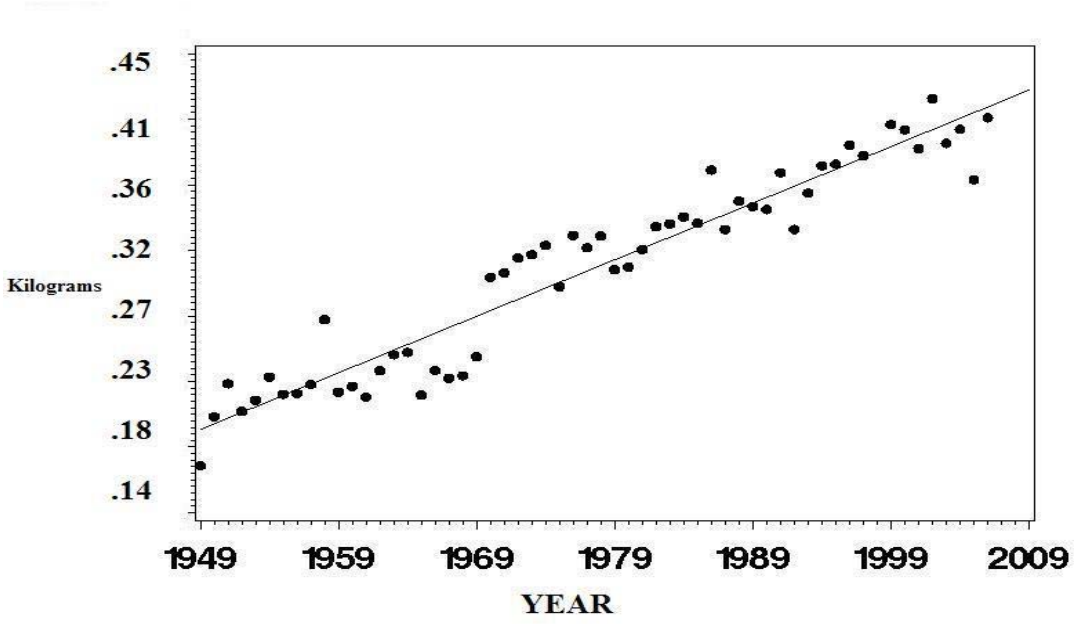

Figure 5. Average Daily Gain by Year for the Texas A&M Ram Test

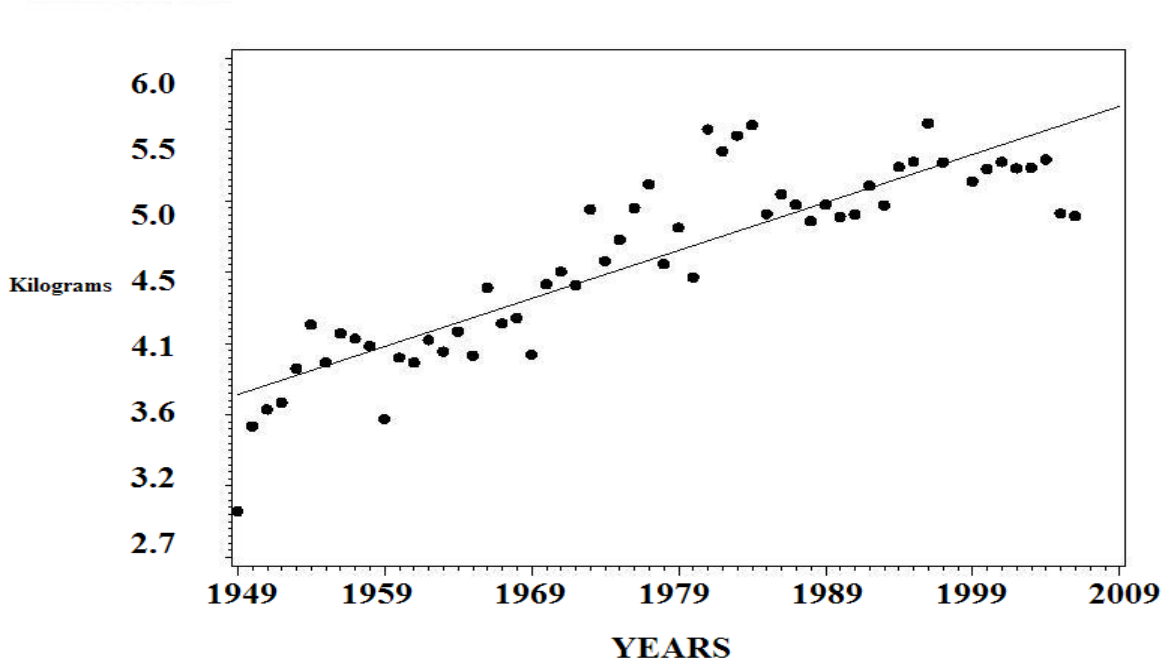

Figure 6. Average Clean Fleece Weight by Year for the Texas A&M Ram Test

Also, averages of staple length by year from 1949 to 2006 are shown in Figure 7. An increase in fleece weight and staple length yields a higher monetary return to the producer, because of the increase in total pounds of wool, which is the reasoning for measuring wool traits in performance testing. In addition, these coupled traits are the most highly heritable (the proportion of differences among animals for performance traits that are due to differences in the additive effects of the genes they possess) wool traits to be passed on to offspring (Salisbury, 1996).

The regression value for clean fleece weight from 1949 to 2006 was .04 kg/yr, whereas the regression value from Shelton's 1979 research was .034 kg/yr. Although the regression value from Shelton's research was higher, the plot for clean fleece weight still has a positive slope indicating that improvement for this trait has steadily improved through the testing duration.

The same scenario applies to staple length (Figure 7). The regression value from 1949 to 2006 for staple length was .03 cm/yr, whereas Shelton's regression value for staple length was .128 cm/yr.

Average Fiber Diameter

Fiber diameter is an important wool characteristic, as it is used as a determinant for the quality of wool. Wool quality is assessed by a combination of two factors consisting of fiber diameter and uniformity of diameter. Uniformity of diameter refers to the even dispersement of the same fiber diameter throughout the entire fleece. This factor becomes an important characteristic as it will influence both quality and price factors in the wool market (Shelton, 1986). The regression value for average fiber diameter from 1949 to 2006 was .04 microns/yr, whereas the regression value from Shelton's research was -.029. The plot for average fiber diameter has a positive slope, which indicated that fiber diameter has not improved throughout the years. However, it is known that fiber diameter is positively correlated with fleece weight (Fogarty, 1995). Therefore, the substantial changes that have been made in fleece weight with only a small increase in fiber diameter indicate that the overall value of the fleece has increased, due to genetic selection.

Belly wool scores have decreased since testing originated in 1948. The decline can be attributed to selection against high belly wool scores. Producers have selected for less belly wool. Average belly wool score by year from 1949 to 2006 is shown in Figure 9.

