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Browsing of Western Snowberry by Goats and Sheep[1]

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Summary

Managers of pastures in the northern tallgrass prairie region are faced with incomplete control of aggressive woody plant species, such as western snowberry (*Symphoricarpus occidentalis* Hook.), due to its high sprouting ability after fire or mowing and the reluctance of managers to use herbicides, which may harm desirable plant species. The objective of this study was to compare browsing preference for western snowberry by goats and sheep as an alternative control method of western snowberry. The study was conducted from 2003 through 2005 at South Dakota State University's Oak Lake Field Station in eastern South Dakota. Small, fenced plots of native prairie vegetation, infested with western snowberry, were grazed by either sheep or goats for three to five days in late June. Western snowberry plant height, foliar cover, forb foliar cover, and grass foliar cover were measured before and after grazing. During the grazing period, goats reduced western snowberry more than did sheep, reducing plant height 12 percent vs. 0 percent and foliar cover 43 percent vs. 19 percent, respectively ($P < 0.10$) adjusted for similar stocking rate. Goats also selected forbs, reducing forb foliar cover by 44 percent vs. 28 percent ($P < 0.10$) for sheep during the grazing period. Goats and sheep selected grass to a similar extent. Goats could be an acceptable alternative to herbicides for western snowberry control. However, managers also should be aware that heavy defoliation of forbs by both species may result in a decrease in desirable plant species.

Key words: Browse, Goats, Sheep, Weeds, Woody Plants

Introduction

The role of grazing animals in providing biological control of unwanted vegetation has been shown to be favored over the use of herbicides, biological control by insects or pathogens, and prescribed burning (Wagner et al., 1998). Costs of herbicides and concerns over environmental safety have made biological control of some unwanted woody species by grazing an attractive alternative (Magadlela et al., 1995). Goat grazing has been an effective, low-cost alternative to herbicides for controlling multiflora rose (*Rosa multiflora* Thumb.) in hill land pasture of the Appalachian region (Luginbuhl et al. 1999) and in reducing brush regrowth in fuelbreaks in California chaparral (Green and Newell 1982). In Kansas, goats have been successful in reducing stem density and biomass of sericea lespedeza [*Lespedeza cuneata* (Dum.-Cours.) Don], an aggressive herbaceous to near-woody perennial plant that invades disturbed sites (Mayo, 2002). Goat and sheep grazing has received attention in the popular press from innovative people and organizations using them to control unwanted vegetation under powerlines (Murray, 2001), in parks and city boulevards (Pfankuch, 2001), and to reduce fuel to prevent forest fires (Revkin, 2000).

Pastureland and native prairie in the eastern Great Plains can be invaded by western snowberry (*Symphoricarpos occidentalis* Hook.), a perennial woody shrub with an expansive root system that forms dense colonies up to 200 m in diameter (Pelton, 1953). Western snowberry is widely distributed from Ontario to British Columbia in Canada and south to northern Missouri, west through Oklahoma, New Mexico, Utah, and Washington in the United States (Johnson and Larson, 1999). High-density western snowberry infestations can severely limit grass understory growth by reducing nitrogen availability (Wilson, 2000). Reports of local, high-density infestations, as a result of cattle not being effective in controlling western snowberry, give rise to suggested alternative control strategies, such as the use of herbicides, mowing, or browsers (Bailey et al., 1990). Observations from the Oak Lake Field Station in eastern South Dakota have shown that western snowberry readily resprouts after mowing or prescribed burning (A.J. Smart, unpublished data). Research is lacking on the diet selection of goats or sheep grazing native vegetation to control western snowberry in the tallgrass prairie. Goats and sheep could offer a promising alternative control method of unwanted woody vegetation. The objective of this study was to compare browsing of western snowberry by goats and sheep.

Materials and Methods

Study site

The study was conducted from 2003 through 2005 at the South Dakota State University Oak Lake Field Station, approximately 5.5 km south of Astoria, South Dakota, in the northern tallgrass prairie. Climate is continental with cold dry winters and wet hot summers. Average annual precipitation is 582 mm (1995-2004) (USDC, 2004). Soils are of the Buse-Laghei complex (Fine-loamy, mixed udic calciborolls). Dominant vegetation is composed of cool-season grasses, such as Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass (*Bromus inermis* Leyss.), and green needlegrass [*Nassella viridula* (Trin.) Barkworth]; warm-season grasses, such as big bluestem (*Andropogon gerardii* Vitman), sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], and prairie dropseed (*Sporobolus heterolepis* A. Gray); and forbs, such as goldenrod (*Solidago spp.*) species, wild bergamot (*Monarda fistulosa* L.), aster species (*Aster spp.*), and thistle species (*Cirsium spp.*).

Experimental design

Eight experimental pastures ranging from 63 m^2 to 134 m^2 were randomly located within the study site infested with western snowberry. The variability in pasture size was dictated by the heterogeneity of the western snowberry infestation. Fifteen mature Spanish female goats weighing approximately 45 kg each were randomly assigned to five 89-m^2 pastures, 3 goats in each pasture. Eight mature female Finn-Dorset-Targhee sheep weighing approximately 70 kg each were assigned to three pastures, two sheep in the two 63-m^2 pastures and four sheep in the 134-m^2 pasture. Grazing was conducted for three to five days in late-June of 2003, 2004 and 2005. Attempts were made to use the same stocking rate in the goat and sheep pastures. However, they ranged from 4.5 to 6.2 animal unit months (AUM) ha^{-1} (Table 1). One AUM equals the amount of oven-dry forage required by one animal unit (454 kg) for a standardized period of 30 days (Bedell, 1998). Stocking rates used in this study were typical of those suggested for eastern South Dakota (Albee et al., 1948). The experimental design was a completely randomized design with pasture considered the experimental unit, five replicates for goats, and three replicates for sheep.

Vegetation measurements

Foliar cover of western snowberry, grass, and forbs was visually estimated in 0.25 m^2 quadrats from four to five quadrats approximately 1 m apart along three to five 9-m long transects for a total of 15 to 20 samples in each pasture before and immediately following the grazing period. Western snowberry plant height measured from the soil surface to the last extended leaf was estimated from 75 to 100 samples by randomly choosing five plants within each 0.25 m^2 quadrat before and immediately following the grazing period. Percent change in foliar cover of western snowberry, grasses, forbs and western snowberry plant height for each year was calculated as pregrazing value minus postgrazing value divided by pregrazing value times 100.

Table 1. Stocking rates of goats and sheep grazing in western snowberry infested pastures in eastern South Dakota from 2003 to 2005.

	Animal Species	
Year	Goats	Sheep
	------ AUM/ha -----	
2003	5.6	6.2
2004	4.5	6.2
2005	4.6	4.5

Statistical analysis

Due to the variability in stocking rate among species and years, response variables were divided by the stocking rate to standardize the data and remove the confounding effect of stocking rate. Percent change in foliar cover and western snowberry plant height divided by stocking rate was analyzed by year and animal species as a two-way analysis of variance with year considered a repeated measure. The analyses were computed using PROC MIXED (SAS, 1999) with a compound symmetry model that adequately accounted for error correlation during the three years. Least squares means were separated using the PDIFF option (SAS, 1999) and considered statistically significant at the 0.10 probability level.

Results and Discussion

Changes in foliar cover and plant height reduction of western snowberry differed between goats and sheep. Goats readily and consistently browsed western snowberry leaves each of three years (Table 2), reducing foliar cover of western snowberry by 43 percent ($P < 0.10$) compared with 19 percent reduction by sheep compared at the same stocking rate. Goats also browsed twigs of western snowberry, which reduced western snowberry plant height each year compared to sheep (Table 3). Averaged over the three years, goats reduced plant height by approximately 12 percent compared to 0 percent for sheep ($P < 0.10$) adjusted for common stocking rate. The negative number in Table 3 indicates plant height increased following grazing. Sheep grazing did not offset plant height since they apparently ate leaves rather than browsed stem. Based on diet selectivity of sheep, this was not surprising.

Percent change in foliar cover of grass adjusted for stocking rate varied by year and animal species (Table 4) and as indicated by a significant year x species interaction ($P = 0.09$). Yearly differences may have been a result of different animals used in the study and their preference for grass during the experimental period. However, when averaged over the three years, goat and sheep preference for grass was similar ($P = 0.62$). Diet preference for forbs, as indicated by decrease in forb foliar cover averaged over the three years, was higher ($P = <0.01$) for goats than sheep, as expected (Table 5).

Diet preferences of goats tend to be skewed toward woody and broadleaf plants compared to sheep which have wider diet selection tendencies (Bartolome et al., 1998; Squires, 1982). Our data supports this observation. Body size, prehensile ability, and agility are directly

Table 2. Percent change in western snowberry cover divided by stocking rate after goat and sheep grazing in western snowberry infested pastures in eastern South Dakota from 2003 to 2005.

	Animal Species	
Year	Goats	Sheep
	----- % Change/AUM/ha -----	
2003	35[b]	15[d]
2004	45[a]	27[c]
2005	47[a]	16[d]
Average	43[y]	19[z]

[a,b,c,d] Means within a row or column followed by a similar letter are not significantly different (P > 0.10).
[y,z] Means within a row followed by a similar letter are not significantly different (P > 0.10).

Table 3. Percent change in western snowberry plant height divided by stocking rate after goat and sheep grazing in western snowberry infested pastures in eastern South Dakota from 2003 to 2005.

	Animal Species	
Year	Goats	Sheep
	----- % Change/AUM/ha -----	
2003	13[a]	0[b]
2004	11[a]	2[b]
2005	12[a]	-3[b]
Average	12[y]	0[z]

[a,b] Means within a row or column followed by a similar letter are not significantly different (P > 0.10).
[y,z] Means within a row followed by a similar letter are not significantly different (P > 0.10).

Table 4. Percent change in grass cover divided by stocking rate after goat and sheep grazing in western snowberry infested pastures in eastern South Dakota from 2003 to 2005.

	Animal Species	
Year	Goats	Sheep
	----- % Change/AUM/ha -----	
2003	31[a]	27[ab]
2004	20[b]	32[a]
2005	9[c]	6[c]
Average	20[z]	22[z]

[a,b] Means within a row or column followed by a similar letter are not significantly different (P > 0.10).
[z] Means within a row followed by a similar letter are not significantly different (P > 0.10).

Table 5. Percent change in forb cover divided by stocking rate after goat and sheep grazing in western snowberry infested pastures in eastern South Dakota from 2003 to 2005.

Year	Animal Species: Goats	Animal Species: Sheep
	----- % Change/AUM/ha -----	
2003	41[a]	30[b]
2004	44[a]	28[b]
2005	48[a]	26[b]
Average	44[y]	28[z]

[a,b] Means within a row or column followed by a similar letter are not significantly different (P > 0.10).
[y,z] Means within a row followed by a similar letter are not significantly different (P > 0.10).

related to the animal's ability to browse on woody vegetation (Bartolome et al., 1998; Hofmann, 1988; Milne, 1991). These differences make selective grazers, such as goats and sheep, useful biological controls for woody vegetation. However, other factors, such as contrasting dry and wet seasons, can also influence the feeding behavior of goats and sheep (Kronberg and Malechek, 1997). Sheep shifted their foraging behavior toward more browse when high-quantity, low-quality forage was available during the dry-season in Brazil (Kronberg and Malechek, 1997). Bailey et al. (1990) observed that western snowberry was more acceptable to cattle later in the growing season compared with grazing early in the growing season. This might be related to the availability of green grass throughout the growing season. It is reasonable to assume that sheep may also select western snowberry to a greater degree later in the grazing season, especially in late-summer when cool-season grasses would be going dormant and declining in quality.

Goats and sheep will graze forb species and have been shown to be a useful tool to reduce undesirable or invasive forb species, such as thistles or leafy spurge (*Euphorbia esula* L.) (Walker et al., 1994). Goats and sheep may differ in their degree of use of forbs depending on the species present (Bartolome et al., 1998; Walker et al., 1994). We observed goats to reduce foliar cover of forbs present in this study to a greater degree than sheep. Bartolome et al. (1998) showed similar amounts of forb fragments in feces of sheep and goats, which indicated that they did not differ in their preference for forbs. Therefore, managers should be aware that sheep and goats may graze desirable forb species, so a planned grazing system should be used to allow desirable plants adequate time to recover from defoliation.

Conclusion

When sheep and goat grazing responses were expressed as a function of stocking rate, goat grazing resulted in a greater reduction in western snowberry foliar cover compare to sheep grazing. Because goats removed both stem and leaf material compared to sheep that grazed only leaves, plant height was reduced more under goat compared to sheep grazing when expressed at the same stocking rate. Also, goats preferred forbs by reducing forb foliar cover more than sheep. Both animal species selected grass to a similar extent. Our data indicate that goats are more effective at controlling western snowberry than sheep. Managers that elect not to use herbicides, due to higher risks of damaging non-targeted plant species, must be aware that goats or sheep may also heavily graze desirable forbs.

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Stocking Rates on Cultivated Winter Pastures for Meat Goats

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Summary

Cultivated cool-season pastures are needed to complement rangeland-based goat production in warmer regions of North America, but optimum stocking rates have yet to be determined. To address this question, growing Spanish X Boer doe kids (average 25 kg) were stocked at 0-12.5 head ha^{-1} from 14 January to 22 April 2002 (366 mm rainfall from October 2001 to April 2002) and 8 January to 23 April 2003 (494 mm rainfall over the same months) on cultivated pastures seeded with annual, cool-season grasses and legumes in north-central Texas, United States. Legumes comprised only 10 percent of the herbage and were less affected by stocking rates than were grasses. Grass biomass increased during the growing season and declined with stocking rate. Herbage fiber concentrations increased and N concentrations decreased with both grass and legume maturity and were not strongly affected by stocking rates. There was an inverse relationship between average daily gains per animal and per area, with the best gains (132 g) per animal at low stocking rates and greatest production (463 g) ha^{-1} at high stocking rates. Stocking rates indicated that herbage availability appeared to be a greater determinant to animal weight gain than did herbage nutritive value.

Key words: Forage Selectivity, Average Daily Gain, Silvopastoral, Cultivated Forages.

Introduction

There are numerous naturalized, self-reseeding annual cool-season legumes with proven adaptation to south-central United States (Diggs et al., 1999) whose productivity and stand regeneration from year-to-year (Muir et al., 2005) may be ideal components of cultivated pastures designed specifically for goats. Mixing well-adapted, self-reseeding native or naturalized grasses, such as *Bromus* spp. and *Lolium multiflorum* L., with self-reseeding legumes that have proven adaptation and nutritive value could benefit the mid-winter period during which rangeland-browse species are dormant. Goat selectivity in these pasture systems, both among species and plant parts, depends on many factors including climate, plant maturity and pasture management (Muir, 2003).

The ideal stocking rates for goats grazing winter-cultivated pastures in south-central North America, however, have not been studied. These stocking rates are important to modify inter-specific, annual-plant competition in pastures where self-reseeding in subsequent years is totally dependent on adequate seed production in late spring (Muir et al., 2005). Research has shown that increasing sward height (negatively correlated to stocking rate) benefits daily gain in kids (Osoro and Martinez, 1995). Lack of stocking- rate studies for cultivated, cool-season pasture systems for goats has managers dependent on data collected from cattle and sheep systems, for which a large body of animal performance vis-à-vis herbage availability exists (Wu and Rykiel, 1986), including complementary rangeland and improved pasture systems (Hart et al., 1988). Studies with sheep on Mediterranean-type pastures, for example, have shown that heavier stocking rates may favor persistence of palatable herbage species but undermine seed production, while lighter stocking rates may result in better animal performance (Ovalle et al., 1987) but also favor domination of more aggressive, less palatable grasses (Torres et al., 1987). The extent to which knowledge from cattle and sheep stocking trials can be transferred to goat production systems is not known. Discerning where the ideal balance between gain-per-animal versus gain-per-area will contribute to our understanding of cool-season pasture managed specifically for goats. The objective of this study was to compare daily gain in Boer X Spanish doe kids and per ha productivity of a mixture of cool-season, annual grasses and legumes at various stocking rates. A further objective was to determine pasture productivity and nutritive value under a range of stocking rates.

Materials and Methods

The trial was conducted at the Texas Agricultural Experiment Station in Stephenville, Texas (32° 13'N / 9° 12'W at 399 m elevation), on 3.2 ha exposed to full sun and 1.6 ha under a pecan orchard with a density of 68.5 trees ha^{-1}. This area was divided into 16 0.4-ha paddocks separated by 6-strand, electrified wire. The soil was a Windthorst fine, sandy loam (fine, mixed thermic Udic Paleustalf) with low phosphorus (10 mg kg^{-1} soil), low nitrate N (4 mg kg^{-1} soil), high K (316 mg kg^{-1} soil), and a pH of 6.4. Pasture planting in the autumn of both 2001 and 2002 was followed by introduction of the animals in January to allow adequate forage accumulation (14 January through 22 April in 2002; 8 January through 23 April in 2003). Animals were removed in April to allow the annual forage species an opportunity to set seed in May of each year. In both years, the pasture was lightly disced (but not completely tilled), seed was broadcast and seedbeds packed with a roller in late September or early October, depending on soil moisture. Arrowleaf clover (*Trifolium vesiculosum* cv. 'Yuchi'), button medic (*Medicago orbicularis* cv. 'Estes'), burr medic (*Medicago polymorpha* cv. 'Armadillo'), crimson clover (*Trifolium incarnatum* cv. 'Dixie'), and annual ryegrass (*Lolium multiflorum* cv. 'Tam90') were seeded, each at 20 percent of the recommended rate for pure stands (2, 2, 2, 6 and 8 kg seed ha^{-1}, respectively) after inoculation of the legumes with specific rhizobia. Bromes (*Bromus* spp.) and black medic (*Medicago lupulina*) germinated naturally in all pastures. Before the trial began, 85 kg P ha^{-1} was applied as triple-superphosphate to all pastures. Following germination, paddocks received 30 kg N ha^{-1}, a low fertilizer application rate meant to avoid making grasses too competitive with legumes.

Thirty-eight 5- to 7-month old Boer X Spanish cross doe kids averaging 25 kg were placed in the 16 paddocks at stocking rates of 5, 7.5, 10 and 12.5 goats ha^{-1}. Two replications of each treatment were placed in the open pasture and a third replication was placed in the pecan grove. Free-choice water and salt was available in each paddock. Precipitation from October to April was 91 percent of the 30-year average (402 mm) during 2001-2002 and 123 percent of the 30-year average in 2002-2003, affecting the duration of the grazing period each year and providing an ideal range in which to test stocking rates. Goats in each system were allowed at least five days before initial weighing to adapt to their respective paddocks and initial weight was used as a reference point to determine changes in subsequent weight. Following the adjustment period, individual goats were weighed at 28-day intervals and data obtained was used to estimate monthly and season-long average daily gain as g weight change per goat per day. Each paddock was considered an experimental unit and average daily gain was obtained per paddock and used in data analyses.

Forage biomass, nutrient concentrations and species composition for each paddock were estimated on a monthly basis by hand-clipping five 1 m^2 samples, cut at 5 cm above the soil surface, randomly taken along a diagonal transect in each pasture. Two permanent 5 by 5 m wire exclosures were placed in each paddock and 1 m^2 samples within each of these were taken at 28-day intervals as well. These exclosures were considered the zero stocking rate treatments (check) for forage data purposes and samples represented forage accumulation to date since a previously unharvested m^2 was used at each sampling date. Forage samples were separated into grass and legume components to provide an estimate of species composition and herbage components over time. All forage samples were dried at 55°C in a forced-air oven to a constant DM prior to final weighing. Forage sub-samples were then ground in a sheer mill through a 1-mm screen and batched by paddock, harvest period, and grass or legume for use in bromotological analyses.

Plant nutritive value measured as percentage of DM in these subsamples included acid detergent fiber (ADF), acid detergent lignin (lignin) and nitrogen [N; these values can be converted to crude protein (CP) by multiplying by 6.25;

A.O.A.C., 1990]. Total N concentrations were measured by using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Sample weight was 1.0 g, digest used was 5 g of 33:1:1 K_2SO_4:$CuSO_4$:TiO_2 and digestion was conducted for 2 h at 400° C using 17 ml of H_2SO_4. Nitrogen concentration in the digestate was determined by semiautomated colorimetry (Hambleton, 1977) using a Technicon Autoanalyzer II (Technicon Industrial Systems, Tarrytown, New York). Lignin and ADF were estimated using a modified method as reported by Van Soest and Robertson (1980) and described by the A.O.A.C. (1990).

The mathematical model included fixed effects due to stocking rates and years with three replications arranged in a completely randomized, block design to exclude potential variability due to soils. Animal daily gain, herbage on offer, and forage ADF, lignin and N concentrations were submitted to analysis of variance, as well as best fit correlation with the treatment levels. Differences among means were based on a least significant difference considered significant at 0.05 or less (SAS Institute, 1991).

Results and Discussion

The relative effect of stocking rate on herbage availability and daily gain was similar between years ($P > 0.05$), despite the large differences in rainfall, and were therefore pooled over years. This was also true for the herbage fiber components and N concentrations, indicating that the 91 percent to 123 percent variation in 30-year average rainfall did not change relationships among stocking rates. No differences were measured between paddocks with and without trees ($P > 0.05$), so these values were also pooled.

Perhaps because of low plant populations, especially in 2002, there was no ($P > 0.05$) correlation between legume herbage biomass and stocking rates (Figure 1). Njwe et al. (1995), using a tropical pasture, determined that goats selected legume over grass, a finding the present study cannot confirm since legume biomass never exceeded 200 kg ha^{-1} in any samples. Previous research in north-central Texas determined goats tend to favor grasses early in the cool season but, as grasses matured, favored legumes (Muir, 2003). In the present study, doe kids at the heavier stocking rates eliminated nearly all legume herbage in February and March with only a slight recovery in April. These plant populations would likely not be sustainable without prior soil seed bank buildup, similar to those reported for burr medic by Muir et al. (2005).

Grass herbage biomass showed a stronger negative correlation ($P < 0.05$) to stocking rate (Figure 1). Grass biomass in exclosures started near 800 kg ha^{-1} in February and rose steadily to approximately 3000 kg ha^{-1} in April. The two heaviest stocking rates reduced this biomass over 60 percent in February, after only one month of grazing, and further reduced it to over 70 percent in April after three months of continuous stocking at either 10 or 12.5 doe kids ha^{-1}.

Correlations between stocking rates and legume herbage ADF (Figure 2) or lignin (Figure 3) concentrations were negligible ($P > 0.05$), indicating that doe kids were not selecting for or against these components. Njwe et al. (1995), examining neutral detergent fiber in tropical legumes, reported similar results. In the present study, legume ADF for all treatments was approximately 15 percent in February, increasing gradually to over 25 percent in April as plants matured. Increases in lignin concentration were more gradual from February to March

Figure 1. February and April herbage available to doe kids in pastures stocked at 0-12.5 kids ha^{-1} at Stephenville, TX (pooled over two seasons; grass $P < 0.05$ both months; legume $P > 0.05$ both months).

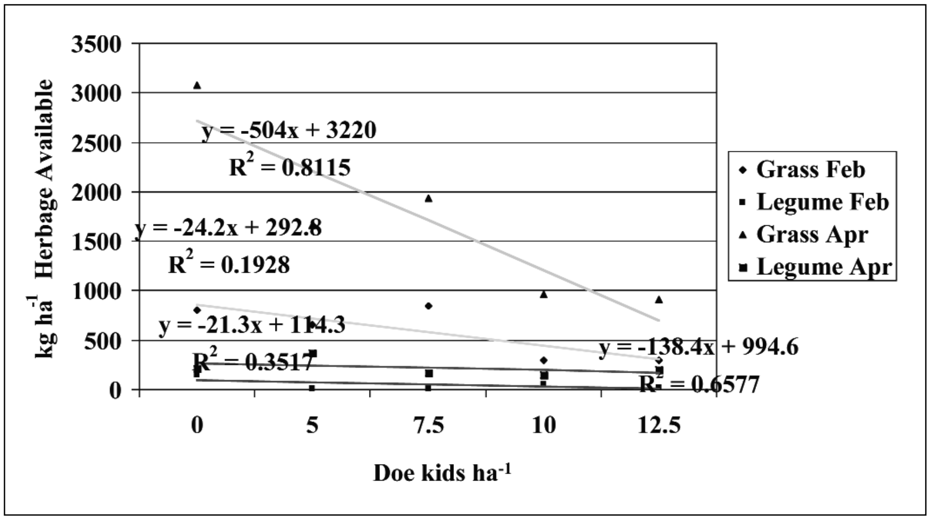
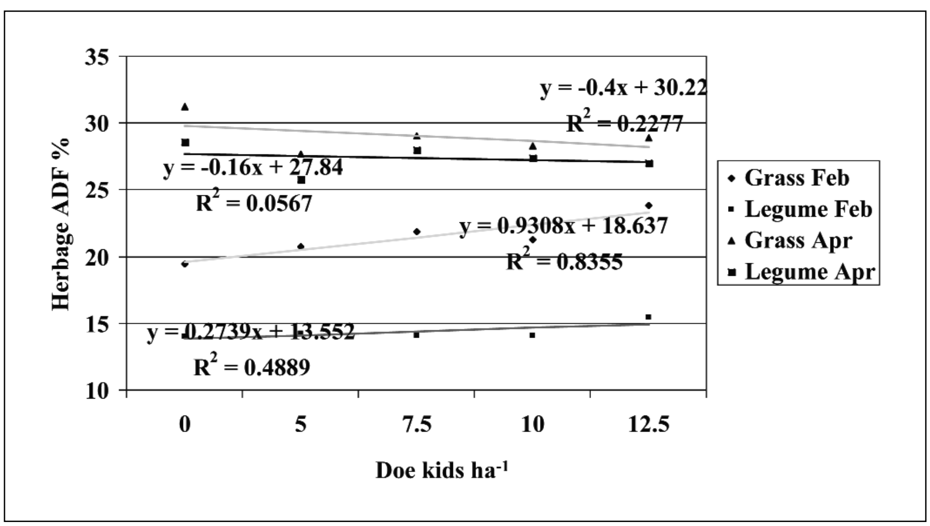


Figure 2. February and April herbage acid detergent fiber (ADF) in paddocks stocked at five different rates (pooled over two years; grass $P > 0.05$ both months; legume $P > 0.05$ both months).



(around 2.5 percent) but rose sharply as legumes entered reproductive stages, reaching nearly 4.5 percent for plants sampled in exclosures during April.

Grass herbage ADF (Figure 2) and lignin (Figure 3) concentrations were positively correlated ($P < 0.05$) to stocking rate even after only one month of grazing. In subsequent months, both fiber components had weak negative correlations to stocking rates, a reflection of grass maturation in exclosures and regrowth following grazing in the paddocks. Relative to the legumes, grass ADF was generally greater while lignin was either similar or, by the end of the season, less concentrated.

Paralleling the findings of Njwe et al. (1995) in a tropical pasture, no relation ($P > 0.05$) between stocking rates and legume herbage N concentration was detected (Figure 4). From February to March, little change in N concentration occurred, but average values during these months (generally over 3.5 percent or the equivalent of 22 percent CP) declined to 2.5 percent in plants protected from grazing in April.

Grass N concentrations were fairly high when rate of fertilizer applied was low (Figure 4). February values around 3.0 percent (approximately 19 percent CP equivalent) reflect young, growing plants. These values remained fairly stable for heavily stocked paddocks through March but declined in the ungrazed exclosures ($P < 0.05$), especially by April when concentrations reached as low as 1.7 percent. An analysis of April grass N concentrations indicated that only grass in paddocks stocked at 10 and 12.5 goats ha^{-1} had greater concentrations than the exclosures and that grass N concentrations were much greater in 2002 than in 2003.

Daily gain at the lowest stocking rate exceeded 130 g day^{-1} and was greater than the two heaviest stocking rates (Figure 5). There was a strong quadratic relationship ($P< 0.05$) between stocking rate and doe ADG (Figure 6) although more stocking rates, especially on the high end, are needed to confirm this trend. Herbage biomass (Figure 1) would indicate that these greater gains were due to greater herbage availability at the lower stocking rate which allowed for greater goat selectivity, in agreement with Osoro and Martinez (1995) that greater sward height improves kid gains. These results contrast with other trials in which goat performance was not affected by 15 to 26 stocking

Figure 3. February and April herbage lignin concentration in paddocks stocked at five different rates (pooled over two years; grass $P \leq 0.05$ both months; legume $P > 0.05$ both months).

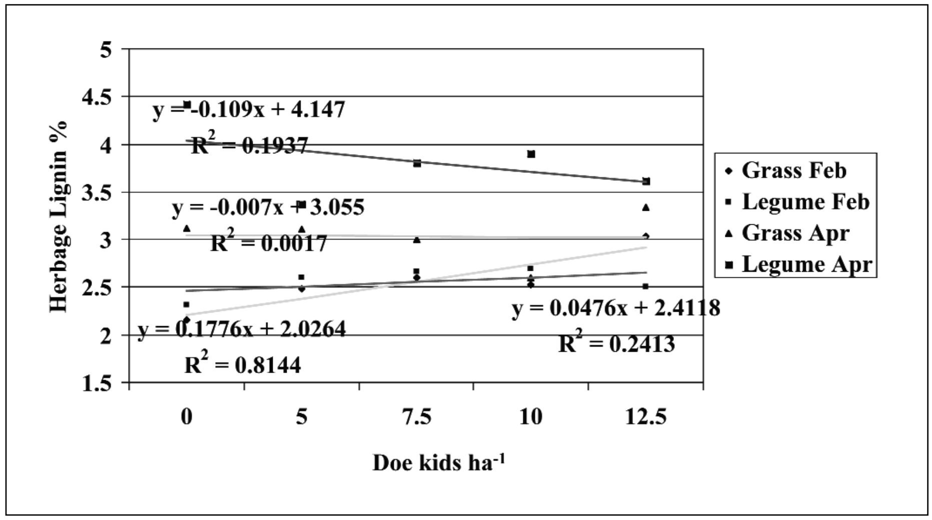
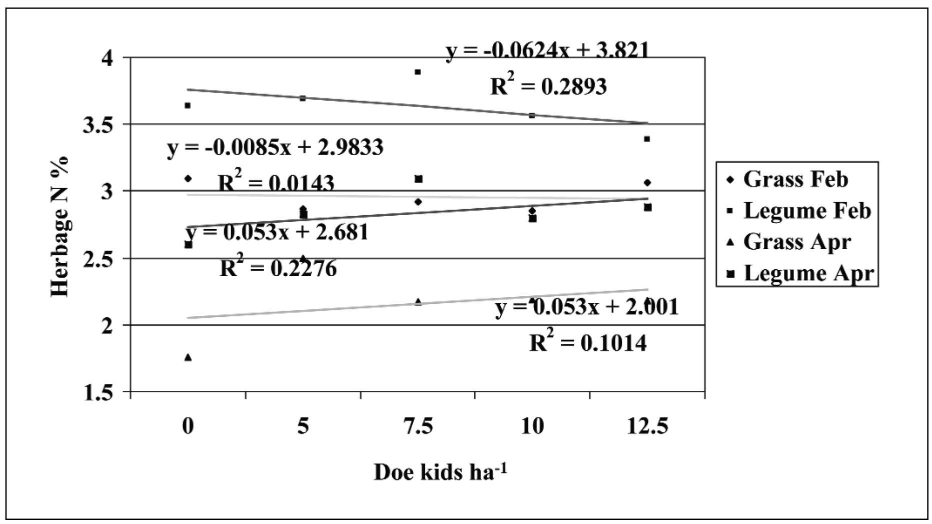


Figure 4. February and April herbage N concentration in paddocks stocked at five different rates (pooled over two years; grass $P > 0.05$ both months; legume $P > 0.05$ both months).



units ha^{-1} on temperate pastures (Thomson and Power, 1993). However, sheep-stocking-rate studies of 1.0 to 4.0 ewes ha^{-1} show that animal performance suffers if stocking rates exceed sustainable carrying capacity (Ovalle et al., 1987).

Late in the trial period, herbage fiber (Figures 2 and 3) and N (Figure 4) concentrations across stocking rates increased or remained stable, so the greater animal performance at the lower stocking rates cannot be explained by superior, total-plant, herbage-nutritive value. Analysis of hand-plucked samples or doe-ingested material would provide clearer indications of this, since forage in this trial was clipped to include stems that goats do not normally ingest. Daily-gain trend lines over time and pooled for both years (Figure 7) parallel herbage availability, confirming that herbage quantity rather than total-plant nutritive value was likely the principal factor determining weight gains in the does. Greater biomass at lower stocking rates may have allowed greater selectivity or reduced grazing effort (canopy density) by the goats, as has been shown in cattle and sheep (Torres et al., 1987) and in goat hay trials (da Silva et al., 1999). There is some indication, however, that canopy height does not always affect apparent intake rates in goats despite a decrease in bite mass as canopy heights

Figure 5. Winter pasture average daily gain (ADG) per animal and per area stocked at 5, 7.5, 10 or 12.5 doe kids ha-1 pooled over two seasons. Columns within groupings headed by different letters differ (*P* < 0.05) according to Least Significant Difference Separation Test.