Yield

Fleece yield has varied throughout the years, however, this is to be expected. Yield is greatly affected by environmental conditions. For instance, in years where yield was substantially lower, rams might have been subjected to rainy and muddy pen situations, therefore causing yield percentage to drop. Average yield by year from 1949 to 2006 is shown in

The regression value for yield from 1949 to 2006 was -.16%, whereas the regression value from Shelton's 1979 research was .17 %. Fluctuation in yield percentage is to be expected, as it is greatly influenced by environmental conditions. Figure 10.

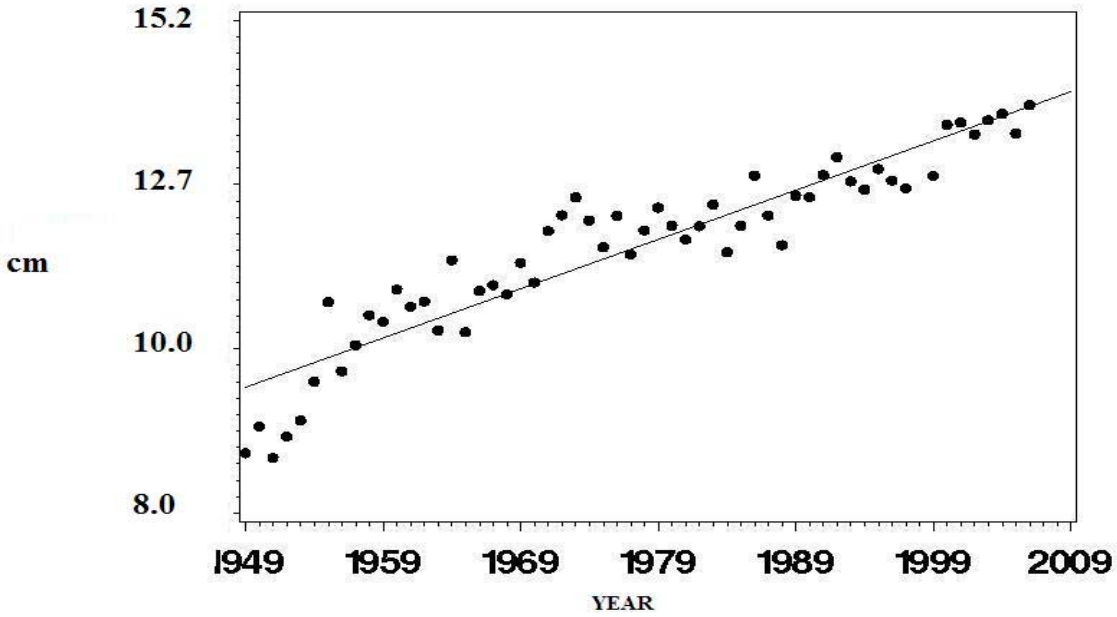

Figure 7. Average Staple Length by Year for the Texas A&M Ram Test

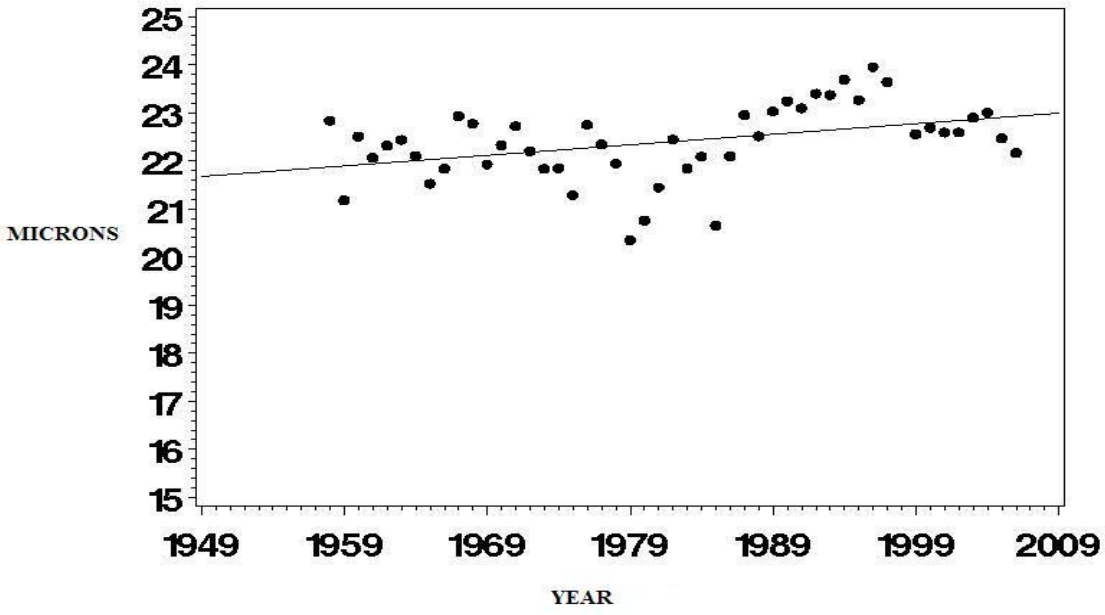

Figure 8. Average Fiber Diameter by Year for the Texas A&M Ram Test

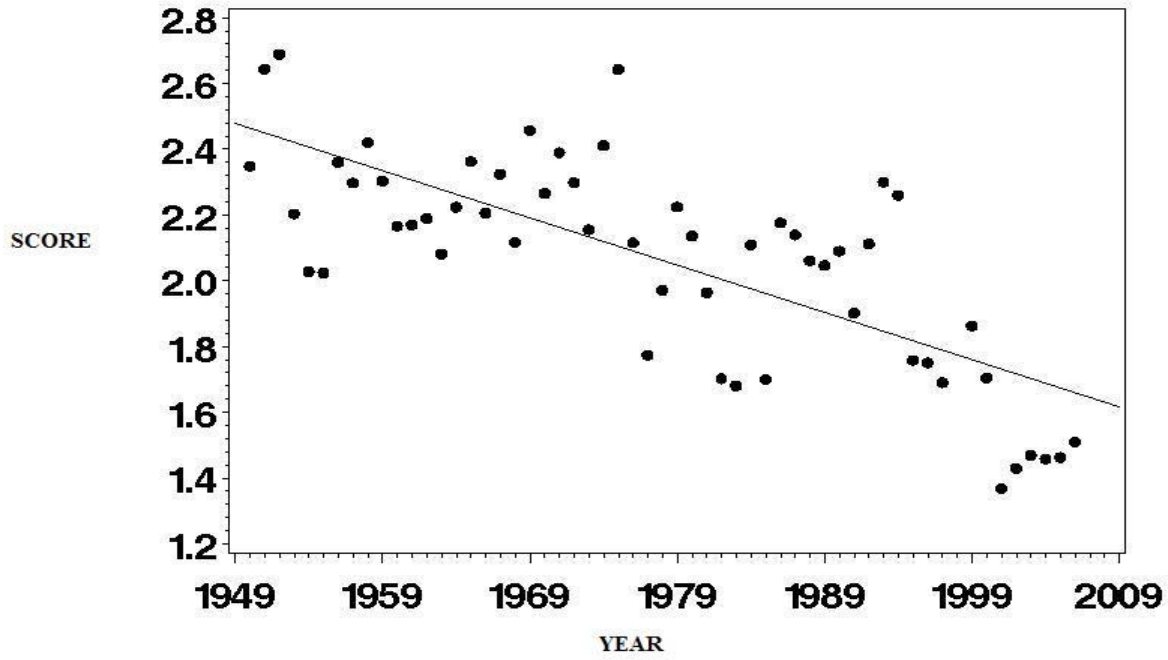

Figure 9. Average Belly Wool Scores by Year for the Texas A&M Ram Test

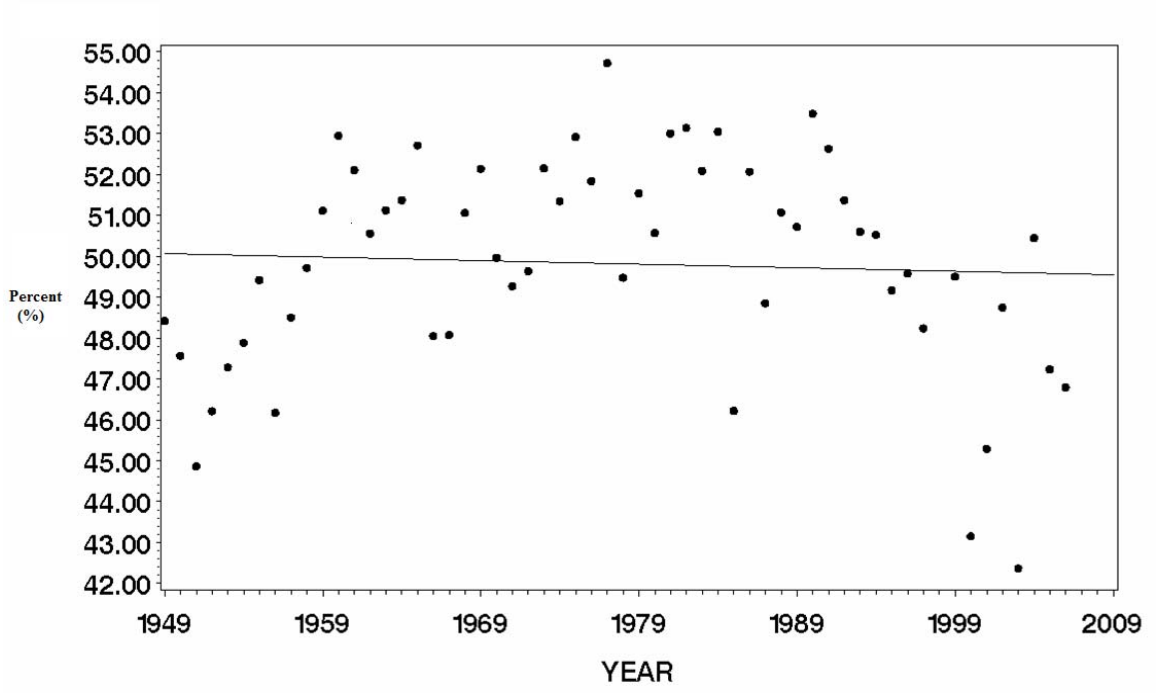

Figure 10. Average Yield Scores by Year for the Texas A&M Ram Test

Variation in Time Trends

Regressions of variances on year indicate that all of the traits, except scores, in the Texas A&M Ram Test in Sonora, Texas all have a positive slope. The positive slope indicates that for each of the traits observed in the ram test, variation is still present, therefore continued improvement for the traits can be realized. Regression coefficients for variance are shown in Table 3.

Table 3. Regression Values for Variance in the Texas A&M Ram Test

TRAITS	ESTIMATE	STD ERROR	P VALUE	R^2
Average Daily Gain	0.0020	0.00001	<.0001	0.774
Initial Weight	1.5011	0.86710	0.089	0.052
Final Weight	3.5970	0.87083	0.0001	0.237
Staple Length	0.0035	0.00043	<.0001	0.548
Clean Fleece Wt.	0.0562	0.00552	<.0001	0.653
Average Fiber Diameter	0.0113	0.02291	0.3157	0.125
Yield	0.1335	0.03823	0.001	0.181
Face Score	-0.0086	0.00119	<.0001	0.489
Belly Score	-0.0065	0.00130	<.0001	0.312
Fold Score	-0.0662	0.00976	<.0001	0.460

IMPLICATIONS

Substantial progress in most traits evaluated on the performance test is evident. The progress has had an impact on the Texas and US sheep population. Even though a small percentage of the US sheep breeders participate in the test, the impact is extended throughout the population because the tested rams are used as breeding stock in other flocks. From the 10,000+ rams tested since 1949, 2,000 of them may have been used as breeding animals.