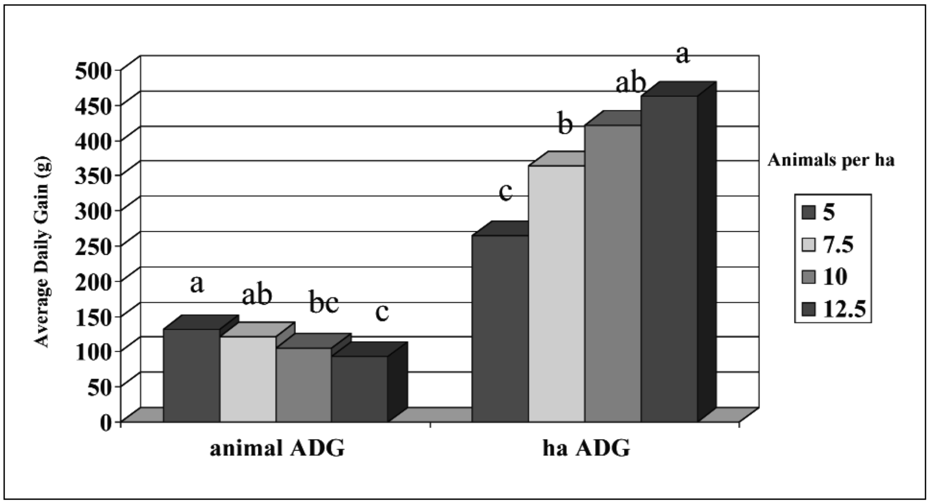


Figure 6. Average daily gains (ADG) of doe kids stocked at 5-12.5 head ha-1 on winter legume/grass pasture in north central Texas (pooled over two years).

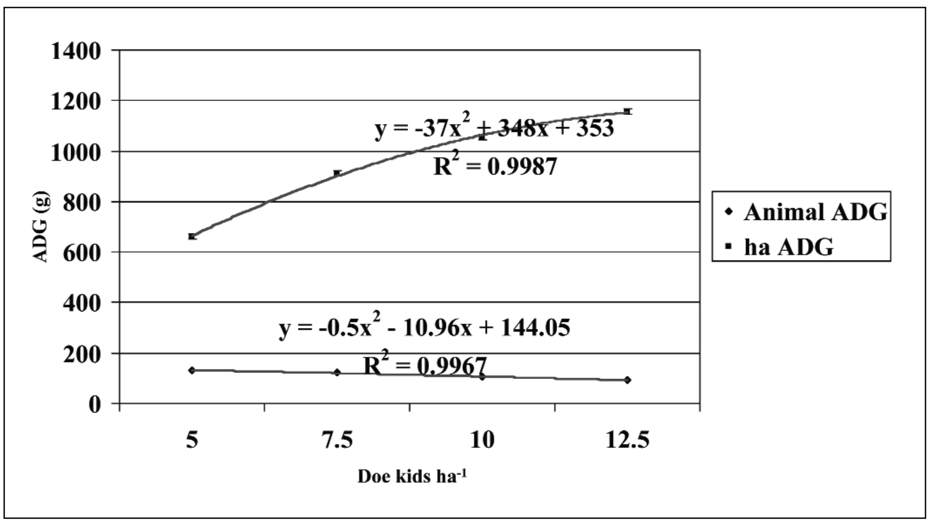
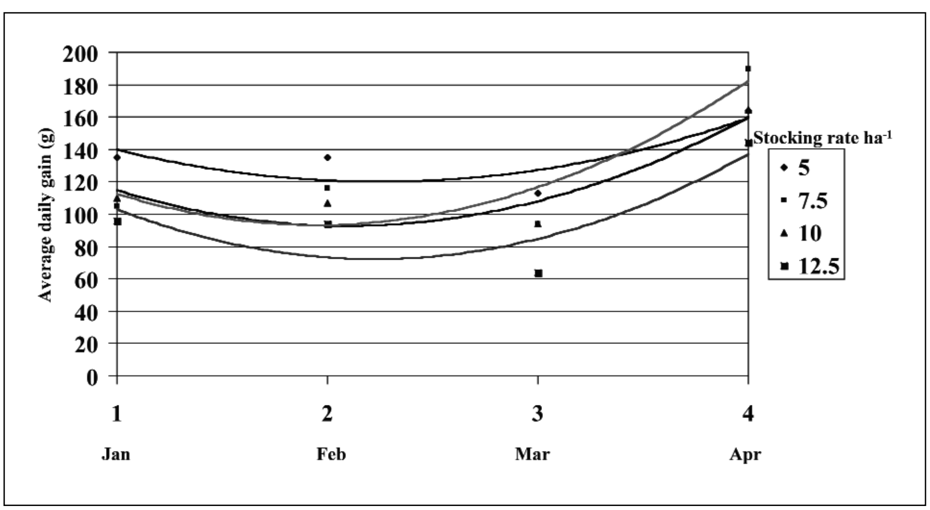


Figure 7. Trend lines of average daily gain (ADG) per animal stocked at 5, 7.5, 10 or 12.5 doe kids ha-1 (pooled over two years).



decrease (Concha and Nicol, 2000). Goat dietary (extrusa) neutral detergent fiber on tropical pastures can be independent of stocking rate, indicating goats will maintain selectivity at the expense of intake (Njwe et al., 1995).

Daily gains per area were greatest at the heavier stocking rates, over 450 g ha^{-1} day^{-1} at the 12.5 rate (Figure 5). These values were positively correlated to stocking rates, showing a close quadratic fit (Figure 6). Additional heavy stocking rates are needed to determine where peak-per-area productivity lies. Detrimental effects on plant seed production at stocking rates greater than the 12.5 ha^{-1} could affect long-term persistence of the pasture, although timing rather than stocking rate may be more important (Muir et al., 2005).

There was an obvious trade-off in daily gain per-animal versus per-area (Figure 5), much as has been observed for cattle and sheep in other studies (Peterson et al., 1965). A low stocking rate of 5 does ha^{-1} resulted in 43 percent greater gain/doe than the 12.5 doe ha^{-1} stocking rate. Conversely, the heavier stocking rate gave 75 percent greater gains/ha than the lightest stocking rate in the study. Long- and short-term animal production goals, favoring per animal or per area production, will determine which stocking rates should be applied. In addition, the effects of the various stocking rates on herbage seed set and subsequent stand persistence should also figure into management decisions. In drier regions, annual, self-reseeding grasses and forbs dominate cool-season, annual pastures and adequate seed set will determine seedling counts in subsequent seasons (Muir et al., 2005).

Conclusions

At the heaviest stocking rates, improved nutritive value of forage regrowth cannot compensate for the lack of herbage quantity that favors animal weight gains at low stocking rates and may also deleteriously affect reseeding potential of annual pasture species. The trade-off is that greater stocking rates produce greater doe kid gain per area, with further research needed to determine just how high stocking rates can go without negatively affecting both animal production and self-reseeding capabilities of these cultivated annual winter pastures.

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Sexual Performance and Reproductive Characteristics of Young Adult Awassi, Charollais-Awassi and Romanov-Awassi Rams

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Summary

This study was conducted to evaluate the reproductive performance of two-yr-old, sexually naïve rams of different genotypes. Eight rams of each Awassi (A), F_1 Charollais-Awassi (CA) and F_1 Romanov-Awassi (RA) genotypes were subjected to sexual performance tests by being individually exposed to two estrous Awassi ewes for five, 20-min periods. Body weight (BW), body condition score (BCS), scrotal circumference (SC) and semen characteristics were recorded every 2 wk for 2 mo prior to sexual performance testing. Awassi rams engaged in more leg-kicking bouts ($P < 0.01$) than RA rams. Mounting frequency, raising the fat tail of females, and ejaculation rate were greater ($P < 0.05$) in A than in CA and RA rams. No genotype x test day interactions were detected, however, test day influenced ($P = 0.05$) ejaculation rate. Rams of the CA genotype had greater BW ($P < 0.01$) than RA and A. The CA rams had greater SC ($P < 0.01$) than A rams and higher BCS ($P < 0.01$) than RA rams. The RA rams had greater ($P < 0.05$) semen mass motility than A and lower ($P < 0.05$) percentage of abnormal spermatozoa than A and CA rams. Additionally, semen concentration tended ($P < 0.10$) to be greater in RA than in A and CA rams. Results of the present study indicate that RA rams tend to have better semen characteristics, while Awassi rams had better sexual performance when mated with fat-tailed females than the CA and RA genotypes, which may necessitate the use of artificial insemination during crossbreeding programs.

Key words: Awassi Sheep, Sexual Performance, Semen Characteristics, Crossbreeding

Introduction

The efficiency of sheep production depends highly on reproductive performance, especially in countries where the sheep industry is important (Ibarra et al., 2000). Most reproductive-efficiency research in sheep focuses on females, due to their seasonal patterns, while giving relatively less attention to males, as they are capable of reproducing all year round. Aspects of ram sexual behavior under various conditions have been studied extensively (Price et al., 1991; Price et al., 1992; Price et al., 1994). However, to our knowledge, little information is available on sexual performance and the ability of thin-tailed rams to naturally mate with fat-tailed ewes.

Awassi, a fat-tailed breed, is the most prevalent sheep breed in the Middle East (Gootwine et al., 1992). Awassi sheep have desirable carcass traits and meat quality (Holloway et al., 1994), especially because the presence of tail allows for leaner carcasses and makes it easier to trim any undesirable fat. The presence of tail, however, causes mating difficulties by impeding copulation (Kridli and Said, 1999). This is observed mostly when using sexually naïve rams or when mating fat-tailed ewes with exotic rams.

In the present study, Awassi were crossed with mutton (Charollais) and prolific (Romanov) breeds in an attempt to combine the adaptability and hardiness of Awassi with the prolificacy and meat production abilities of Romanov and Charollais sheep, respectively. The success of such breeding programs highly depends on reproductive performance. The objective of this study was to evaluate sexual performance and reproductive characteristics of crossbred rams as compared with Awassi and to test their ability to naturally mate with fat-tailed Awassi ewes.

Materials and methods

The experiment was conducted during the autumn season at the Center of Agricultural Research and Production at Jordan University of Science and Technology located in the northern part of Jordan at 32° 34' N and an altitude of 520 m above sea level. Experimental animals were kept in open-front barns with free access to shade, water and mineral blocks. The natural breeding season occurs during the period of June through December for Awassi (Epstein, 1985), August through March for Romanov (Fahmy, 1996) and July through December for Charollais (British Charollais Sheep Society).

Sexually naïve, two-yr-old rams of three different genotypes were used in this study. Eight rams of each Awassi (A) and its first crosses with either Charollais (CA) or Romanov (RA) sheep were subjected to sexual performance tests by being individually exposed to two estrous Awassi ewes (fat-tailed) for five, 20-min periods. Thus, each ram was tested five times, each on a different test day. Thirty, mature Awassi ewes were synchronized to exhibit estrus on five test days, each two days apart (six ewes/occasion). Vaginal progestogen sponges (40 mg flourogestone acetate sponges, Ceva, France) were inserted for 12 d. Six hundred IU of PMSG were injected intramuscularly at the time of sponge removal. Only four of the six ewes were used on each test day. The reason for synchronizing six ewes to exhibit estrus on each test day was to ensure having the four required estrual females. The four ewes to be used in the testing procedures were detected to be in estrus by mature, experienced Awassi rams.

Sexual performance testing started one week after the end of blood sampling and semen evaluation. Sexual performance tests were conducted during the morning hours between 0700 and 1200. Four estrual ewes were placed in two 6 x 6 m pens (two ewes/pen). A third similar pen, where the observers stood, separated the two test pens. Ewes were kept unrestrained in the pens. Each ram was individually evaluated by exposing it to the two estrual ewes for 20 min on each test day. Two rams were tested simultaneously while the remaining rams were kept about 20 m away with visual barriers between them and the test pens. Rams were randomly selected for testing, whereby each pen was used to test rams of all genotypes on each test day.

Observations were recorded for each ram throughout the 20-min period. Collected observations were similar to those reported by Kridli and Said (1999) and Kridli and Al-Yacoub (2006) and included bouts of leg kicking, anogenital sniffing, mount attempts (both front feet off the ground without complete positioning of the ram on the ewe's rump), mounts without ejaculation, frequency of raising the fat tail of ewes, and ejaculation frequency.

Testosterone concentration, semen characteristics, body weight (BW), body condition score (BCS) and scrotal circumference (SC) were recorded for each ram every 2 wk for 2 mo (September and October) before sexual performance was evaluated. Blood samples were collected via jugular venipuncture into heparinized tubes, centrifuged and stored at –20° C until analyzed for testosterone concentration by RIA (Immunotech, France). Blood samples were collected at 0700 followed by semen collection and evaluation at around 0800.

Scrotal circumference was measured using a flexible tape at the widest scrotal diameter. Semen samples were collected using a battery-operated electro-ejaculator [as it does not require previous training of ram lambs (Belibasaki and Kouimtzis, 2000)] and a series of short electrical stimuli (approximately 5 sec) were administered at 20 sec intervals (Buckrell et al., 1994). Two ejaculates were collected and discarded on the first day of semen collection to remove any poor quality sperms present, due to rams being sexually inactive prior to the start of the experiment. Ejaculate volume was determined immediately after collection using a transparent graduated vial. Mass motility was assessed as a percentage by viewing one drop of semen at low magnification (40x) as described by Al-Ghalban et al. (2004). An aliquot of semen was diluted in a physiological saline solution containing 0.01 percent mercury chloride at 1:400 (semen:diluent) for hemocytometric determination of concentration and percentage of abnormalities (Chemineau et al., 1991). The same person evaluated BCS, measured SC, operated the electroejaculator and evaluated the semen samples throughout the study.

Data were analyzed by analyses of variance for completely randomized design using the "general linear model" procedure of SAS. Semen characteristics, BW, BCS, SC and sexual performance data were submitted to a repeated measures multivariate model by the "repeated" statement, to evaluate the effect of the within-subject "sampling day" factor, and the between-subject "genotype" factor. Differences were tested by a pairwise *t* test using the "least square means" statement. Because the study included count data, log (x + 1) transformation was conducted on all sexual performance parameters. However, the actual sexual performance data are presented with means being separated based on transformed data. Simple correlations were conducted among the various variables for all rams within all classes. All analyses were conducted using the General Linear Model procedure for SAS (SAS, 1997).

Table 1. Sexual performance (mean ± SE) of Awassi (A), Charollais-Awassi (CA) and Romanov-Awassi (RA) rams averaged over five test days[1].

	Genotype		
Variable[2]	A (n=8)	CA (n=8)	RA (n=8)
Leg kicking	9.8^{a} ± 1.4	6.6^{ab} ± 1.4	3.3^{b} ± 1.4
Anogenital sniffing	9.1 ± 1.6	6.1 ± 1.6	7.0 ± 1.6
Mount attempts	2.6^{de} ± 0.7	2.8^{d} ± 0.7	0.7^{e} ± 0.7
Mounts	17.6^{a} ± 1.9	9.1^{b} ± 1.9	6.9^{b} ± 1.9
Tail raising	3.9^{a} ± 0.5	0.3^{b} ± 0.5	0.1^{c} ± 0.5
Ejaculation	0.4^{a} ± 0.1	0.0^{b} ± 0.1	0.0^{b} ± 0.1
Tail raising per mount	0.23^{a} ± 0.02	0.03^{b} ± 0.03	0.01^{b} ± 0.03

[1] Sexual performance testing was performed on 5 test days (20 min. ram^{-1} day^{-1})
[2] There were no test day x genotype interactions.
[abc] Means within the same row with different superscripts differ ($P < 0.01$)
[de] Means within the same row with different superscripts differ ($P < 0.05$)

Results

Awassi rams had greater bouts of leg kicking ($P < 0.01$) while CA had greater mount attempts ($P < 0.05$) than RA rams (Table 1). Mounting frequency, raising the fat tail of females, tail raising per mount and ejaculation rate were greater ($P < 0.01$) in A than in CA and RA rams (Table 1). Correlations were detected ($P < 0.01$) between mounting and ejaculation rate (r = 0.4) and tail raising and ejaculation rate (r = 0.8). Pre-copulatory behavior (kicking and sniffing) was moderately correlated ($P < 0.05$) with ejaculation rate (r = 0.41).

There was no ($P > 0.10$) genotype x test day interaction for any of the sexual performance parameters. Test day, however, influenced mounting frequency ($P < 0.05$) and tended to influence (P = 0.10) ejaculation rate (Table 2). Mounting frequency declined from 21.8 ± 2.9 mounts per 20 min on day 1 to 7.5 ± 2.9 mounts per 20 min on day 5 (Table 2). Ejaculation rate increased from 0.1 ± 0.1 on day 1 to 0.4 ± 0.1 on day 5. Even though it was not significant, kicking frequency and mount attempts declined while sniffing frequency, tail raising and tail raising per mount increased as test day advanced.

Rams of the CA genotype were heavier ($P < 0.01$) than RA and A (Table 3). Additionally, CA rams had greater SC ($P < 0.01$) than A rams and higher BCS ($P < 0.01$) than RA rams (Table 3). Correlations existed ($P < 0.001$) between BW and BCS (r = 0.67), BW and SC (r = 0.79) and between BCS and SC (r = 0.59).

There was no ($P > 0.10$) test day effect on testosterone concentrations and any semen characteristic of rams. Testosterone concentrations were greater ($P < 0.05$) in RA than A rams while CA were intermediate (Table 4). Testosterone concentrations were correlated ($P < 0.01$) with BW (r = 0.51) and SC (r = 0.58). Ejaculate volumes did not differ ($P > 0.05$) among genotypes (Table 4). The RA rams had greater ($P < 0.05$) mass motility than A and lower ($P < 0.05$) percentage of abnormal spermatozoa than A and CA rams. Additionally, semen concentration tended ($P < 0.10$) to be greater in RA than in A and CA rams.