Each of those 2000 rams could have sired 300 lambs in their lifetime. Therefore, the impact of improved genetic merit on the test would be spread to 600,000 1st generation offspring and substantially more 2nd generation offspring. The trend in variances suggest that sufficient variation exists within the population to continue improvement into the future.

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The Effect of Zinc Supplementation on Feedlot Performance and Carcass Characteristics of Growing and Finishing Lambs

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Cody B. Scott, and Kirk W. Braden

ABSTRACT

Sixty Rambouillet, Rambouillet x Suffolk corss feed lambs of approximately 30 kg in weight were blocked by weight and pen and randomly assigned to 1 or 3 treatments. Each of the three treatments received a different level of zinc supplementation (standard sheep mineral premix, 40 mg hd-1, 60 mg hd-1). Feed and water was offered *ad libitum*. Blood samples were collected via jugular venipuncture at trial's onset and every 30 days thereafter until trial's end, for utilization in determination of plasma zinc concentration. Feed samples were collected at each feeding for nutritive and supplemental evaluation. Live body weights were collected every 28 days until trial's end for utilization in determining finishing rates. Lambs were fed until approximately 54 kg in weight, at which time the lambs were harvested. Carcasses were evaluated for quality characteristics. No differeneces ($P>0.05$) in ADG, plasma zinc concentration or carcass characteristics were observed across treatments.

INTRODUCTION

Many sheep producers have been turning their primary focus away from wool production to meat production as the main source of profitability within their flock. As a result of increased meat production, utilization of feedlot systems in finishing feeder lambs has increased. Feedlot systems have advantages in growth and gain because of the ability to feed higher concentrate rations, which have been shown to positively impact rate of gain (Glimp et al., 1989). Maximizing rate of gain is important because it decreases the retention time of market animals, as well as producing an animal that is younger at slaughter.

Evidence shows that rate of gain can be further enhanced by supplementing high concentrate diets with certain vitamins and trace minerals. Zinc, an essential trace mineral, has been positively implicated in rate of gain (Zinpro Corp., 2007). Zinc is found in almost every cell within the

body and plays a major role in stimulating enzyme activity, promoting biochemical reactions, metabolizing feed constituents, and synthesizing protein. It is also a major component of insulin.

Work is being conducted that indicates increased supplementation levels of certain vitamins and minerals, such as zinc, can improve carcass quality at slaughter (Zinpro Corp., 1999). Increased yield grade is critical as it is another means of increasing profitability. Carcass quality is an important area of focus because by market standards a high percentage of feeder lambs are considered to be too fat (Jackson et al., 1997). According to the United States Department of Agriculture (USDA) yield grade scale of 1-5, with 1 being very lean and 5 being very fat, the majority of feeder lambs grade toward the high end, whereas the lamb industry actually prefers a product with a USDA yield grade of 1 or 2 (USDA, 1996).

ZINPRO zinc methionine, a highly bioavailable mineral source, when used in finishing diets, has been demonstrated to produce consistent increases in gain, performance and feed conversions (Zinpro Corp., 2007).

The objectives of this study were to: (1) determine the effect of zinc supplementation within high concentrate rations on feedlot performance of Rambouillet and Rambouillet x Suffolk cross feeder lambs, and (2) to determine the effect of zinc supplementation within high concentrate rations on carcass characteristics of Rambouillet and Rambouillet x Suffolk cross feeder lambs.

MATERIALS AND METHODS

Animals and Feeding

Research was conducted at the Angelo State University (ASU) Management, Instruction, and Research (MIR) Center, San Angelo, Texas. Sixty feeder lambs of approximately 30 kg in weight were blocked by weight and pen and randomly assigned to one of three treatments. The lambs were housed in twenty pens with three lambs per pen and 6 or 7 pens per treatment. Treatment 1 consisted of a control, where the feeder lambs received a standard sheep mineral pre-mix (Table 1), Treatment 2 consisted of feeder lambs receiving zinc supplementation at a rate of 40 $mg \cdot hd^{-1} \cdot d^{-1}$, Treatment 3 consisted of feeder lambs receiving zinc at a rate of 60 $mg \cdot hd^{-1} \cdot d^{-1}$. The animals were provided a step-up feed ration, where the level of concentrate was increased over the course of four rations (Table 1). Initially the animals started at approximately a 60:40 ratio (concentrate: roughage) and by trial's end were provided a ration that was approximately 85:15 (concentrate: roughage). The

rations were provided in continuous self-feeders and feed refusals were weighed weekly. The animals had *ad libitum* access to clean fresh water. For health reasons one lamb was culled from both the control and treatment two group. The data for these two animals was excluded from analysis.

Sampling

Blood samples were taken via jugular venipuncture at the beginning of the trial for base line assessments and every 30 days thereafter, until the end of the trial for utilization in determination of plasma zinc content. The samples were placed in EDTA tubes and centrifuged for 15 min at 3000 rpm to achieve proper blood plasma constituent separation.

Table 1. Dietary composition and nutritive values of feedlot finishing diet (as fed basis).

Ingredients	Ration #1	Ration #2	Ration #3	Ration #4
Milo, %	36.0	50.0	62.0	73.0
Soybean hulls, %	22.0	10.5	19.0	13.0
Cottonseed meal, %	6.5	4.5	3.0	2.0
Alfalfa pellets, %	30.0	29.5	10.5	6.5
Molasses, %	3.0	3.0	3.0	3.0
Sheep Mineral Premix[a], %	2.5	2.5	2.5	2.5

	Treatment		
Nutrient Analysis, %	Control	Two	Three
TDN	70.0	69.0	72.0
Acid Detergent Fiber	17.7	18.6	14.8
Neutral Detergent Fiber	25.9	28.6	21.3
Crude Protein	11.4	12.5	12.1
Zinc, PPM	62.0	77.0	116.0

[a]Premix included CP (54%), Ca (21.4%), Salt (20.6%), Mn (1075 PPM), Zn (1780 PPM), Cu (0.00 PPM), Se (3.95 PPM), Vit A (40,455 IU/Lb), Vit D (13,485 IU/Lb), Vit E (224 IU/Lb).

Approximately 2 mL of plasma was collected per sample and was transferred via pipet into scintillation vials and frozen for preservation until later plasma zinc content analysis was conducted. Feed samples were collected at each feeding and saved for later nutritive and supplemental analysis

(A.O.A.C.,1990) (Table 1). Live body weights were measured every twenty-eight days until the end of the trial and utilized in determining finishing rates.

Carcass Characteristics

Lambs were harvested at Angelo State University's Food Safety and Product Development Laboratory located at the MIR Center in San Angelo Texas. Carcass data, including conformation, flank streaking, fat thickness, and loin-eye area, were collected by facility technicians on all lambs at the time of harvest.

Statistical Analysis

This trial utilized a randomized complete block design, with a pen of three lambs serving as the experimental unit for feedlot performance data, including gain. All blood constituents were analyzed as a repeated measure analysis with each lamb serving as an experimental unit and sampling time as the repeated measure. Treatment effects on feedlot performance and blood constituents were analyzed utilizing a mixed model of JMP (SAS Institute Inc., Cary, NC). Results are considered to have significance at a variance (α) level of 0.05.

RESULTS AND DISCUSSION

Feed Analysis

Chemical analysis of each of the three zinc supplemented feed rations was conducted by Dairy One Inc., Ithaca, NY. Feed analysis confirmed that as the level of zinc supplementation increased, the availability of zinc within the overall ration was elevated. Therefore, in theory, the lambs receiving the highest level of zinc supplementation should have had an increased level of zinc uptake.

Average Daily Gain

Average daily gain was not significantly different ($P > 0.05$) across treatments for any of the weigh days (Table 2). These results contrast those found by the Zinpro Corporation (1994), where they demonstrated that increased zinc supplementation resulted in advantages in feedlot performance. However, it should be noted that the majority of current research deals with cattle, not feeder lambs. It is a possibility that there could be differences between species, which result in different response to zinc supplementation. There was a significant difference found within this study,

in that all three treatments had a higher ADG for d 0 to d 28 ($P < 0.05$). The ADG of all three treatments also started to increase toward the end of the trial, d 75 to d 95 ($P < 0.05$).

Table 2. Effect of zinc supplementation level on average daily gain[a] of finishing Rambouillet and Rambouillet x Suffolk cross feeder lambs.

	Treatment		
Period	Control	Two	Three
0-28d	0.31 ± .02	0.29 ± .02	0.29 ± .02
28-56d	0.28 ± .02	0.27 ± .02	0.27 ± .02
56-75d	0.26 ± .02	0.25 ± .02	0.26 ± .02
75-95d	0.31 ± .02	0.23 ± .02	0.27 ± .02

[a] Means and standard errors in kg.

Carcass Characteristics

Table 3 illustrates least square means for carcass characteristics of Rambouillet and Rambouillet x Suffolk cross feeder lambs fed three levels of zinc supplementation. No significant differences ($P > 0.05$) were found within any of the carcass characteristics analyzed. In addition to the characteristics presented in the table, all lambs were evaluated for conformation. The majority of the lambs across treatments graded low choice, with the exception of one lamb from both the control and Treatment 3 grading good and one lamb from Treatment 2 grading low prime. These findings conflict with those found by McBeth et al. (2002), where they demonstrated that feeding added levels of zinc in addition to the basal diet resulted in carcass advantages.