Discussion

This study aimed at evaluating sexual performance characteristics of Charollais-Awassi and Romanov-Awassi as compared with Awassi rams in order to determine the capabilities of crossbred males to naturally mate with the fat-tailed Awassi ewes.

In addition to evaluating sexual performance, we also examined other biological variables and seminal characteristics of rams from the three genotypes.

Most sexual performance parameters were better in Awassi compared with the crossbred males. Awassi rams engaged in more leg-kicking behavior than RA, while anogenital sniffing was similar among genotypes. Pre-copulatory behavior (leg-kicking and anogenital sniffing) was correlated with ejaculation rate, which supports the hypothesis by

Table 2. Effect of test day on sexual performance (Mean ± SE) of Awassi, Charollais-Awassi and Romanov-Awassi rams exposed to estrous Awassi ewes for 20 minutes on five occasions[1].

	Test day					
Variable	1	2	3	4	5	P
Leg kicking	8.4 ± 2.3	7.8 ± 2.3	6.6 ± 2.3	7.2 ± 2.3	4.1 ± 2.3	> 0.05
Anogenital sniffing	6.7 ± 2.1	6.8 ± 2.1	8.3 ± 2.1	8.8 ± 2.1	9.6 ± 2.1	> 0.05
Mount attempts	3.3 ± 1.0	2.3 ± 1.0	2.7 ± 1.0	1.3 ± 1.0	1.1 ± 1.0	> 0.05
Mounts	21.8 ± 2.9	9.1 ± 2.9	11.3 ± 2.9	8.3 ± 2.9	7.5 ± 2.9	< 0.005
Tail raising	1.2 ± 0.9	1.1 ± 0.9	1.5 ± 0.9	2.0 ± 0.9	1.9 ± 0.9	> 0.05
Ejaculation rate	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0.4 ± 0.1	= 0.10
Tail raising per mount	0.04 ± 0.05	0.12 ± 0.05	0.09 ± 0.05	0.15 ± 0.05	0.17 ± 0.05	> 0.05

[1] Sexual performance was conducted on five test days each two days apart (20 min. ram^{-1} day^{-1}).

Table 3. Body weights, body condition scores and scrotal circumferences (mean ± SE) of Awassi (A), Charollais-Awassi (CA) and Romanov-Awassi (RA) rams averaged over the experimental period[1].

	Genotype		
Variable[2]	A (n=8)	CA (n=8)	RA (n=8)
Body weight (kg)	$70.3^{a} \pm 0.3$	$78.7^{b} \pm 0.3$	$70.5^{a} \pm 0.3$
Body condition score	$3.9^{cd} \pm 0.1$	$4.1^{c} \pm 0.1$	$3.7^{d} \pm 0.1$
Scrotal circumference	$30.9^{d} \pm 0.3$	$33.0^{c} \pm 0.3$	$32.5^{cd} \pm 0.3$

[1] Data were collected every 2 wk for 2 mo.
[2] There were no test day x genotype interactions.
[ab] Means within the same row with different superscripts differ ($P < 0.01$)
[cd] Means within the same row with different superscripts differ ($P < 0.05$)

Price et al. (1992) that the frequency of pre-copulatory behavior in rams reflects their underlying sexual motivation.

There are many factors that affect sex drive and sexual performance. These factors include: season of year, genetics, breed differences, hormonal influence, post-weaning management, temperature and nutrition (Mickelsen et al., 1982). The fact that Awassi rams outperformed CA and RA rams could be attributed to genetic factors, particularly those related to the presence of fat-tailed females during sexual performance testing. This is supported by the higher frequency of mounting, tail-raising, ejaculation and tail-raising per mount observed in the Awassi rams. When mounting, Awassi rams have a side approach to females (stand behind the ewe and slightly to the side) while CA and RA rams position themselves directly behind females before attempting to mount. This approach is essential for successful mating. As Awassi males "kick up" to mount females, they raise the fat tail with their front legs thus increasing the probability of penile intromission. This difference in approach led to differences in tail-raising and ejaculation rate among genotypes.

Mounting frequency declined with the advancement of test day. This is attributed to the improvement in ejaculation rate as ejaculations are normally followed by periods of sexual inactivity (Price et al., 1992) resulting in lower mounting frequency. The improvement in ejaculation rate over the successive test days is caused by the experience gained by each ram during the testing procedure. According to Price et al. (1991), libido in virgin rams is lower when first exposed to females than during subsequent exposures. Additionally, virgin rams exhibit an improvement in sexual performance after the first and the second exposures to estrous females to a level comparable to that of experienced males (Price et al., 1991).

Body weights and BCS vary among breeds of sheep (Dawson, 2002), as influenced by body conformation. In this study, CA were heavier than A and RA and had greater BCS than RA rams. This is due to the fact that Charollais is a meat breed (Farid and Fahmy, 1996) compared with the prolific Romanov (Fahmy, 1996) and the dual-purpose Awassi (Gootwine et al., 1992). Scrotal circumferences were lower in A than in CA lambs. Scrotal circumference differs among breeds of sheep (Belibasaki & Kouimtzis, 2000) being higher in crossbred than purebred lambs. The significant correlation between BW, SC and BCS is in agreement with previous research (Duguma et al., 2002; Fourie et al., 2002).

Testosterone concentrations may differ between pure and crossbred rams (Fahmy, 1997) and among breeds of sheep (Dickson and Sanford, 2005). In the present study, RA crossbred rams had higher testosterone concentrations than Awassi rams. Despite differences in SC, ejaculate volume was similar among genotypes. This may be due to the use of electrical stimulation for semen collection. The use of electroejaculation increases ejaculate volume due to stimulating the accessory sex glands (Bearden and Fuquay, 1997). Even though larger ejaculate volumes are obtained when using electrical impulses as compared with using artificial vaginas, the total number of sperms produced and the fertilizing capacity of sperms are about the same using both methods (Bearden and Fuquay, 1997).

Semen characteristics followed the same trend as did testosterone concentrations being in favor of the RA genotype. Semen mass motility was higher in RA than A while the percentage of abnormal spermatozoa was lower in RA than the other genotypes. The RA rams tended to have greater semen concentration than the other genotypes. These differences in semen characteristics may be related to differences in testosterone concentrations among genotypes. As scrotal circumference increases, sperm output increases (Langford et al., 1987). Therefore, scrotal circumference can be used as an index for sperm production in sheep (Toe et al., 2000). Differences in

Table 4. Testosterone concentration and semen characteristics (mean ± SE) of Awassi (A), Charollais-Awassi (CA) and Romanov-Awassi (RA) rams averaged over the experimental period[1].

	Genotype		
Variable[2]	A (n=8)	CA (n=8)	RA (n=8)
Testosterone (ng/ml)	$4.7^{b} \pm 0.5$	$5.7^{ab} \pm 0.5$	$6.3^{a} \pm 0.5$
Semen volume (ml)	0.9 ± 0.2	1.1 ± 0.2	1.3 ± 0.2
Mass motility (%)	$59^{b} \pm 6.5$	$76^{ab} \pm 6.5$	$90^{a} \pm 6.5$
Semen concentration (109)	$1.40^{d} \pm 0.5$	$1.8^{d} \pm 0.4$	$2.9_{c} \pm 0.4$
Abnormality (%)	$21^{b} \pm 2.8$	$18^{b} \pm 2.8$	$7^{a} \pm 2.8$

[1] Data were collected every 2 wk for 2 mo.
[2] There were no test day x genotype interactions.
[ab] Means within the same row with different superscripts differ ($P < 0.05$).
[cd] Means within the same row with different superscripts tend to differ ($P < 0.1$).

semen quality among genotypes in the present study may be related to the more fertile and prolific nature of the Romanov breed (Dufour et al., 1984).

Conclusion

In conclusion, results of the present study indicate that even though CA and RA crossbred rams have good body conformation and semen characteristics, they have difficulties when naturally mating with fat-tailed Awassi females, which may necessitate the use of artificial insemination during crossbreeding programs. The sexual performance of CA and RA crossbred males may have been improved had they been exposed to docked or thin-tailed females.

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The Color of Scoured and Carded Wools: A Comparison of U.S., Australian and New Zealand Wools

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Summary

Fifty greasy core samples of wool fibers representing various regions of the United States were obtained from Yocom-McColl Testing Laboratories. In addition 50 greasy core sample of New Zealand wool (Société Générale de Surveillance [SGS]) and 10 greasy core samples Australian Wool Testing Authority (AWTA) were obtained. After scouring, average fiber diameter and clean color were determined. After measurement of clean color, the samples were carded to evaluate its effect on the measured color of the wool. Color measurements of the scoured and the scoured and carded wools clearly indicated that there were differences between the yellowness of the samples. Wools from each country were grouped according to fiber diameter into four groups; <20 µm , 20 – 22.9 µm, 23 – 25.9 µm, and ≥26 µm, and color was evaluated for each group. The results indicated that in most cases the mean color among samples was not significantly different which was expected. However, U.S. wools had a much wider range of yellowness indices compared to those from Australian and New Zealand.

Key words: Wool, Clean Color, Yellowness

Introduction

The color of wool is an important characteristic. It provides for example, a limit to the dyeing potential of that wool. Clean-color specification is becoming increasingly more important for wool marketing, especially for both high quality wool and lower types, such as pieces and bellies (Australian Wool Corporation, 1987). Greasy wool color is determined not only by the inherent color of the wool, but also by the grease, suint, dirt and vegetable matter the wool contains. These extraneous materials are removed in processing by scouring and carding. Therefore, these impurities do not affect the color of the final product. Thus, before a relevant color measurement can be made, greasy wool must be processed to a state of cleanliness.

The technical demands and limitations of manufacturing worsted and woolen yarns, weaving and knitting fabrics require individual items in the broad spectrum of wool textile products to be composed of specific grades or classes of wool or blends thereof. Since between and within fleece variation of diameter, color, length, strength and degree of cleanliness is often large, normal quality control requires fleeces to be graded and sorted prior to scouring. Traditionally, this function has been performed at the textile mills or by companies that specialize in providing specific grades of raw materials to the textile industry. An opportunity has and still does exist for ranchers to skirt and grade wool either at shearing or pay a marketing organization to do the job for them. Theoretically, when it is no longer necessary for a textile mill to perform these tasks, labor savings can be passed back to the grower on return for prepared wools. Such efforts to increase the value of raw wool have been practiced for years by individual ranchers and at some warehouses and co-ops.

To be able to characterize wools from the United States is a primary requirement in developing marketing strategies. Characterization includes determination of both greasy and clean wool characteristics. These fiber specifications are directly related to the potential spinning performance. Characteristics to be measured are those which the industry uses as a guideline for predicting processing performance of wool. They also allow for the prediction of how different wools will perform when blended together. Color is becoming an increasingly important parameter for processors. The primary purpose of this project was to evaluate the color of U.S. wools as compared to wools obtained from Australia and New Zealand.

Materials and Methods

Fiber Samples

Fifty greasy core samples of U.S. wools representing various regions of the United States were obtained from Yocom-McColl Testing Laboratories Inc, Denver, Colo. In addition, 50 greasy core samples of New Zealand wools were randomly obtained from commercial lots tested in the laboratory of SGS New Zealand and 18 randomly selected greasy core samples of Australian wools tested in the AWTA Sydney laboratory were obtained. All core samples were processed by Yocom-McColl according to American Society of Testing and Materials (ASTM) test method ASTM D584-96 (ASTM, 1998) and average fiber diameters were determined. The laboratory scouring process involves a mild alkali scour followed by rinsing and drying at 105°C.

Determination of Fiber Diameter

Fiber diameter of the scoured core residue was measured using the Sirolan-Laserscan (AWTA, Sydney) (IWTO-12, 1993). A sub-sample of the core residue was minicored to obtain 2mm long fiber snippets that were subsequently utilized to determine average fiber diameter, standard deviation and coefficient of variation of the sample.

Determination of Yellowness Indices

Yellowness indices were determined using a Spectrogard Color Control System (Pacific Scientific, Silver Spring, Md.). ASTM E313-96 (ASTM, 1998b) was utilized to calculate yellowness indices (YIE). As yellowness increases YIE values increase. In addition, the Y/Y-Z value of yellowness was also calculated. The Y value indicates the lightness of the wool sample (lightness generally ranges between 50 to 70) with the higher values denoting lighter wools. Y-Z denotes the yellowness of the sample and generally ranges from -2 to 12. The greater the yellowness the higher the Y-Z value (Cottle et al., 1992). Eight measurements per sample were taken for both scoured and carded wool samples.

Statistical Analysis

Statistical analyses were conducted using SAS (SAS Institute, 1995). T-tests were used to determine differences in color between paired scoured- and carded-wool samples and to determine differences between wools from different countries and different micron groups.

Results and Discussion

Average fiber diameters and yellowness indices for U.S. wool samples are shown in Table 1. There is a wide range of fiber diameters with samples ranging from 18.6 μm to 32.9 μm. Yellowness indices of 50 pairs of scoured and carded wools (U.S.) clearly indicated that carding improved the color of the wool. In the majority of cases (36 samples) carding significantly improved (decreased) the YIE value. A lower value for YIE indicates a sample that is less yellow or a sample that is more white. While not being significantly different, nine additional samples had lower carded YIE values compared to the scoured value. When evaluating color based on Y-Z values, 31 samples showed significant improvement after carding while a further 12 showed improved values, though not significant. As with the case of YIE, a lower Y-Z value indicates whiter wool. These results were as expected, as carding is a further cleaning process and thus would be expected to remove further dark-colored, extraneous material, which can impact the overall clean color of wool. In fact there is an accumulative effect with scouring and carding, which can be taken even further with subsequent combing, dyeing and finishing in changing the color of wool.

The yellowness of the U.S. scoured wools ranged from a high of 33.63 to a low of 20.69 (YIE) and a high of 20.77 to a low of 4.17 (Y-Z), while with the carded wools the yellowness ranged from a high of 30.77 to a low of 17.87 (YIE) and a high of 11.49 to a low of 2.47 (Y-Z). Thus there is a wide variation when looking at individual wool samples. However, in terms of yellowness, it would appear that even after carding the wools continue to be quite yellow. Aus-

Table 1. Yellowness indices of scoured and carded U.S. wool samples.

Sample Number	Average Fiber Diameter (μm)	YIE[1]		Y - Z[2]	
		Scoured	Carded	Scoured	Carded
87025	24.3	23.79	24.26	6.31	7.08
87081	22.1	24.79	21.28***	6.56	4.92**
87083	22.3	26.60	20.17***	17.57	3.96***
87150	30.6	33.53	30.71*	10.17	10.47
87156	21.8	24.36	17.87***	16.89	2.47***
87163	27.0	29.79	27.40**	9.36	8.61
87167	20.8	25.75	24.47**	7.74	7.15*
87173	22.2	22.96	23.75	5.66	6.50
87221	30.4	28.18	24.10***	7.51	6.14**
87250	22.1	26.61	25.10**	6.96	6.99
87252	22.1	28.83	25.82**	10.21	8.19*
87253	21.8	32.40	27.34***	13.41	9.47
87254	25.4	33.63	30.77*	20.77	11.49***
87259	23.1	22.72	19.98*	5.68	3.73*
87260	20.9	25.53	21.11***	7.51	4.64
87265	20.0	28.67	24.09***	19.17	7.02***
87283	21.9	27.03	23.98***	17.75	10.46
87291	22.9	20.87	19.46	4.17	3.23
87295	22.3	22.39	20.97	5.55	4.75
87306	18.6	26.83	23.69***	7.82	6.76**
87307	20.7	26.07	23.16**	7.58	6.25*
87323	18.9	26.41	22.52***	7.95	5.92**
87325	19.8	29.33	24.19***	18.91	7.17***
87327	21.0	27.05	25.32	8.69	7.54
87328	22.0	27.28	21.93***	16.84	4.96***
87343	20.7	27.06	21.00***	18.60	4.59***
87360	20.3	27.58	22.97***	18.17	6.19***
87370	20.8	23.46	19.09***	16.52	3.13***
87415	21.8	20.69	19.54	4.26	3.42
87425	23.3	23.41	18.45***	15.76	2.57***
87428	24.1	21.14	21.37	4.34	6.65
87432	22.1	26.03	21.84***	16.84	4.96***
87440	22.3	21.89	19.90**	5.01	3.71*
87442	22.5	26.61	20.93***	16.65	4.20***
87443	25.4	25.59	21.46***	16.09	4.74***
87449	23.6	25.45	20.54***	16.62	4.05***
87468	32.9	28.34	23.50***	8.58	6.17***
87469	19.5	24.32	23.26	6.68	6.16
87475	19.7	25.96	23.95**	6.83	6.51
87484	21.0	24.84	20.06***	16.65	3.80***
87488	22.1	22.23	21.16	5.24	4.53
87492	25.9	25.42	21.22***	6.44	4.29***
87494	19.3	25.05	20.38***	6.59	3.99***
87499	29.2	29.56	26.89	18.37	8.35***
87500	20.9	28.04	23.66***	19.02	6.46***
87504	18.9	25.72	24.29	6.95	6.79
87511	23.5	25.23	21.91***	16.16	5.03***
87512	21.4	22.83	23.23	5.31	6.08*
87519	23.8	23.40	23.32	5.84	6.35
87520	21.3	20.76	21.26	4.18	4.64

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
[1] Yellowness Index (YIE) – as yellowness increases, YIE increases
[2] Yellowness Index (Y-Z) – as yellowness increases, Y-Z increases

tralian wools by comparison generally have Y-Z values ranging from 1 to 4 (Cottle and Zhao, 1995), although in this study we found Australian wools to range from 2.72 to 10.05. Of the 50 U.S. samples evaluated only ten had Y-Z values of less than 4 even after carding. Only three of the 18 Australian samples had Y-Z values of less than 4 after carding. The difference in yellowness values found for Australian wools in this study compared to previously reported studies could be explained by the fact that these wools were given an alkali scour, which typically results in an increased yellowness. Australian wools are usually given a neutral detergent scour, which generally results in a whiter (less yellow) fiber. It is important to note however, that all wools in this study were processed in the same manner. An alkali scour was used in this study as per ASTM D584-96 procedures (ASTM, 1998a).