Dietary Zinc and Plasma Zinc Content

Table 4 illustrates least square means of plasma zinc levels for each of the three treatments at three sampling intervals. No differences ($P > 0.05$) were found for level of plasma zinc across treatments. This finding counters research by Kececi and Keskin (2002) where it was demonstrated that when both sheep and goats were supplemented with a zinc source, there were concurrent increases in zinc plasma levels. According to human research (Freeland-Graves et al., 1982), it is possible that increases are not seen due to the body's attempt to maintain homeostasis despite

increases in supplementation. Their research demonstrated that supplementation initially increased zinc plasma but levels do not continue to increase and plateau after four weeks. It is also a possibility that since the level of available zinc contained within the sheep mineral pre-mix, used during the research

Table 3. Effect of zinc supplementation level on carcass data[a] of finished Rambouillet and Rambouillet x Suffolk cross feeder lambs.

	Treatment		
Item	Control	Two	Three
N	6	7	7
Hot Carcass Weight, kg	29.1 ± 0.92	29.2 ± 0.86	29.6 ± 0.86
Loin-Eye Area, cm^2	8.6 ± 0.18	7.9 ± 0.16	8.1 ± 0.16
Back-Fat, cm	0.46 ± 0.03	0.36 ± 0.03	0.48 ± 0.03

[a]Means and standard errors

Table 4. Effect of zinc supplementation level on plasma zinc content[a] of Rambouillet and Rambouillet x Suffolk cross feeder lambs.

	Treatment		
Period	Control	Two	Three
Baseline	0.41 ± .09	0.57 ± .08	0.55 ± .07
30d	0.65 ± .07	0.60 ± .07	0.65 ± .07
Pre-slaughter	0.86 ± .08	0.74 ± .07	0.70 ± .06

[a]Means and standard errors in ppm

conducted at the MIR, was higher than NRC recommended levels, the additional zinc administered to the treatment two and three groups increased the available zinc to a level that was beyond what the lambs were physiologically capable of utilizing. The research conducted at the MIR resulted in a significant difference based on sampling period, where the plasma zinc content increased for all treatments from the initial sampling period to the pre-slaughter sampling ($P < 0.05$).

IMPLICATIONS

The data collected in this trial indicates that supplementing Rambouillet and Rambouillet x Suffolk cross feeder lambs, in a feedlot feed system, with levels of zinc beyond what they receive with a standard sheep mineral pre-mix, will yield no increases in either performance or carcass characteristics.

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Agriculture Graduates

Bold denotes graduate student

1975

Robert Glenn Burwick (December 1974)
Tom Burson
Ronnie Edington
Alton Everett
Randy Gill
Rebecca Harris
Marcus McCellan
Donald Phelps
Horace B. Walker
Randy Bredemeyer
Thomas Jernigan
Guy Levey
Ricky Marks
Riley Sterling

1976

Bobbie Baldwin, Jr
Debra Beth Barker
Ricky Lane Childress
Warren Fay Dozier
Charles E. Fant
Ronald Edward Halfmann
Daniel Wayne Kujawski
John William Van Court
Donald Joe Wilde
James Carl Williams
Calvin Jackson
Johnny Wayne Todd
Malcolm F. Gerngross
Curtis Ben Cox, Jr.
Larry William Dean
Jimmie Lee Trojcak

1977

Thomas Lee Allen
Richard Ray Collett
William Stephen DeHay
Bernard Fuchs
Ernest Fred Groff
Charles Jackson Hughes
Sidney Truman Johnson
Kevin James May
Mark Louis Shepard
Virgil Neil Conner
Charles Bernard Halfman
Stephen Morris Hinshaw
Steven Hoelscher
James K Kiunga
Jerry Talley Jr.

1978

Paul Daniel Barnhill
Raymond W. Beam
Terry Lynn Blair
Tony Carl Frerich
James Keith Hood
Michael Fred Matthews
Jo Ann Snodgrass
Terry Lynn Stokes
Kenneth Wayne Straw
Jack M. Sykes
Jim William Wright
Danny David Daniels, Jr.
Darrell Gene Meyer
Dale Edward Neagle
Donald Harold Bunch
Vickie Patterson Hillger
John Lloyd Newman
John L. Seaton
Lee Edwin Warren
Galen Ray Weiershausen
Thomas Alton Williamson

1979

Shelia Elaine Allbright
Joe Bass Arnett
Calvin Dee Boatright, Jr.
Debra Ann Clouse
Andy Mike Eubanks
Ronald James Gill
Joel Wayne Holladay
Robert Benjie Jay
Brian Forrest Meeks
Randall Oein Pittman
David Lane Tunmire
Dennis Jay Uherik
Faron Almon Pfeiffer
Joe Don Roach
Tom Heath
Milford Logan
Bill Wilson

1980

Preston Elba Adams
John T. Bassinger
Howard Gene Callison
Mark Winn Dobbins
Dean William Eckert
Steven Neil Glass
David H. Masters, Jr.
Brian John May
Joseph Gregory McReynolds

Charles Richard Bradshaw
Bruce Deere
Michael Garza
Kelly Jean Gully
Brent Heinze
James Alton Kolb
Victor Roy Probandt
Jay Thomas Holstein
Mark Allan Mishnick
Gary Don Stokes
Tandy Sueann Wilmeth
Gary Lee Wilson

1981
Bruce Backland
Steve Cook
Kyle Christopher Hodges
Ricky Machen
Julie Ann McFarlin
Dennis Newton
Charles O'Connell
Brad Pierce
Rodolfo Diaz Ortiz
Elias C. Rodriquez
Pat H. Shannon
Vernon Elliot Sublett
Bernie Wallace
Brenda Kay York
Duane Allan Stryker
Mark Louis Shepard
George Scott
Gerald Glen Risher
Ronald J. Gill
Lee Edwin Warren

1982
Randall Bankhead
Terry Lee Criner
Pat Dryden
David Fuessel
Stephen Kuhlmann
Mary Jean Owens
Danielle Rosser
Patty Dietrich Stokes
Arthur Wayne Striegler
Terry Waller
Michael Scott Wilburn
Mark Wylie Worthington
Robert Charles Surratt
Brian J. May
Milburn Wright, Jr.
Curtis Glenn Childress
Kelley Ann Collins
Craig Demere
Louie Grant Drennen
Timothy Clay McReynolds
Frank Pecina Jr. III
Vaden Aldridge
Stephen Byrns
Faron A. Pfeiffer
Henry Gene Adams, Jr.
Alan Bossenger
Harlan Clay Nance
Ken Roy Pfluger
Paula Kay Saunders
Jeffery Kyle Wright

1983
Mike Barrera
Curtis Boos
Donald Loding Campbell
Dennis Vinson Cumbie
Edward Earwood
Kevin Hale
David Hayden
Joey Henderson, Jr.
Roberto Hernandez, Jr.
Dana Johnson
Johnny Murchison
Roy Musquiz, Jr.
Donald Reeh
Mark Swening
Alfred Vardeman
Brett Alan Williams
Bruce Backlund
Yousef Bengharsa
Will Walter Allison
Carol Cervenka
Mary Ann Kirk
Emily Elizabeth Moll
Barbara Pfieffer
Jack Renfro
Sandra Lynne Stewart
Mustafa Mohamed Mankusa
Randall C. Ward
Gary Lynn Bishop
James Robert Harris
Brand Mund

1984
James Hood
Molly Baskett
Wilburn Baucom
Gideon Cheruiyot
Craig D. Cook
Charles Brett Cypert
Keith Floyd
Lisa Gabier
Danny Gunn
Timothy Fred Hardt
Taylor Dean Hayes
R.D. Hinojosa, III

Vanessa Lusby
Bill Pitman
Eddie Probandt
Bobby Rogers
Dee Ann Smart
Stephen Surratt
Wesley Joseph John Thee
Mike Thomas
Bradley Dean Thompson
James Wilde
Bruce Deere
Robert R. Allen
Greg Browning
Leland Hunt, Jr.
Partick Pearce
Steve Sappington
David Wayne Schofield
Calvin Glenn Steward
Rodney Jay Winn
Gary Dewayne Callaway
Renee Michelle Evans
Rex C. Ewert
Hillie Hunter Hayes
Wesley Zane Hodges
Leland Wayne Key
Daniel Russell Koenig
William C. Kothmann
Roger Woods Lux
David Brent Sherrill
Joe David Sherrod
Todd Wade Swift

1985
Donald Blair
Randall Brown
Jimmy Fontenot
Randall Jenkins
Charlotte Klepac
Scott Porter
Stephen Wayne Reynolds
Pat Thomas
Wilton Weise
Ben Wilde
Darrell James Wilde
Rafael Suarez
Johnny Murchison
Sulaiman Awagi
Jeff Hamilton
Jay Hawkins
Mark Ramirez
Danny Vann
David Bruce Fletcher
Ricard Kelly Gilbert
John Harvey Gronold
Cary Dean Hannsz
Stehpen Scott Mooney
Steven Reece Moore
Royce Lee Pyssen
George William Smith
James Curtis Turk

1986
Thomas Ray Allen, Jr.
William Banner
Scott Lamar Cauthen
Jonama Cox
Joe Branton Day
Carlos Gibbs
Greg Keith Hagel
Lee Strait Hitch
Wayne Carl Hofmann, Jr.
James Walter Keeton
James William Kothmann
Randy Dale Kruse
Mike T. Kyzar
Mark Randall Oates
Clay Yandell
Cary Don Baker
J.W. Carter, II
Jeffrey Duncan
Michael Wayne McDaniel
Wade McMurrary
Kaung-Huei Liu
Stephen Ray Sappington
Jeffery Kyle Wright
Kevin Dale Barron
Carle Max Brandenberger
Stacy Todd Campbell
Eddie Frank Dusek
Kirk Lane Griffin
Gregory Irvin Hohensee
Regan Stuart Kirk
Bonnie Lou Mayer
Joao Livio Norberto
Steven Mark Quade
Eugene Bitner Roberts
Rocky Stewart Vinson
Raymond Roy Walston, Jr.
Jeffrey Craig Williams

1987
Leland J. Hunt
Terry Brent Baucom
James Hubert Bell
Ella Marie Blair
Lonnie Randall Bolf
Jay Donivan Daniel
Samuel D. Fuhlendorf
Bradley Dwayne Fulton
Jeb Brant Henderson
Robert P. Hunter
Courtney Lance McNeely

Kathering Inez Pappas
Fernando Adlolfo Reyes
Darren Ray Richardson
Gregory Ray Schwertner
Maribel Alicia Tarango
Karl Tatsch
Rex Taylor
Roger Tinder
Jerry Don Vinson
Bryan A. Davis
Troy Lennon
Helio Paranagua, Jr.
Jimmy Fontenot
Randall Jenkins
Steve Moore
Bennie Caly Edwards
Jan Hatler
Kraig Peel
Kenny Strube
Tracy Tippett

1988
Steve Kuhlman
Nancy Benson
Scott Christopher Blanton
Kay Carrig
Michael Fanning
David Feldhoff
Karen Frey
Lee Higdon
Jeff Lewis
Wade Menges
Chris McReynolds
Monica Reining
Kathy Thompson
Ken Weidenfeller
Allan West
Cheryl Robinson
Dave Cleavinger
Terry Criner
Larry Herd
Trey Glen Morgan
C.W. Roberts

1989
Deborah Sue Divich
Russell Stevens
Clinton Calk
Browder Graves
Mark Gray
Kelly Griffin
William Mark Harris
Lester Everett Matthews
Kevin Pounds
Joseph Raff
Jacqueline Hermesmeyer
James Glen Miller
Noel Williams
David Carlisle
Amy Teagarden
Roddy C. Gordon II.
Novice Joe Moore
Russell Rogers
Frankie Sablan
Marck Todd Schafer
Barry Smith

1990
Adebanjo Adesoji
David Bohnert
Bill Head
James Horton
Clint Koenig
Kevin Owen
Cody Scott
Troy Seals
Jim Meredith
Larry Herd
Lee Clark
Ron Gillaspy
Bobby Herrington
Randy Houston
Ed Miller
Britton Lee Roman
Wiley Payne Rudasill
Trent Tankersley
Tom Underwood
Kevin Pfeiffer
Brad Spenrath

1991
Bryan Davis
Lynn Dye
Robert Charles Graff
Mike Harbour
Wendy Holman
Randall McCarty
Wade Menges
Miguel Rendon
Richard Shaver
Daryl Whitworth
Scott Grote
Frank Habecker
Gus Ward
Joe Raff
John Clifford Fisher
John David Laxson
Billy Jay Ledet
Eldon Todd Love
Kevin P. Przilas
Kristi Lynn Stone
Todd Swift

1992

Albert L. Booky
Clinton Calk
Barry Lee Cooper
Cody Burk Scott
Justin Amerine
Shawn Burns
Jeffrey William Cowan
Roy Kevin Downey
Sharilyn Sue Friesen
Justin Henefey
Jamie Carole Inman
Brett Johnson
Chad Seward
Robyn Sims
Timothy Smith
James Sullivan
William Alan Head
Melissa Bollinger
Tim Lust
Keith Randall Shaffer
John David Whipple
Pammy Lynn Millican
Timothy Sean Phy
Todd Rossington
Debra Rozell
Todd Schafer

1993

Bryan Davis
James Weldon Faught
Randy Alan Gartman
Linda B. Naranjo
Steven Don Parker
Robert Pritz
Nikki Dawn Ramsey
Virginia Shannon Riley
Belinda Rivera
Kelly James Sanders
Mitchell Elton Wilmeth
Chad Coburn
Chris George
Kip Giles
Cody Hill
Kevin Shane Kelton
Kelly Gully
David Laxson
Jason Lee Bannowsky
Michael Brent Crawford
Robbie Glenn Eckhoff
Charles Estanol
Dawn Alicia Kleiber
James Clayton Richards
Dale Anthony Schwarts
Terri Bibb Webber