Average fiber diameters and yellowness indices for New Zealand wool samples are shown in Table 2. Fiber diameters ranged from 17.5 μm to 38.6 μm. Yellowness indices of 50 pairs of scoured and carded wools clearly indicated that carding also improved the color of these samples. In half of the samples (25 cases) carding significantly improved (decreased) the YIE value while in an additional 20 cases, though not significant, the samples had lower carded YIE values compared to the scoured value. When evaluating color based on Y-Z values, 15 samples showed significant improvement after carding while a further 25, though not significant, showed improved values. As with the case of YIE, a lower Y-Z value indicates a whiter wool.

The yellowness of these wools when scoured ranged from a high of 40.02 to a low of 24.20 (YIE) and a high of 13.96 to a low of 6.25 (Y-Z), while with the carded wools the yellowness ranged from a high of 38.19 to a low of 22.14 (YIE) and a high of 15.69 to a low of 5.17 (Y-Z).

Average fiber diameters and yellowness indices for Australian wool samples are shown in Table 3. Fiber diameters ranged from 19.2 μm to 36.3 μm. Yellowness indices of 18 pairs of scoured and carded wools clearly indicates that carding also improved the color of these samples. In six samples carding significantly improved (decreased) the YIE value while in the other 12 cases, though not

Table 2. Yellowness indices of scoured and carded NZ wools.

Sample Number	Average Fiber Diameter (µm)	YIE[1]		Y – Z[2]	
		Scoured	Carded	Scoured	Carded
00001	31.4	26.89	25.61	8.59	7.61
00002	34.9	31.61	29.61*	10.69	9.58*
00003	24.1	28.86	27.64	9.84	8.98
00004	26.4	34.99	32.93*	11.31	10.98
00005	35.9	33.15	31.60**	11.75	11.55
00006	26.0	31.44	29.65**	11.15	10.32*
00007	32.6	30.78	28.55**	10.55	9.39*
00008	19.6	29.41	28.66	9.87	10.07
00009	34.6	34.09	30.75*	12.59	10.90
00010	30.9	27.51	25.76*	8.50	7.39*
00011	33.3	39.05	37.68	13.96	14.07
00012	35.5	30.97	28.73*	10.22	9.47
00013	33.3	27.76	26.24**	8.46	8.15
00014	22.3	25.27	24.65	7.29	7.22
00015	18.2	25.84	25.27	7.16	7.07
00016	26.3	26.68	24.85	8.10	6.90
00017	19.1	25.48	22.62**	7.65	5.57**
00018	31.1	27.40	25.06***	8.36	7.05**
00019	35.7	32.21	30.30*	11.39	10.41
00020	19.1	26.53	25.21	8.11	7.26
00021	36.9	33.54	31.98*	12.55	11.59
00022	28.5	28.25	28.42	9.00	9.74
00023	18.4	25.09	22.14**	7.18	5.41**
00024	18.8	24.19	23.10	6.53	6.00
00025	21.7	28.07	26.29	9.27	8.36
00026	36.6	32.62	28.50***	13.11	9.21*
00027	20.7	27.76	27.80	7.49	8.15
00028	20.7	26.90	27.03	7.47	8.26
00029	30.2	29.96	28.36**	10.47	9.19**
00030	31.2	32.69	29.27**	11.52	9.83*
00031	21.4	27.63	26.32	8.35	8.21
00032	26.2	30.70	28.59**	10.02	9.59
00033	24.6	28.58	27.28	10.02	9.26
00034	22.0	27.94	28.43	8.83	9.29
00035	26.2	25.03	23.69*	7.05	7.25
00036	21.1	24.20	22.22**	6.25	5.17
00037	20.8	33.35	32.42	11.82	11.88
00038	18.9	26.76	25.70	8.22	7.87
00039	32.9	29.85	28.07*	10.14	9.37
00040	25.8	26.06	23.07**	8.18	6.12*
00041	22.4	30.06	28.40	10.34	9.88
00042	24.5	31.12	29.52	10.27	10.03
00043	37.7	35.54	34.54	13.07	13.06
00044	38.6	34.56	31.58***	12.67	10.86***
00045	18.9	29.73	28.86	9.92	9.61
00046	19.5	28.44	26.56	9.55	12.50
00047	28.6	35.80	38.19	13.36	15.69*
00048	28.7	40.52	32.09	13.62	11.96
00049	25.6	29.42	25.74*	10.12	7.83*
00050	17.5	27.59	23.68**	8.96	6.41**

* $p<0.05$ ** $p<0.01$ *** $p<0.001$
[1] Yellowness Index (YIE) – as yellowness increases, YIE increases
[2] Yellowness Index (Y-Z) – as yellowness increases, Y-Z increases

significant, the samples had lower carded YIE values, compared to the scoured value. When evaluating color based on Y-Z values, four samples showed significant improvement after carding while a further 11, while not being significant, showed improved values. As with the case of YIE, a lower Y-Z value indicates a whiter wool.

The yellowness of these wools when scoured ranged from a high of 31.25 to a low of 21.96 (YIE) and a high of 10.63 to a low of 4.93 (Y-Z), while with the carded wools the yellowness ranged from a high of 29.71 to a low of 20.10 (YIE) and a high of 10.05 to a low of 2.72 (Y-Z).

Table 4 shows the Y-Z yellowness indices of scoured and carded U.S., Australian and New Zealand wools by average fiber diameter ranges. Wools from each country were grouped according to fiber diameter into four groups; <20 µm, 20 to 22.9 µm, 23 to 25.9 µm, ≥ 26 µm. Statistical analysis (t-tests) of these fiber diameter groups yielded some interesting results. As was expected, wools from the different countries were not always significantly different in terms of their yellowness. Most of the major differences occurred between U.S. and New Zealand wools or Australian and New Zealand wools. In only one case was U.S. wool significantly different from Australian wool – scoured wools between 20 µm and 22.9 µm.

However, what was of interest in this analysis was the range of yellowness indices, particularly for the scoured wools. The results indicated that U.S. wools had a much wider range of yellowness indices compared to that of both Australian and New Zealand wools. For example, for fiber diameters less than 20 µm; U.S. wools had a mean Y-Z value of 8.82 and the yellowness ranged from 6.59 to 18.91, Australian wools had a mean of 5.96 and ranged from 4.93 to 7.78, and New Zealand wools had a mean of 8.32 and ranged from 6.53 to 9.92. It is unclear how meaningful this result is because of the small number of samples in some of the fiber diameter groupings. More samples are needed to better characterize both U.S. and Australian and New Zealand wool. This is a result that requires additional research using much larger sample sizes. However, if the results were significant they could have ramifications for the selling price of U.S. wools based on color measure-

Table 3. Yellowness indices of scoured and carded Australian wools.

Sample Number	Average Fiber Diameter (μm)	YIE[1]		Y – Z[2]	
		Scoured	Carded	Scoured	Carded
00101	22.1	24.71	22.94	6.41	5.75
00102	23.6	26.26	24.21	7.13	6.36
00103	21.1	25.45	24.14	7.24	6.50
00104	20.9	29.03	26.02*	9.17	8.18
00105	20.4	25.62	24.07	7.47	6.72
00106	24.1	24.96	23.42**	6.94	6.04*
00107	22.1	26.20	25.40	7.63	7.68
00108	36.3	31.25	29.71*	10.63	10.05
00109	23.8	25.96	23.68**	7.6	6.45
00110	20.7	25.30	24.44	7.14	2.72
00111	19.2	26.45	25.67	7.78	7.78
00112	21.1	27.19	27.10	7.58	7.79
00113	20.1	25.01	23.45	6.69	5.45*
00114	18.0	21.96	20.74	4.93	4.18
00115	21.0	23.51	22.72	5.46	4.87
00116	21.0	22.75	20.45**	5.26	3.93*
00117	19.5	22.21	20.73	5.18	4.16
00118	20.2	22.01	20.10**	5.29	3.95**

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

[1] Yellowness Index (YIE) – as yellowness increases, YIE increases

[2] Yellowness Index (Y-Z) – as yellowness increases, Y-Z increases

ments. These measurements, if done, are typically carried out on scoured or otherwise cleaned wool.

We believe that the yellowness values found in this study may not be indicative of the color of wools obtained from the United States, New Zealand or Australia because some of the fiber groupings were underrepresented. A reason for this belief is that as far as fiber diameter is concerned a full range of the wools produced by each country was not evaluated. Further study is needed to better understand the comparative relationships between the color of wools from the different countries. In particular, as well as conducting alkaline scours, all wools also need to be given neutral scours before evaluation. Additionally, further study needs to be done in evaluating wool's susceptibility to yellowing. Two tests have been developed to predict the susceptibility of wool to yellow, one an indirect method the other a direct method. The indirect method – the yellow predictive test (YPT) – developed by Raadsma and Wilkinson (1990) involves incubating wool samples for five days under high humidity. Supernatant is then extracted and the color of the liquid can be used as an indicator or the yellow discoloration of the wool. Aliagra et al. (1996) developed the yellow challenge test (YCT). This is a direct method of evaluating the propensity to wool to yellow. The yellowness of clean wool fibers is evaluated after incubation of grease wool for 14 days under high humidity.

The uniformity and cleanliness of wool grown on different body areas of sheep are major influences on the degree of skirting and wool preparation required (Lupton, et al., 1989). Although wool production and quality control are year-round activities, the manner in which wool is shorn and prepared for sale has an immediate impact

Table 4. Yellowness indice (Y-Z) of scoured and carded U.S, Australian and New Zealand wools by average fiber diameter.

Wool Origin	Average fiber Diameter <20 μm		Average fiber Diameter 20.0 – 22.9 μm		Average fiber Diameter 23.0 – 25.9 μm		Average fiber Diameter 26.0 μm	
	Scoured	Carded	Scoured	Carded	Scoured	Carded	Scoured	Carded
U.S.	N=7	N=7	N=28	N=28	N=10	N=10	N=5	N=5
Average	8.82	6.19	11.38[1,2]	5.51[2]	11.40	5.60[2]	10.80	7.95[2]
Range	6.59-18.91	3.99-7.17	4.17-19.17	2.47-10.46	4.34-20.77	2.57-11.49	7.51-18.37	6.14-10.47
Australia	N=3	N=3	N=11	N=11	N=3	N=3	N=1	N=1
Average	5.96[3]	5.37	6.85[1,3]	5.69[3]	7.22[3]	6.28[3]	10.63	10.05
Range	4.93-7.78	4.16-7.78	5.26-9.17	2.72-8.18	6.94-7.60	6.04-6.45		
New Zealand	N=10	N=10	N=9	N=9	N=5	N=5	N=26	N=26
Average	8.32[3]	7.78	8.57[2,3]	8.49[2,3]	9.69[3]	8.44[2,3]	10.85	10.04[2]
Range	6.53-9.92	5.41-12.50	6.25-11.82	5.17-11.88	8.18-10.27	6.12-10.03	7.05-13.96	6.90-15.69

[1] Australian wool different from U.S. wool ($p<0.001$).

[2] U.S. wool different from N.Z. wool ($p<0.001$).

[3] Australian wool different from N.Z. wool ($p<0.001$).

upon its value and utility to the textile manufacturer. Processing of wool has changed, placing new requirements on fibers. Since 1970, processing rates have increased between 100 percent and 500 percent in almost every stage of worsted processing with the exception of ring spinning, which sustained only a modest increase (Teasdale, 1988). Improved specification of wool will be necessary, especially for processors who do have not extensive wool experience and expertise. Better perception by the mills of their own requirements will be translated into premiums and discounts for particular properties, preparation and marketing methods.

Wools purchased from some overseas suppliers (e.g., in Australia, New Zealand or South Africa) typically do not have to undergo this sorting and grading process because they are prepared by professional skirters and classers in the shearing barn in their respective countries. Thus, these wools are more valuable to the processor. This allows a premium to be paid for wools prepared in this manner.

Processors are paying more attention to the color of wool. A recent study (Cottle and Zhao, 1995) has shown that incubation can bring wool to a more stable color. The color is less likely to change during subsequent storage, scouring or dyeing. Using this information, processors should be able to better predict the processing performance of raw wool (Cottle and Zhao, 1995). A recent development has been a mill-scale, automated-color, sorting device that is capable of sorting large quantities of undyed fibrous material in a continuous on-line operation and removing colored faults, such as stained wool, dark fibers, etc. (Abbott, 1995).

The major wool exporting nations (Australia and New Zealand) place different emphasis on the clean color of wool, with New Zealand placing a high emphasis on clean color, whereas Australia places a lower emphasis (Baxter, 1995). The reason for this is that New Zealand exports more scoured wool than does Australia and therefore the visual appearance of the wool becomes an important characteristic when supplying wool to a customer (Marler, 1992).

Yellow discoloration of wool can be classified as scourable and non-scourable, however, there is no clear distinction between the two (Aitken, et al., 1994). Non-scourable yellow discoloration develops during growth, storage and processing of wool fiber (Winder, et al., 1998). Genetic and environmental factors have been implicated in the yellow discoloration of wool. Wilkinson (1982) found that animals could be classified according to their genetic predisposition to yellow but that environmental factors, such as warmth, humidity and dampness, tended to promote yellowness in genetically susceptible sheep. Non-scourable yellowing was also shown to be prevalent in sheep susceptible to fleece rot (Wilkinson, 1981).

It has been shown that yellow fleeces suffer a significant price discount in international markets (Benavides and Maher, 2000). During the three wool seasons 1996-97 to 1998-99, New Zealand wools, particularly, had Y-Z values ranging from -1.6 to 9.5. Wool up to 30 μm is used primarily in apparel manufacture. Yellow discoloration is of greater importance here than it may be with coarser wools that are used in other applications. During this three-year period, price reductions of up to $NZ 0.10 were observed per Y-Z unit increase (Benavides and Maher, 2000). This translated to an overall price reduction of 16.6 percent for wools having a Y-Z of ≥ 6 compared to those wools with a Y-Z <6 (Benavides and Maher, 2000). Thus there is the potential for significant economic gain for U.S. producers if it can be shown that U.S. wools do not have a propensity to yellow.

Conclusion

It is evident from the results of this study that carding typically improves the color of wool as measured by either YIE value or Y-Z value. This was expected as carding is a further cleaning process and most likely removes dark-colored, extraneous materials, which would otherwise detract from the clean color of the wool.

What was of interest, and warrants further study, is that it appears that while U.S. wools on average may compare favorably, particularly in certain fiber-diameter groupings, the range of yellow color within these diameter groups may be of concern. This could be of significance as far as potential marketing of the wool, both domestically and internationally, especially since yellow fleeces in today's international markets may suffer a significant price discount.

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Development and Consumer Acceptance of Pre-cooked Lamb Leg Roasts[1]

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Summary

The objective of this study was to develop a palatable pre-cooked lamb leg roast. Lamb legs (n = 60) were fabricated into 240 roasts. Roasts were assigned to one of four spice treatments: control (CON), Italian, Mexican, prime rib. After being injected with a 15 percent brine mixture, roasts were smoked to an internal temperature of 63°C, vacuum packaged, and frozen at -10°C. Roasts were thawed and reheated one of three ways (conventional oven, microwave oven, or boiling) and served to a trained sensory panel to determine differences in reheating method. No differences ($P > 0.05$) were found between reheating methods. The trained panel rated the prime rib spice the juiciest, the most tender, the most flavorful, and the best in overall acceptability. The control treatment (CON) was rated higher ($P < 0.05$) for lamb flavor, warmed-over flavor, and flavor intensity by trained panelists. Upon completion of trained sensory panel, a consumer panel (n = 199) was served samples of roasts to determine the preferred spice blend. Consumers rated the prime rib spice the highest ($P < 0.05$) for all palatability attributes and the CON the lowest ($P < 0.05$). This study indicated the prime rib spice treatment was preferred most often for tenderness, juiciness, flavor, and overall liking by both the trained sensory panel and consumer panel. Therefore, roasts seasoned with the prime rib rub appear to have the most market potential.

Key words: Lamb, Pre-cooked Roasts, Flavor, Reheating Method

Introduction

With the ever-increasing trend of both men and women working outside of the home, the demand for a convenient, fast, palatable meal has been on the rise (Salvage, 1999). The red-meat industry, especially the beef and pork industries, has taken steps to develop products that are not only low in fat, but also quick, easy, and convenient to prepare to accommodate the changing lifestyles of consumers (Nayga, 1993). Between 1970 and 1989 red-meat consumption, especially lamb, in the United States fell by nearly 50 percent (Nayga, 1993). It is obvious that the lamb industry needs to regain market share and needs to find a way to rebuild consumer confidence for flavor and rebuke any negative past experience in lamb products.

The biggest change in retail markets between 1988 and 1998 was toward convenience items (Nunes, 1998). The field of ready-to-eat products has been expanded greatly over the past few years in order to meet the convenience demands of consumers. Today, consumers tend to be more inclined to pay for the convenience of a pre-cooked, ready-to-eat meal (Nunes, 1998). Unfortunately, little effort has been focused on pre-cooking lamb. Most supermarkets have a variety of ready-to-eat foods and frozen prepared foods ready for heating (Nayga, 1993), a pre-cooked lamb product seems to be economically marketable and sustainable. Therefore, the lamb industry needs a product that can gain market share in home-meal replacement to increase the consumption of lamb and reverse the negative opinion that some consumers have about the overall eating satisfaction of lamb. The objective of this study was to determine the most acceptable reheating method, and the spices and flavorings most acceptable with lamb to develop a palatable, convenient, pre-cooked lamb leg roast.

Materials and Methods

Preparing the Roasts

Lamb legs (n = 60) were purchased from Pak Marketing in San Angelo, Texas. The legs were transported to the Texas Tech University Meat Laboratory for further processing. First, the patella was removed from the legs. The legs were cut into four 3.81 cm roasts with a bandsaw for a total of 240 uniform roasts. The most anterior roast from each leg was labeled roast number one, the next was labeled roast number two, the next most anterior was labeled roast number three, and the most posterior was labeled roast number four for all 60 legs. All roasts were then trimmed free of any external fat, and the seam fat containing the poplitenal lymph node was removed. All roasts were injected with a 15 percent brine mixture of water, 0.50 percent phosphate, and 1 percent salt using a Gunther Pickler Injector (model P1632, Koch Supplies, Inc., Kansas City, Mo.). After the roasts were injected, they were allowed to drain for 10 minutes at 36°F. Three spice blends (Table 1) were formulated (60 roasts/spice blend), and 60 roasts were used as a control group. The roasts were randomly assigned within location (1 to 4) to one of four spice treatments: control (CON), Italian, Mexican, and prime rib. This ensured an equal number of roasts from each anatomical location per treatment. Immediately after all roasts were rubbed, they were cooked and smoked in a smokehouse (model 1000, Alkar Corporation, Lodi, Wis.) to an internal temperature of approximately 63°C to achieve a medium-rare degree of doneness (AMSA, 1995). The smoke cycle consisted of two stages. Stage 1 lasted for 1.5 h, with the dry bulb set at 65°C and the wet bulb set at 38°C for a relative humidity of 18.5 percent. Stage 2 was set to cook to an internal core temperature of 63°C, with the dry bulb set at 74°C and the wet bulb set at 60°C to equal a 50 percent relative humidity. After cooking, the roasts were chilled to 2°C, vacuum packaged, and frozen at -10°C.

Table 1. Ingredient list of three different spice blends and the percentage of each spice for lamb roasts.

Italian	Mexican	Prime Rib
Italian spice (37.5%)	Coriander (10.7%)	Prime rib rub[a]
Rosemary (6.25%)	Paprika (21.4%)	
Oregano (12.5%)	Garlic powder (14.4%)	
Savory (6.25%)	Ground pepper (21.4%)	
Ground pepper (37.5%)	Cumin (10.7%)	

[a] AC Legg Blend RF-04-161-000 (Calera, AL).

Trained Sensory Panel

Trained sensory panel analysis was conducted on 120 roasts (30 roasts/treatment) to determine the ideal reheating method and to detect differences between spices for differing palatability characteristics. The roasts were thawed and reheated one of three ways (10 roasts/treatment/reheat method): conventional oven, microwave, and boiling to an internal temperature of approximately 63°C for each reheating method. A conventional oven was preheated to 163°C, four roasts were placed in an aluminum pan, and 250 mL of distilled water was placed in the bottom of the pan. Two roasts were placed on paper plates, covered with wax paper, and reheated in a microwave at 1100 watts for 3.5 min (model JES1036PWH, General Electric, Louisville, Ky.). Boiling involved placing each individual roast into unsealed cryovac bags and placing them into pots containing two liters of distilled water. After reheating, roasts were cut into 1 cm x 1 cm x 3.81 cm pieces, placed into serving pans, and kept at 60°C. Samples were served warm to a seven-member panel, trained as recommended by Cross et al. (1978). Panelists evaluated the samples based on an 8-point hedonic scale involving initial and sustained juiciness, initial and sustained tenderness, flavor intensity, characteristic lamb flavor, and overall acceptability (8 = extremely juicy, tender, intense, characteristic lamb flavor, and like extremely; 1 = extremely dry, tough, bland, uncharacteristic lamb flavor, and dislike extremely). Panelists also evaluated the samples for warmed-over flavor (WOF) based on a 5-point hedonic scale (1 = no WOF; 5 = extreme WOF). Samples were served under red lights to mask color differences, and panelists were given apple juice and water to cleanse their palates between samples. Results from the trained panel were used to determine the most appropriate reheating method for the consumer panel.

Consumer Panel

The remaining 30 roasts per treatment were used for a consumer panel to determine which spice blend was preferred. Consumers (n = 199) at the San Angelo Livestock Show and Rodeo were asked to participate in the study. The trained panel detected no differences between reheating methods for palatability traits. Therefore, a microwave was used for ease of resources to serve consumers. Roasts were thawed and then reheated for 3.5 min using an 1100 watt microwave (model JES1036PWH, General Electric, Louisville, KY). Roasts were then cut into 1.5 cm x 1.5 cm x 3.81 cm pieces, placed into serving pans, and kept at 60°C. Each consumer tasted samples from each treatment. Panelists tasted each sample to determine juiciness, tenderness, flavor, and overall liking (6-point scale from 1=like extremely to 6=dislike extremely). Also, panelists were asked their likelihood to buy the roast (5-point scale from 1=definitely would buy to 5=definitely would not buy) if it was available in a grocery store. After tasting all four samples, consumers were asked which sample they preferred the least and the most. Additionally, consumers were asked to answer demographic questions including: marital status, gender, ethnicity, age, household income level, and how many times they have consumed lamb in the last month.

Statistical Analysis

Individual legs were blocked and data from the trained sensory panel were analyzed using the GLM procedure of SAS (2003), as a 3 x 4 factorial design (three cooking methods and four spice blends) with individual roast as the experimental unit. Least-square means were computed for each dependent variable and statistically separated by pairwise t-test (PDIFF option of SAS) with predetermined $\alpha = 0.05$.

Data from the consumer panel were analyzed using the GLM procedure of SAS as a completely randomized design with spice blend as the treatment and individual roast sample as the experimental unit. Least-square means were computed for each dependent variable and statistically separated by pair-wise t-test with predetermined $\alpha = 0.05$. Also, comparisons of frequencies from consumer panelists' responses were tested for significance ($\alpha \leq 0.05$) using Chi-Square tests.

Results and Discussion

Trained Sensory Panel

No differences ($P > 0.05$) were found between roasts from each anatomical location for tenderness, juiciness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF. Also, no differences ($P > 0.05$) were found between reheating methods for initial and sustained juiciness and tenderness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF. This result is similar to that reported by Boles and Parrish (1990), who found the flavor of pre-cooked pork roasts did not deteriorate when reheated with a microwave. In contrast with the results of the current study, Lyon and Ang (1990) found pre-cooked chicken patties to vary in their off-flavor development when reheated in either a microwave or a convection oven. Those reheated in a convection oven had higher off-flavor intensities. This could be because lamb contains fewer polyunsaturated fatty acids, and the chicken patties were refrigerated and the roasts for this study were vacuum packaged and frozen. No differences ($P > 0.05$) for a spice x reheating method interaction were found for initial and sustained juiciness and tenderness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF. A significant difference existed between spices for initial and sustained juiciness and tenderness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF (Table 2). For both initial and sustained juiciness, prime rib was the juiciest ($P < 0.05$), followed by Italian, Mexican, and the CON. According to Romans et al. (2001), the addition of phosphates helps to maintain juiciness of the product. Therefore, no differences should have been detected between spices for juiciness since all roasts were injected with the same brine solution. Certain spices used in the blends could have helped to increase the products overall juiciness, particularly the extra salt in

Table 2. Least square means and standard errors of sensory panel ratings for different spice blends.

	Treatment				
Trait	CON[k]	Italian[l]	Mexican[m]	Prime Rib[n]	SEM
Initial juiciness[e]	4.68[d]	5.46[b]	4.96[c]	6.52[a]	0.10
Sustained juiciness[e]	4.84[d]	5.76[b]	5.13[c]	7.15[a]	0.10
Initial tenderness[f]	6.00[c]	6.90[ab]	6.62[b]	7.05[a]	0.12
Sustained tenderness[f]	6.27[c]	7.23[ab]	6.94[b]	7.35[a]	0.11
Flavor intensity[g]	5.88[a]	4.85[b]	4.91[b]	4.89[b]	0.09
Lamb flavor[h]	5.94[a]	4.26[b]	4.30[b]	4.35[b]	0.19
Overall acceptability[i]	4.01[d]	6.19[b]	5.37[c]	6.84[a]	0.10
Warmed-over flavor(WOF)[j]	1.39[a]	1.01[b]	1.05[b]	1.00[b]	0.03

[abcd] Means in a row with different superscripts differ ($P < 0.05$).
[e] 1 = extremely dry; 8 = extremely juicy.
[f] 1 = extremely tough; 8 = extremely tender.
[g] 1 = extremely bland; 8 = extremely intense.
[h] 1 = extremely uncharacteristic; 8 = extremely characteristic.
[i] 1 = dislike extremely; 8 = like extremely.
[j] 1 = no WOF; 5 = extreme WOF.
[k] CON = Control.
[l] Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[m] Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[n] Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

the prime rib pre-mix. Prime rib was more tender ($P < 0.05$) compared to the Mexican and the CON; and the CON was the toughest ($P < 0.05$) when compared to other treatments for both initial and sustained tenderness. The most intense flavor, characteristic lamb flavor, and WOF were associated with the CON group when compared to other treatments ($P < 0.05$). This indicates that the spices and seasonings used covered up the natural lamb flavor and helped to prevent WOF. Smith et al. (1984) reported adding phosphates to pre-cooked roasts decreases the occurrence of an off-flavor development, and Boles and Parrish (1990) discovered when phosphates were added to roasts, they were more palatable. Prime rib was rated the most acceptable overall, followed by Italian, Mexican, and the CON group ($P < 0.05$).

Consumer Panel

The 199 consumers who participated in the study varied in demographic characteristics (Table 3). The percentages and numbers are based on all data provided; however, not all of the participants provided complete demographics. The most common ethnic groups represented were Caucasian and Hispanic totaling 98 percent, with Caucasian totaling 91 percent of the total consumers surveyed. American-Indian and other ethnic groups comprised the other 2 percent. Because of the overwhelming percentage of Caucasians in the study and the lack of ethnic diversity, the effect of ethnicity on consumer ratings was omitted.

Results from the consumer panel are similar to the results from the trained sensory panel for tenderness, juiciness, flavor, and overall liking of the spice blend treatments. Consumers rated the roast with the prime rib spice the most tender, most juicy, most flavorful, and the highest for overall liking ($P < 0.05$) compared to all other treatment groups (Table 4.) The CON treatment was rated less desirable ($P < 0.05$) for tenderness, juiciness, flavor, and overall liking compared with other treatments. Roasts with the prime rib treatment were rated the most likely to be purchased ($P < 0.05$) and CON roasts were rated the least likely to be purchased compared to other treatments.

No differences ($P > 0.05$) in tenderness, juiciness, flavor, overall liking, and likelihood to buy between the treatments were found based on differences in demographic data. Combined responses for the upper three tenderness categories of like extremely (LE), like very much (LVM), and like slightly (LS) for the CON, Italian, Mexican, and prime rib treatments were 87.9 percent, 89.9 percent, 91.5 percent, and 94.9 percent, respectively. Prime rib was rated LE a greater percentage of the time ($P < 0.05$) compared to other treatments. No differences ($P > 0.05$) existed between treatments for LVM, dislike slightly (DS), dislike very much (DVM), and dislike extremely (DE). For the bottom three categories combined, prime rib had the lowest total percentage (5 percent), followed by Mexican, Italian, and the CON at 9 percent, 10.1 percent, and 12.2 percent respectively.

The juiciness category also heavily favored the prime rib spice. Ninety-five percent of the responses for prime rib fell into the LE, LVM, and LS categories, while responses from the other three treatments were comprised mainly in the LVM, LS, and DS categories. Consumers chose LE a higher ($P < 0.05$) percentage of the time and LS and DS a lower ($P < 0.05$) percentage of the time for prime rib compared to the other three treat-

Table 3. Demographic characteristics of consumer panel.

Trait	No.[a] of consumers	Percent
Gender		
Male	132	67.01
Female	65	32.99
Marital Status		
Married	132	68.39
Single	61	31.61
Ethnicity		
Caucasian	179	90.86
Hispanic	14	7.11
American-Indian	1	0.51
Other	2	1.52
Age, yr		
18 to 25	45	22.96
26 to 35	34	17.35
36 to 45	48	24.49
46 to 55	46	23.47
56 to 65	19	9.69
Over 65	4	2.04
Household Income Level		
<$10,000	19	10.11
$10,000 to 14,999	4	2.13
$15,000 to 24,999	6	3.19
$25,000 to 34,999	36	19.15
$35,000 to 49,999	29	15.43
$50,000 to 74,999	43	22.87
$75,000 to 99,999	34	18.09
>$99,999	17	9.04
Lamb Consumption[b]		
0	141	72.31
1	30	15.38
2	14	7.18
3	5	2.56
4	3	1.54

[a] Not all consumers who participated in the study provided complete data.
[b] Number of times consumers have consumed lamb in previous month.

Table 4. Least square means and standard errors of consumer panel ratings for different spice blends.

Trait	CON[f]	Italian[g]	Treatment Mexican[h]	Prime Rib[i]	SEM
Tenderness[d]	2.31[c]	2.01[b]	2.09[b]	1.69[a]	0.08
Juiciness[d]	3.06[c]	2.67[b]	2.84[b]	1.86[a]	0.08
Flavor[d]	3.03[c]	2.77[b]	2.59[b]	1.91[a]	0.08
Overall liking[d]	2.95[c]	2.71[b]	2.64[b]	1.90[a]	0.08
Likelihood to buy[e]	2.95[c]	2.71[b]	2.64[b]	1.93[a]	0.08

[abc] Means in a row with different superscripts differ ($P < 0.05$).
[d] 1 = Like extremely; 6 = Dislike extremely.
[e] 1 = Definitely would buy; 5 = Definitely would not buy.
[f] CON = Control.
[g] Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[h] Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[i] Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

ments. Consumers chose DVM a higher percentage ($P < 0.05$) of the time for the CON compared to other treatments for juiciness.

Consumer panelist ratings for flavor percentages followed the same trend as juiciness scores. The top four categories combined comprised 88.9 percent, 94 percent, 92.5 percent, and 96 percent of the CON, Italian, Mexican, and prime rib responses, respectively. Prime rib received a higher ($P < 0.05$) percentage of responses for the LE category compared to other treatments. The Mexican spice received a significantly higher percentage of responses than the CON for the same category. Prime rib was chosen significantly fewer times for LS compared to other treatments and a lower (P < 0.05) percentage of the time for DS and DVM compared to the CON. No differences (P > 0.05) were found for the LVM and DE categories between treatments.

The percentages of consumer ratings for overall liking of different spice blends are presented in Table 5. Of the responses, 82.3 percent, 82.7 percent, and 82.5 percent fell into the LVM, LS, and DS categories for the CON, Italian, and Mexican spices, respectively, whereas LE and LVM constituted 79.9 percent of the responses for the prime rib. Prime rib had a higher percentage ($P < 0.05$) for LE compared to other treatments. The CON had a higher percentage for DVM compared to prime rib, and the CON, Italian, and Mexican were chosen a higher percentage ($P < 0.05$) for LS and DS compared to the prime rib spice.