1994

Amber Bickham
Terry Blair
David Bohnert
Marvin Dale Dunlap
Russell Rogers
Shannon Bennie Bannowsky
Michael T. Billingsley
Donna Cates
Melvin R. Davis
Darrell Dusek
William Todd Friend
Charles R. Hollingsworth
Gilbert Horton
Jason Victor Jones
Alyson Kay McDonald
Daniel Park
Micheal Salisbury
Roxanna Kate Schwinge
Allie Snider
Walker Walston
Keith Shaffer
Thomas Bryan
Olen Burditt
Jeff Chisum
Janet Cox
Thomas Hughes
Jeremy Don McCollom
Michael Moore
Martin Weatherbee
Ed Miller
Glen Allan Phillips
Brain Harwell
Rebecca Haschke
Winston Herndon
Justin Marschall
Elizabeth McFadin
Allen Russell Morgan
Stacy Lane Morris
Chad Sims
Travis Kent Wier

1995

Marty Gibbs
Kelly Sanders
Katherine Allison
Ross Benson
Malcom Boger
Jimmy Caughron
Wade Cypert
Blain Ferris
Ramiro Guzman
Brian Hill
Brantely Hoelscher
Eddie Onofre

Fulton Pizzani
Rowdy Rea
Scott Smetana
Faron Sultemier
Make Zuniga III
Chad Coburn
Mikel Harbour
Homer Lee Higdon III
Nancy Law
Kimberly Ann Ball
Shelly Summerour
Philip Carter
Ross Stultz
Shelly Frazier Best
Kevin Duke
David Foster
Walden Hillert
Todd Holbrooks
Scott Hohensee
Thomas Franklin Kelso
Tara Mallett
James Murdoch
David Hershel White
Katerine Wurster

1996
Gibert Horton
Wade Armke
Michelle Behrends
Billy Belew
Cain Cline
Jill Dice
Steven Hise
Thi Hoang Oanh Hoang
Billy Mac Howe III
Pam James
Shawn Nanny
Jeffrey Osbourn
Jody Osbourn
Brad Roeder
Cody Schoenfeld
Gwendolyn Sue Taff
Kathrine Valdez
Dan Vestal
Richelle Renee Wilson
Doug Bawcom
Bryan Bendele
Todd Broncy
Trey Garmon
Pascual Hernandez
Sara Lewis
Abel Robles
Tim Sims
James Steen
Jason L. Denman
Christopher S. Herzog
John David Isenhower
Brook Dowell Matthews
Richard Minzenmayer
Mike Salisbury
Brady Weishuhn
Sandi Zimmerman

1997
Kim Ball
George Trey Poage
Rowdy Rea
Ronnie Brewer
Kim Cox
Eddie Hall
Brandon Heiser
Bridget Mansell
Jerry McGinnis
Dac Pennick
Octavio Ramos
Christy Strube
Jodie Uptergrove
Shawn Uptergrove
Jeremy Blain Myers
Amy J. Pilmer
Peggy Simpson
John Barfield
Kevin Kuhlmann
Bennett Tate Thoreson
Whitney Whitworth
Rebecca Young

1998
Justin Alexander
Wade Armke
Reace Bennett
Bryan Campbell
Richie Griffin
Lane Hughes
Pamela James
Bridget Jones
Steven Jost
Charles Kneuper
Richard Lepard
Leesha Ligon
Jason McCoy
Rachel Pentecost
Andria Perales
Jennifer Rose
Geoffrey Scott
Adam Clay Warren
Casey White
William Wood
Jason Frost
Jeremy Brandon Hartgrove

Jay Holt
Robert Paul Law
Wesley Whitehead
Brain Shane Atzger
Parrish Braden
Rusty Fleeman
Daniel Kuntz
Thomas Randall Rakowitz
Stephen Wade

1999

Jennifer Bedell
William D. Burns
M'Liss Burrier
Amy Coburn
Kim Cox
Dewey Alan Drennan
Bronson Gobert
Eddie Hall
Dale Ashton Harris
Brandon Heiser
Brantely Heiser
Tessie Ingram
Shelby Johnston
Chris Lupton
Leslie Moczygemba
Fred Reyna
Karalina Rigsby
Anthony Sanchez
Kristina Schulze
Peggy Simpson
David Sirmons
Shelly Smith
Julie Smithwick
David Stone
Wade Travis Tellinghuisen
Juan Vasquez
Clint Warren
Justin Weishuhn
Laurie Weishuhn
Karee May Wiggins
Jeriann Williams
Ashley Wilson
Grady Wilson
Brandon Zesch
Rhea Allen
Clint Matt Culp
Sarah Fitzgerald
Ronald Heineman
Ladd Hughes
Pamela Jetton
Kevin Shane Kelton
Charles Seidensticker
Terry Sirmons
Whitney Whitworth
Justin Clark
Sherry Hall
Mark Martinez
Todd O'Neil
Robert Allen Parry
Byron Wayne Pfeifer
Robert Phillips
Monica Swenson
Michael Weckel
Cynthia Whitehead

2000

Maria Anzaldua
Brandon Asbill
Jamie Bass
Andrew Boomer
Garry Branham
Bret Breitenkamp
Bill Burnes
Cory Carroll
David Bradley Cook
DeAnna Crain
Dee Dusek
Kelly Edwards
Jason Frost
Rachel Frost
Brandon Green
Richard Griffin
Beverly Gully
Tom Guthrie
Devin Hoover
Caleb Kattner
Charles Kneuper
Stacey Kotrla
Justin Lampier
David Lytle
Jerry McGinnis
Zeno McMillan
Alvaro Ruiz
Robert Ross Sims
Robert Steakley
Jared Taylor
Wynne Whiteworth
Lee Brinegar
Justin Douglas Dunlap
Kelly Hart
Matt McMillan
Kari Ashcraft
Amanda Browder
Brock Fry
Jana Jackson
Quinn Johnston
Caylie McClure
Martin Schuh
Stephen Wade
Charlie Wakefield
Chad Zibilski

2001
Jesus Becerra
Blake Belcher
Russell Dean Black
Joshua Blanek
Ben Brandon Brooks
Christopher Carey
Justin Collins
Marshall Davidson
Curry Dawson
Susan English
Heidi Ertresvaag
Caitlyn Felder
Becca Ferguson
Jeff Fiedler
Sarah Fitzgerald
W.C. Foster
Curtis L. Garrett
Briana E. Harbaugh
Tami Harris
Ladd S. Hughes
Jon Jennings
Will Kiker
Haley Jo Knutson
Eli Ornelas
Kari Pierce
Laura Rush
David Sirmons
Craig Thomas
Jake Wagner
G.W. Yandle
Andy M. Laughlin
James William Loveday
Deana L. Moore
Jason William Stewart
Jeffrey Wheeler
Justin Will Avery
Jeffrey Lane Berry
Corrie Maria Canava
Chad R. Ellis
Brian Faris
Patrick Fowlkes
Casey Ray Hayes
Jennifer Ann Heard
Shy L. Middleton
Fred Reyna
Gary Alan Witt