Therefore, the roast seasoned with the prime rib spice would be the most likely to sell in a grocery store setting for pre-cooked lamb roast. This was evident by the consumers rating of likelihood to buy a roast seasoned by each treatment. Prime rib results showed that consumers chose "definitely would buy" or "probably would buy" 77.9 percent of the time, compared to 38.1 percent, 42.4 percent, and 45.8 percent for CON, Italian, and Mexican spices respectively. "Probably would buy," "may or may not buy," and "probably would not buy" were the most common ($P < 0.05$) answers for the CON and Mexican spice.

While demographics had no significant effect on ratings for tenderness, juiciness, flavor, overall liking, and likelihood to buy; significant effects were found between demographics and which spice blend was preferred the most and the least. Married and single consumers each preferred the prime rib spice the most and the CON the least ($P < 0.05$) compared to other treatments. Males and females also each preferred the prime rib spice the most ($P < 0.05$) compared with other treatments. Males ranked the CON as being preferred the least ($P < 0.05$), followed by Italian and Mexican, and then by prime rib. All age groups from 18 to 65 preferred the prime rib spice ($P < 0.05$) over the other treatments. The 18 to 25 age group chose the prime rib spice fewer ($P < 0.05$) times as the least favorite compared to other treatments. All income levels preferred the prime rib spice higher ($P < 0.05$) than the other treatments except for the $10,000 to $14,999 and $15,000 to $24,999 groups, where no significant differences were found. No income level rated one particular spice as the least ($P > 0.05$) favorite over the other treatments. As income level rose, the percentage of consumers that preferred the CON the least declined, and the percentage that preferred the prime rib the least increased. This could be explained by the fact that people with higher incomes tend to consume lamb more often (Nayga, 1993), and therefore, prefer the natural flavor of lamb over stronger spices that override its flavor.

Table 5. Percentages of each rating by consumer panelist for overall liking of samples from different spice blends.

Rating Scale	CON[c]	Italian[d]	Treatment Mexican[e]	Prime Rib[f]
Like extremely	7.6[b]	10.7[b]	12.6[b]	42.7[a]
Like very much	30.5	29.6	33.2	37.2
Like slightly	30.0[a]	40.3[a]	34.2[a]	13.1[b]
Dislike slightly	21.8[b]	12.8[b]	15.1[b]	4.0[a]
Dislike very much	8.1[b]	4.1[ab]	3.5[ab]	2.5[a]
Dislike extremely	1.0	2.6	1.5	0.5

[ab] Percentages in a row with different superscripts differ ($P < 0.05$).
[c] CON = Control.
[d] Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[e] Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[f] Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Implications

The results of this study revealed roasts from lamb legs can be processed and retailed as a pre-cooked product to increase the value of these primal cuts. Certain spices have the ability to mask general lamb flavor and improve palatability characteristics held in high regard to consumers. An advantage exists to marketing a pre-cooked lamb product that is palatable and convenient, especially one with prime rib spice. Results from the current study are in agreement with previous research showing tenderness and flavor to be the two most important factors for determining overall eating satisfaction in lamb. Overall, these products should improve the overall eating quality of lamb and appeal to a large number of new consumers.

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Efficacy of Dried Distiller's Grains with Solubles as a Replacement for Soybean Meal and a Portion of the Corn in a Finishing Lamb Diet[1]

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Summary

The objective of this experiment was to determine the effects of replacing soybean meal (**SBM**) and a portion of the corn with dried distiller's grains with solubles (**DDGS**) on growth performance, carcass characteristics, and the incidence of acidosis, bloat, or urinary calculi in wethers fed a high-grain finishing diet with soyhulls (**SH**) as the only source of dietary fiber. Wethers (n = 40) were allotted by weight to ten pens (average lamb weight per pen 43.4 kg ± 0.54 kg). Dietary treatments, SH-CORN-DDGS or SH-CORN-SBM, were assigned randomly to five pens. Diets were balanced to have similar CP (14.6 percent), ME (3.4 Mcal/kg), and calcium:phosphorous (2:1) and were pelleted and delivered through self-feeders. Wethers were observed twice daily for symptoms of acidosis, bloat, and urinary calculi. Feed offerings and feeder contents at trial termination were weighed and DMI was calculated. Gain:feed and ADG were calculated based on weights recorded at initiation and termination of the 64-d finishing period. Growth performance, DMI, and carcass data were analyzed statistically in a one-way analysis of variance with pen as the experimental unit. Average daily gain, DMI, gain:feed, and carcass characteristics did not differ ($P > 0.05$) between dietary treatments. Wethers did not exhibit symptoms of acidosis, bloat, or urinary calculi regardless of treatment. Dried distillers grains with solubles is a suitable substitute for SBM and a portion of the corn in a finishing wether diet where SH are the only source of fiber.

Key words: Dried Distiller's Grains with Solubles, Soyhulls, Lambs

Introduction

In the Midwest, the growing ethanol industry has increased the availability of dried distillers grains with solubles (**DDGS**). In 2004, it was estimated that 6.9 metric tons of DDGS was produced in the United States, and this amount of DDGS was expected to increase by 17 percent to 20 percent in both 2005 and 2006 (Markham, 2005). The growing supply of DDGS is likely to lower the cost of the feed ingredient, making it more favorable for use as a protein and energy source in the livestock industry. Large quantities of soybeans are processed in the Midwest resulting in the availability of soyhulls (**SH**). Soyhulls are a highly fermentable fiber source that can be mixed into a total mixed ration and pelleted easily. Increasing the use of DDGS and SH in finishing lamb diets would allow producers to take advantage of these economically priced and regionally available feeds. Currently, the majority of lamb-finishing operations are in the plains states (80 percent), with less than 20 percent of lambs being finished in the Midwest (Jones, 2004). The increasing availability of DDGS and SH could provide a competitive advantage to Midwestern feeders. However, the high phosphorous content of DDGS raises concerns as to its inclusion rate in finishing lamb diets because of environmental impact and potential problems with urinary calculi. Additionally, the inclusion of SH, as the sole source of fiber, is of concern because it is a highly fermentable fiber source with limited effective fiber and may lead to greater incidence of acidosis or bloat (Martin and Hibberd, 1990; Weidner and Grant, 1994; Shriver et al., 2000). This experiment was designed to determine if DDGS can replace SBM as a protein source and a portion of the energy supplied by corn in a high-grain finishing wether diet, where the only fiber source is SH. We hypothesize that when diets are balanced to have similar protein and energy content, wethers will have similar feedlot performance and carcass merit regardless of whether the nutrients are supplied by SH-CORN-SBM or SH-CORN-DDGS.

Table 1. Ingredient composition of diets composed of soyhulls (SH), dried distillers grains (DDGS), soybean meal (SBM) and corn.

	Treatment	
Ingredients[a]	SH-CORN-SBM	SH-CORN-DDGS
SH, %	10.0	10.0
DDGS, %	-	22.9
SBM, %	10.2	-
Corn, %	75.2	62.2
Dehydrated molasses, %	2.5	2.5
Limestone, %	1.5	1.8
Sheep TM salts[b], %	0.1	0.1
Ammonium chloride, %	0.5	0.5
	Calculated Nutrient Composition[c]	
CP, %	14.6	14.6
ME, Mcal/kg	3.4	3.4
Calcium, %	0.70	0.80
Phosphorous, %	0.35	0.40
Calcium : Phosphorous	2 : 1	2 : 1
Sulfur, %	0.143	0.165

[a] DM basis
[b] Sodium chloride 95 ≤ 93%, zinc (zinc oxide) 1.5%, manganese (manganous oxide) 0.80%, iron (ferrous carbonate) 0.46%, iodine (calcium iodate) 0.007%, cobalt (cobalt sulfate) 0.006%, selenium (sodium selinite) 90 ppm
[c] Calculated based on NRC values (NRC, 1985) on a DM basis

Materials and Methods

Animals and Treatments.

This trial was conducted at South Dakota State University in compliance with the regulations of the Institutional Animal Care and Use Committee. Forty crossbred wethers (43.4 kg ± 0.54 kg) of unknown origin were housed in an enclosed livestock facility with cross-flow ventilation, cement flooring and side walls in pens. Pens were bedded with straw and limestone weekly. Wethers were allotted by weight to 10 pens. Dietary treatments were assigned randomly, with each treatment represented by five pens of wethers. Dietary treatments were SH-CORN-DDGS or SH-CORN-SBM in pelleted form (Table 1). Diets were balanced to have similar CP and ME content. A calcium (Ca):phosphorous (P) ratio of 2:1 was maintained in both diets to account for the higher phosphorous content in the SH-CORN-DDGS diet. Ammonium chloride (0.5 percent, DM basis) was added to both diets to prevent urinary calculi. Upon arrival at the facility, wethers were offered fresh water, and water was offered twice daily throughout the experiment. Wethers were observed twice daily for symptoms of bloat (distended abdomen, labored breathing, profuse salivation) or acidosis (diarrhea, unthriftiness), or urinary calculi (frequent urination, distended abdomen, unthriftiness). Wethers were adapted to the facility over a 10-d period prior to trial initiation. During the acclimation period lambs were adapted to their assigned diet and feeding from self-feeders. Once the trial was initiated, self-feeders were filled with the treatment diets and not allowed to empty until the trial was completed. Weight of the initial feed and each subsequent feed addition was recorded. Feeders were checked daily to assure that animals had access to the feed and that bedding and fecal contaminant was removed from the feeder. On a weekly basis, feed fines were cleaned from the trough and their weight was recorded. At trial termination, feed remaining in the self-feeder was removed and weighed. Weight of removed feed fines and feed remaining at trial termination was subtracted from the sum of the feed additions to establish DMI.

Feedlot Performance Data Collection.

Weights were recorded on two consecutive days at trial initiation and averaged to establish average initial weights. Final weights were calculated by averaging two consecutive weights recorded within in a four-hour period on the final day of the 64-d trial. Feed efficiency (gain:feed) was calculated as the ratio of weight gain to DMI. Four intermediate weights were recorded at two-week intervals throughout the trial to monitor growth of the animals and determine when market weights were reached. Wethers, regardless of treatment were marketed at a common time endpoint when the average weight of the wethers reached an acceptable market weight of 60 kg.

Table 2. Growth performance of lambs fed diets composed of soyhulls (SH), dried distillers' grains (DDGS), soybean meal (SBM) and corn.

	Treatment			
	SH-CORN-DDGS	SH-CORN-SBM	SE	*P*-value
Pens per treatment	5	5	-	-
Animals per pen	4	4	-	-
Initial weight (kg)	43.4	43.4	0.54	0.97
Final weight (kg)	62.1	61.9	0.77	0.88
Gain: Feed	0.18	0.18	0.01	0.80
ADG (kg/d)	0.29	0.29	0.02	0.90
Average DMI (kg/d)	1.65	1.59	0.04	0.26

Carcass Data.

Wethers were transported 180 km to be harvested at Iowa Lamb Inc. (Hawarden, Iowa). Hot-carcass weights were recorded on the day of slaughter. Back fat, body wall thickness, longissimus muscle area, USDA quality and yield grades were recorded after carcasses were chilled at 4°C for 24 h. Percent boneless, closely trimmed, retail cuts (%BCTRC) were calculated according to the method of Savell and Smith (1998).

Statistical Analyses.

Growth performance, DMI, and carcass data were analyzed as a completely randomized design using a one-way analysis of variance with pen as the experimental unit.

Results and Discussion

Dry-matter intakes were not different ($P > 0.05$) between the two treatment groups and as hypothesized, ADG and gain:feed were not different ($P > 0.05$) between the two treatment groups (Table 2). Carcass measurements, including hot carcass weight, USDA yield grade, body-wall thickness, longissimus muscle area, and dressing percentage, were not different ($P > 0.05$) as a result of dietary treatment (Table 3). However, back fat was greater for wethers assigned to the SH-CORN-SBM treatment ($P < 0.05$). During the 64-d finishing trial, wethers were not observed to exhibit symptoms of bloat, acidosis, or urinary calculi, regardless of dietary treatment.

Several factors should be considered when feeding diets composed of grain and by-products to ruminants. First, dietary fiber must be an amount that maintains rumen function and minimizes the likelihood of bloat and acidosis. Schauer et al. (2005) reported that when a traditional fiber source (25 percent chopped alfalfa hay) was used in a mixed ingredient diet offered through self-feeders, that DDGS could replace 20 percent of the barley in a finishing diet without adverse effects on feedlot performance or carcass merit. In their research, the hay was adequate to maintain rumen function. Diets containing long-stem forage can be difficult to pellet and deliver via a self-feeder. Delivery of finishing diets via self-feeders minimizes labor expenses associated with finishing lambs. Soyhulls are a fiber source that can be pelleted and therefore conform to a self-feeding management system. Pelleting can be advantageous because it prevents ingredient sorting and enhances flow in self-feeders, but the cost of pelleting adds to the expense of the feed and can decrease the effective fiber content of the diet.

Soyhulls and DDGS have characteristics of fiber that are similar to those found in traditional forages (NDF 45 percent to 70 percent), however, their effective fiber content (2 percent to 4 percent) is considerably lower than that of traditional forages (> 90 percent) (NRC, 2000). Additionally, SH are more fermentable than long-stem forages and therefore have higher energy values than traditional forages. There is, however, concern that SH are not a sufficient source of effective dietary fiber to maintain normal rumen function and prevent the occurrence of bloat and acidosis. Small particle size of SH may result in faster rate of passage through the rumen and more rapid fermentation that decreases rumen pH when compared to traditional dietary fiber sources (Martin and Hibberd, 1990; Weidener and Grant, 1994; Shriver et al., 2000). In the current experiment, no wethers, regardless of dietary treatment, were observed exhibiting symptoms of bloat (distended abdomen, labored breathing,

Table 3. Carcass characteristics of lambs fed diets composed of soyhulls (SH), dried distillers' grains (DDGS), soybean meal (SBM) and corn.

	Treatment			
	SH-CORN-DDGS	SH-CORN-SBM	SE	*P*-value
Pens per treatment	5	5	-	-
Animals per pen	4	4	-	-
Hot carcass weight (kg)	33.3	33.3	0.40	0.97
Back fat (cm)	0.5	0.6	0.03	0.04
Body wall thickness (cm)	2.5	2.5	0.08	1.00
Longissimus muscle area (cm^2)	19.1	18.3	0.38	0.16
Yield grade	2.4	2.4	0.14	0.80
BCTRC (%)[a]	46.7	46.2	0.18	0.10
Dressing percent (%)	53.7	53.9	0.39	0.77

[a] Boneless closely trimmed retail cuts.

profuse salivation) or acidosis (diarrhea, poor condition). These data suggest that SH are a sufficient source of fiber for wethers fed a finishing diet composed primarily of corn. However, without a negative control treatment of traditional long-stem fiber source, it is difficult to determine if wethers were experiencing depressed feed intakes as a result of sub-clinical acidosis. Wethers allowed ad libitum consumption of a high-grain diet can develop sub-clinical acidosis (Merck, 2006). Whereas outwardly apparent symptoms do not occur with sub-clinical acidosis, cyclic feed-intake patterns result in poor feed efficiency (Holcombe et al., 1999). Additional research to evaluate pH decline in the rumen and more precise feeding behavior would be valuable to assure that feeding a non-traditional fiber source, such as SH, is not contributing to sub-clinical acidosis and reduced performance.

A second consideration when feeding diets composed of a high amount of corn and corn by-products, such as DDGS, to finishing wethers, is that phosphorous content of the diet is high. High phosphorous is of concern because when in excess of the wether's requirement, it contributes to environmental pollution generated by livestock feeding operations. Additionally, urinary calculi can result when the ratio of Ca:P is less than 1.5:1 (DelCurto and Cheeke, 2005). However, problems with urinary calculi can be avoided by adding limestone to maintain a Ca:P ratio greater than 1.5:1 and including ammonium chloride in diets where corn and DDGS are included. Grains and by-products generally have a low Ca content, and it may be necessary to add limestone to the diet to ensure that the Ca requirement of the animal is met and that a desirable Ca:P ratio is maintained. Additionally, nutrient composition of DDGS and SH can vary considerably and having load-specific nutrient analyses will aid proper diet formulation (Holt and Pritchard, 2004). A management technique that can be used to prevent the formation of urinary calculi is the inclusion of ammonium chloride in the diet. The recommended inclusion rate of ammonium chloride for the prevention of urinary calculi is 0.5 percent on a DM basis (Jordan, 1990). Ammonium chloride lowers urine pH and prevents the precipitation of phosphates of calcium, magnesium and ammonium (Rush and Grotelueschen, 1996). However, ammonium chloride is not palatable, and feed refusal can result if the intended inclusion rate is exceeded. Using non-traditional fiber sources, such as soyhulls, allows all dietary ingredients to be combined, as opposed to feeding a grain mixture and fiber separately. Mixing ammonium chloride into a total mixed ration rather than the grain portion alone decreases the likelihood of feed refusal (Oetzel et al., 1988). Palatability of diets that include ammonium chloride can be improved by including other dietary ingredients such as molasses and DDGS that have a strong aroma and are palatable to the animal (Oetzel and Barmore, 1993).