2002
Casey Alexander
Garry Branham
Loree Branham
Maria Terrie Carr
Cory Carroll
Robert Cook
Justin Corzine
Bobby Deeds
Robert Diaz
Wayne Trey Dunson
Amy Heathcott
Jed Hruska
Haden Keyser
Brandon Payne
Fabian Rodriguez
Eric Ross
Alicia Simpson
Robert Steakley
Jeff White
Ty Williams
Telitha Winge
Jason E. Entzminger
Rebecca Lynne Hill
Tessie Irene Ingram
Kristopher Kaufmann
Charles H. Wakefield
Lue F. Arn III
Bobbi Lee Blanek
Jessica Sue Boesen
Jason Brooks
John Lee Carr
Casey Dawn Carroll
Jessica Cobos
Melissa A. Cone
Derric Dustin Crowe
Justin Matthew Duyck
James Robert Ellison
Cameron Wade Everton
Richard H. Fohn
Brock Fry
Brandi Lane Loftis
Fernando Martinez
Heidi Erin McIntyre
Norberto Mendoza, Jr.
Jerrod K. Pitcock
Joe Martin Self, Jr.
Scott Jeffery Talley
Krista Renee Tydlaska
Cassidy Watson
Wynne Rae Whitworth
Dara Alyssa Wilde
John Zertuche

2003
Jessica Renee Atchley
James Ray Bilbrey, Jr.
Kevin Jacob Drennan
Brent J. Dugas
Daniel C. Dusek
William C. Foster
Jessica Y. Gomez
Phoebe Ann Harrell

Justin Waid Jackson
Will Kiker
Haley Jo Knutson
Lacy Darlene Mercer
Christopher Merren
Jonathan Wayne Meurin
Michael J. Pentecost
David D. Powell
Mark Ray Sheets
Benjamin D. Taylor
Carrie A. Taylor
Lena Alison Williams
Spencer W. Wyatt
Paul G. Yandle
Lessa Ann Bullock
James M. Clark
Andrew M. Hart
Sean M. Kendrick
Kristy Ann Melton
James Paul Skipworth
Sonya M. Washington
Audrey Akers
Courtney Allen
Leslie Ann Fangman
Dustin Gragg
Mary Elizabeth Guerra
Lauren Hahn
Jeremy Haynes
John Allan Henkhaus
Bryan Jennings
Jessica Kiker
Jason McDaniel
Trenton Stephens
Brian Stevens
Leticia Stogner
Cody York

2004
Leslie Alexander
Levi Babb
William Travis Bond
Michael Burrows
Shannon Counts
Mia Dues
Kyle Ellis
Krystal Farmer
Blake Gentry
Jenai Gill
Scarlett Lampier
John Henry Leifeste
Cathleen Moore
Chris Moore
Elliott Parks
Jamin Phipps
Kimberly Terrell
Jessica Williams
Loree Branham
Robert Cook
Daniel de Carvalho
Bobby Deeds
Wayne Dunson
Shy L. Middleton
Brandon Payne
Marc Tucker
Daniel Woolley
Jon Austin
John Craig
Tara Basse
Ned Dunbar
Jonathan Ellison
Nathaniel McMillan
Michael Lackey
Norberto Mendoza

2005
Jon Calcote
Kevin Corzine
Jarrod Cook
Rodney Henderson
Cliff Kinnibrugh
Clint LeMay
Teresa Lovett
Rayle Taylor (Self)
Kayla Niehues
Corey Owens
Andrea Payan
Chase Ratliff
Andy Sandbothe
Levi Wilhite
Andrea Shields
Brandon Asbill
Will Hartnett
John Kellermeier
Michael Thornton
Lauren Hahn
Joe Self
Tammy Vretis
Tyler Bybee
Ross Copeland
Blake Franke
Aaron Hart
Jeremy Hasty
Tabitha Lloyd
Darby Makloski
Morgan McCutchen
Alfredo Munoz
Thomas Parks
Dustin Ratliff
Dixie Simpson
Heath Stoerner
Cole Wadsworth
Trevor Watson

Ty Wheeler
Billy Krasowsky
Jessica Cobos
Matthew Dahlberg
Curry Dawson
Steven Sturtz
Lacy Vinson

2006
Jon Bean
Cody Bundick
Jessica Burrus
Crystal Clayton
Destiny Dartez
Travis Downs
Clay Evans
Luke Everett
Dusty Gressett
Trey Hale
Justin Harlin
Jacob Harrison
Chance Hundley
Samson Jackson
Cole Jacoby
Kale Jones
Jake Johnson
Dustin Knowles
Drew McEachern
John McEachern
Matthew Menchaca
Douglas Miller
Anthony Munoz
Kasey Murphy
Bartley Murray
Blake Payne
Travis Pitcock
Braden Riha
William Ritter
Heather Rogers
Mario Saenz, Jr.
Thomas Schenkel
Sam Schiwart
Elizabeth Schulze
Victor Schulze
Chase Settle
Anthony Soliz
Jamie Steen
Elizabeth Stubsjoen
Shelley Talley
Aaron Taylor
Josh Thweatt
Justin Trimble
Rodney Weiser
Ryan Wells
Cole Wilkins
Evan Wilson
Kyle Youngblood
Blake Coates
Tim Dietz
Ned Dunbar
Shelley Gunter
Andrea Payan
Jamin Phipps
Natalie Sato
Don Skiles
Dustin Yates

2007
Brandon Aery
Tiffany Barr
Thomas Bloodworth
Clinton Caudle
Kyle Cheatle
Katy Churchill
Matthew Coffman
Warren Day
Holly Ellis
Chad Evans
Tyler Frey
Jonathan Gilbert
Blake Hinckley
Carrie Koennecke
Elliott Love
Rick Luna
Valarie Marshall
Russell Massey
Juan Munoz
Kole Murchison
Darci Owens
William Renfro
Cooper Riley
Alan Sandbothe
Quisto Settle
Tyler Springer
Heather Stout
Cody Strube
Trey Weishuhn
Sarah West
Randy Whitlock
Ryan Yates
Ross Copeland
Wade Day
Chad George
Teresa Lovett
Alfredo Munoz
Corey Owens
Raelye Taylor Self

2008
Justin Ahlers
Jess Anderson
Robin Anderson

Leo Batot
Chad Behrends
Brycce Burdick
Kellen Cave
Chris Connor
Kegan Crouch
Wesley Crouch
Tyler Davidson
Danielle DeFrain
Ashley Denton
Lyle Durst
Colin Elmore
Thomas Epting
Kari Galm
Aaron Gillespie
Clay Hale
Brandon Halfmann
Christopher Hart
Jared Hicks
Dustin Klein
Barrett Koennecke
Will Lindsey
Manzy Lowry
Kimberly Menchaca
West Moreland
Bradley Morgan
Casey Mund
Cody Pape
Joseph Petrowski
Shawn Reininger
Travis Rose
Michele Sanchez
Blake Scandolari
Eugene Schmidt
Jared Schniers
Laura Sleutel
Amanda Stallings
Kendall Tidwell
Kory Ware
Lauren Watts
Cody Bundick
Jessica Burrus
Kimberly Terrell (Dickinson)
Chance Hundley
John McEachern
Drew McEachern
Matthew Menchaca
Anthony Munoz
Sam Schiwart
Chase Settle
Shannon Wilber