Conclusion

Soybean meal and a portion of the corn can be replaced with DDGS in high-grain finishing diets with SH as the only source of fiber with no negative effects on growth performance, DMI and carcass characteristics. Additionally, SH and DDGS can serve as the only source of fiber in the diet and not result in the incidence of clinical acidosis or bloat. When feeding wethers a diet that contains a significant amount of corn and corn by-products, it may be necessary to include limestone and ammonium chloride to prevent the occurrence of urinary calculi.

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Development and Consumer Acceptance of Pre-cooked Goat Roasts[1]

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Summary

The objective of this study was to develop a palatable, pre-cooked goat roast. Goat legs (n = 64) were fabricated into 220 roasts and assigned to one of four spice treatments: control (CON), Italian, Mexican, prime rib. After being injected with a 15-percent brine mixture, roasts were smoked to an internal temperature of 63°C, vacuum packaged, and frozen at -10°C. Roasts were thawed and reheated one of three ways (conventional oven, microwave oven, or boiling) and served to a trained sensory panel to determine differences in reheating method. The trained panel rated roasts boiled lower ($P < 0.05$) for initial and sustained juiciness and tenderness than roasts reheated in the microwave or conventional oven. The trained panel rated the prime rib spice juiciest, most tender, most flavorful, and the best in overall acceptability. The control treatment (CON) was rated higher ($P < 0.05$) for goat flavor, warmed-over flavor, and flavor intensity by the trained panelists. Upon completion of the trained sensory panel, a consumer panel was conducted to determine differences in treatments. Consumer panelists (n = 200) were served samples of roasts to determine preferred spice blend. Consumers rated the prime rib spice the highest ($P < 0.05$) for all palatability attributes and the Italian roasts the lowest ($P < 0.05$). This study indicated the prime rib spice treatment was preferred most often for tenderness, juiciness, flavor, and overall liking by both trained sensory panelists and consumer panelists. Therefore, roasts seasoned with the prime rib rub appear to have the most market potential.

Key words: Goat, Pre-cooked Roasts, Flavor, Reheating Method

Introduction

The demand for new, red-meat products, especially convenient, pre-cooked items, is greatly increasing (Resurreccion, 2003). The red-meat industry, especially the beef and pork industries, has taken steps to develop products that are not only low in fat, but also quick, easy, and convenient to prepare and accommodate the changing lifestyles of consumers (Nayga, 1993). However, little research has been done to develop a convenient, pre-cooked goat meat product.The meat goat industry could benefit from gaining red-meat-consumption market share by providing consumers with a high-quality, convenient product.

Meat goats have been used primarily as a control of noxious plants or as part of multi-species grazing systems without much emphasis on meat production (Glimp, 1995). However, recently the demand for goat meat has increased. In 2001, 10.9 million kg of goat meat were produced and consumed in the United States and another 5.7 million kg were imported (Shurley, 2002). Currently, live meat goats are sold directly to consumers, or to brokers who in turn sell the animal directly to consumers, or goat processors sell goat meat to retail stores that cater to various ethnic groups (Cosenza et al., 2003). With little goat meat offered at major retail stores and very few consumers who know how to prepare goat, the industry could benefit by the introduction of a convenient, pre-cooked product that could establish a continuous market share. Therefore, the objective of this study was to develop a palatable, convenient pre-cooked goat roast.

Materials and Methods

Preparing the Roasts

Goat legs (n = 64) were purchased from Texas Tech University (Lubbock, Texas) and transported to the Angelo State University Food Safety and Product Development Center (San Angelo, Texas) for further processing. Legs were cut into 5.08 cm roasts (n = 220 roasts) with a bandsaw. Roasts were trimmed of any external fat, and the seam fat containing the popliteal lymph node was removed. All roasts were injected with a 15 percent injection of a brine mixture of water, 0.05 percent phosphate, and 1 percent salt using a Gunther Pickler Injector (model P1632, Koch Supplies, Inc., Kansas City, Mo.). After the roasts were injected, they were allowed to drain for 10 minutes at 2°C. Three spice blends (Table 1) were formulated (55 roasts/spice blend), and 55 roasts were used as a control group. The roasts were randomly assigned to one of four spice treatments: control (CON), Italian, Mexican, and prime rib. Immediately after all roasts were rubbed, they were cooked and smoked in a smokehouse (model 1000, Alkar Corporation, Lodi, Wis.) to an internal temperature of approximately 63°C to achieve a medium-rare degree of doneness (AMSA, 1995). The smoke cycle consisted of two stages. Stage 1 lasted for 1.5 h, with the dry bulb set at 65°C and the wet bulb set at 38°C for a relative humidity of 18.5 percent. Stage 2 was set to cook to an internal core temperature of 63°C, with the dry bulb set at 74°C and the wet bulb set at 60°C to equal a 50 percent relative humidity. After cooking, the roasts were chilled to 2°C, vacuum packaged, and frozen at -10°C for 21 to 25 d.

Table 1. Ingredient list of three different spice blends and the percentage of each spice for goat roasts.

Italian	Mexican	Prime Rib
Italian spice (37.5%)	Coriander (12.5%)	Prime rib rub[a]
Rosemary (6.25%)	Paprika (20%)	
Oregano (12.5%)	Garlic powder (15%)	
Savory (6.25%)	Ground pepper (20%)	
Ground pepper (37.5%)	Cumin (12.5%)	
Salt (20%)		

[a] AC Legg Blend RF-04-161-000 (Calera, AL).

Trained Sensory Panel

Trained sensory panel analysis was conducted on 120 roasts (30 roasts/treatment) to determine the ideal reheating method and to detect differences between spices for differing palatability characteristics. The roasts were thawed at 2°C for 24 h and reheated to an internal temperature of approximately 63°C in one of three ways (10 roasts/treatment/reheat method): conventional oven, microwave, and boiling. A conventional oven was preheated to 163°C, four roasts were placed in an aluminum pan, and 250 mL of distilled water was placed in the bottom of the pan. Two roasts were placed on paper plates, covered with wax paper, and reheated in a microwave at 1100 watts for 4.5 min (model JES1036PWH, General Electric, Louisville, Ky.). Boiling involved placing each individual roast into unsealed bags and placing them into pots containing two liters of distilled water. After reheating, roasts were cut into 1 cm x 1 cm x 5.08 cm pieces, placed into serving pans, and kept at 60°C. Samples were served warm to an eight-member panel trained as recommended by Cross et al. (1978). Panelists evaluated the samples based on an 8-point hedonic scale involving initial and sustained juiciness, initial and sustained tenderness, flavor intensity, characteristic goat flavor, and overall acceptability (8 = extremely juicy, tender, intense, characteristic goat flavor, and like extremely; 1 = extremely dry, tough, bland, uncharacteristic goat flavor, and dislike extremely). Panelists also evaluated the samples for warmed over flavor (WOF) based on a 5-point hedonic scale (1 = no WOF; 5 = extreme WOF). Samples were served under red lights to mask color differences, and panelists were given apple juice and water to cleanse their palates between samples. Results from the trained panel were used to determine the most appropriate reheating method for the consumer panel.

Consumer Panel

The remaining 25 roasts per treatment were used for the consumer panel. Consumers (n = 200) at the Taste of San Angelo Food Festival were asked to participate in the study to determine which spice blend was preferred. Each consumer tasted samples from each treatment. Trained panelists detected no differences between microwave and oven reheating methods for palatability traits, so a microwave was used for ease of resources to serve consumers. Roasts were thawed at 2°C for 2 d and then reheated for 4.5 min using an 1100 watt microwave (model JES1036PWH, General Electric, Louisville, Ky.). Roasts were cut into 1.5 cm x 1.5 cm x 5.08 cm pieces, placed into serving pans, and kept at 60°C. Panelists tasted each sample to determine juiciness, tenderness, flavor, and overall liking (6-point scale from 1=like extremely to 6=dislike extremely). Also, the panelists were asked their likelihood to buy the roast (5-point scale from 1=definitely would buy to 5=definitely would not buy) if it was available in a grocery store. After tasting all four samples, consumers were asked which sample they preferred the least and the most. In addition, the consumers were asked to answer demographic questions including: marital status, gender, ethnicity, age, household income level, and how many times they have consumed goat in the last month.

Statistical Analysis

Data from the trained sensory panel were analyzed using the GLM procedure of SAS (2003), as a 3 x 4 factorial design (three cooking methods and four spice blends) with individual roast as the experimental unit. Cooking method x spice blend interaction was analyzed in the original model but no significance was found. Least-square means were computed for each dependent variable, and statistically separated by pair-wise t-test (PDIFF option of SAS) with predetermined $\alpha = 0.05$.

Data from the consumer panel were analyzed using the GLM procedure of SAS as a completely randomized design with spice blend as the treatment and individual roast sample as the experimental unit. Least-square means were computed for each dependent variable, and statistically separated by pair-wise t-test with predetermined $\alpha = 0.05$. Also, comparisons of frequencies from consumer panelists' responses were tested for significance ($\alpha \leq 0.05$) using Chi-Square tests.

Table 2. Least square means and standard errors for goat roasts of sensory panel ratings for different reheating methods.

	Reheating Method			
Trait	Boil	Microwave	Oven	SEM
Initial juiciness[c]	5.64[b]	6.09[a]	6.10[a]	0.09
Sustained juiciness[c]	6.16[b]	6.55[a]	6.64[a]	0.08
Initial tenderness[d]	6.10[b]	6.48[a]	6.61[a]	0.09
Sustained tenderness[d]	6.59[b]	6.92[a]	7.03[a]	0.08
Flavor intensity[e]	6.08	6.21	6.07	0.05
Goat flavor[f]	3.59	3.55	3.54	0.07
Overall acceptability[g]	6.00[b]	6.28[a]	6.39[a]	0.09
Warmed-over flavor(WOF)[h]	1.05	1.03	1.01	0.01

[ab] Means in a row with different superscripts differ ($P < 0.05$).
[c] 1 = extremely dry; 8 = extremely juicy.
[d] 1 = extremely tough; 8 = extremely tender.
[e] 1 = extremely bland; 8 = extremely intense.
[f] 1 = extremely uncharacteristic; 8 = extremely characteristic.
[g] 1 = dislike extremely; 8 = like extremely.
[h] 1 = no WOF; 5 = extreme WOF.

Results and Discussion

Trained Sensory Panel

When compared to the other two reheating methods, sensory panel scores were lower ($P < 0.05$) for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, and overall acceptability when goat meat was reheated by boiling (Table 2). These results differ from results reported by Kellermeier et al. (2006), who found no differences ($P > 0.05$) in reheating methods for pre-cooked lamb roasts. No differences ($P > 0.05$) were found among reheating methods for characteristic goat flavor, flavor intensity and WOF. In

Table 3. Least square means and standard errors for goat roasts of sensory panel ratings for different spice blends.

	Treatment				
Trait	CON[k]	Italian[l]	Mexican[m]	Prime Rib[n]	SEM
Initial juiciness[e]	5.30[c]	5.56[c]	6.24[b]	6.69[a]	0.11
Sustained juiciness[e]	5.82[c]	6.01[c]	6.73[b]	7.16[a]	0.10
Initial tenderness[f]	5.85[c]	6.21[b]	6.67[a]	6.85[a]	0.11
Sustained tenderness[f]	6.35[c]	6.71[b]	7.07[a]	7.26[a]	0.11
Flavor intensity[g]	5.42[d]	6.03[c]	6.30[b]	6.73[a]	0.06
Goat flavor[h]	5.45[a]	2.85[b]	3.05[b]	2.89[b]	0.08
Overall acceptability[i]	5.51[d]	5.82[c]	6.55[b]	7.00[a]	0.10
Warmed-over flavor(WOF)[j]	1.11[a]	1.01[b]	1.00[b]	1.01[b]	0.02

[abcd] Means in a row with different superscripts differ ($P < 0.05$).
[e] 1 = extremely dry; 8 = extremely juicy.
[f] 1 = extremely tough; 8 = extremely tender.
[g] 1 = extremely bland; 8 = extremely intense.
[h] 1 = extremely uncharacteristic; 8 = extremely characteristic.
[i] 1 = dislike extremely; 8 = like extremely.
[j] 1 = no WOF; 5 = extreme WOF.
[k] CON = Control.
[l] Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[m] Mexican = Coriander, paprika, garlic powder, ground pepper, cumin, salt.
[n] Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

contrast, Lyon and Ang (1990) reported that pre-cooked chicken patties varied in their WOF development when heated in either a microwave or a convection oven. Goat may have less WOF development because it is relatively low in fat, and unsaturated fats have been shown to be a major cause of WOF.

A significant difference was found between spice blends for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, flavor intensity, characteristic goat flavor, overall acceptability, and WOF (Table 3). For both initial and sustained juiciness, prime rib was the juiciest ($P < 0.05$) followed by Mexican. No significant differences were found between the CON or Italian treatments for initial or sustained juiciness. No differences ($P > 0.05$) were found between the prime rib and Mexican treatments for initial or sustained tenderness. Roasts from the CON treatment were the least tender ($P < 0.05$), as indicated by both initial tenderness and sustained tenderness, when compared to the other treatments. Roasts from the CON treatment had the lowest flavor intensity score, most characteristic goat flavor, and highest WOF score ($P < 0.05$). Higher WOF scores may be attributed to the absence of spices. Many of the spices used in this study have antioxidative properties that retard WOF. Common spices with antioxidative properties include rosemary (Brewer and Decker, 1998), cumin, pepper, and garlic products (Rhee and Myers, 2003). Rhee and Myers (2003) also showed trained sensory panelists detected increasing "cardboard" aromatic intensity in a plain goat meat loaf as compared to a chili seasoned goat meat. Prime rib was rated the most acceptable overall, followed by Mexican, Italian, and CON ($P < 0.05$).

Table 4. Demographic characteristics of consumers attending the Taste of San Angelo who sampled goat roasts.

Trait	No.[a] of consumers	Percent
Gender		
Male	103	52.28
Female	94	47.72
Marital Status		
Married	88	44.90
Single	108	55.10
Ethnicity		
Caucasian	142	72.08
Hispanic	44	22.34
African-American	6	3.05
American-Indian	2	1.02
Other	3	1.52
Age, yr		
18 to 25	71	36.04
26 to 35	32	16.24
36 to 45	36	18.27
46 to 55	33	16.75
56 to 65	19	9.64
Over 65	6	3.05
Household Income Level		
<$10,000	43	22.99
$10,000 to 14,999	4	2.14
$15,000 to 24,999	1	0.53
$25,000 to 34,999	36	19.25
$35,000 to 49,999	31	16.58
$50,000 to 74,999	28	14.97
$75,000 to 99,999	25	13.37
>$99,999	19	10.16
Goat Consumption[b]		
0	146	74.49
1 to 3	40	20.40
4 to 6	8	4.08
Over 7	2	1.02

[a] Not all consumers who participated in the study provided complete data.
[b] Number of times consumers have consumed goat in previous month.

Consumer Panel

Table 4 shows the demographic characteristics of the 200 consumers that participated in the study. The percentages and numbers are based on consumer responses; however, not all consumers completed all the questions. Fifty-two percent of those surveyed were male while 48 percent were female. Forty-five percent of participants were married, and 55 percent were single. Caucasian (72 percent) and Hispanic (22 percent) were the most common ethnic groups represented. The majority of the participants reported a household income level of $25,000 or more. Seventy-five percent of the participants had not consumed goat in the previous month, 20 percent had consumed goat one to three times in the past month, and 5 percent had eaten goat four or more times in the past month.

Results from the consumer survey show roasts with prime rib and Mexican spice were not different ($P > 0.05$) in tenderness (Table 5). Roasts from the CON and Italian treatments were less tender ($P < 0.05$) than prime rib and Mexican roasts, but not statistically different when compared to each other. Consumers rated prime rib the most tender, juiciest, most flavorful, and the highest for overall liking ($P < 0.05$). Kellermeier et al. (2006) determined that consumers also prefer lamb seasoned with prime rib spice over other spice blends. Roasts with Italian spices were rated lowest ($P < 0.05$) for tenderness, juiciness, flavor, and overall liking. However, Kellermeier et al. (2006) found consumers preferred lamb seasoned with Italian spice over lamb seasoned with Mexican spice or not seasoned. Consumers rated roasts with prime rib spices the most likely to buy, followed by Mexican then CON ($P < 0.05$). Italian roasts were rated least

Table 5. Least square means and standard errors for goat roasts of consumer panel ratings for different spice blends.

	Treatment				
Trait	**CON[f]**	**Italian[g]**	**Mexican[h]**	**Prime Rib[i]**	**SEM**
Tenderness[d]	2.30^b	2.43^b	1.82^a	1.68^a	0.08
Juiciness[d]	2.38^c	2.72^d	2.08^b	1.81^a	0.08
Flavor[d]	2.82^c	3.26^d	2.17^b	1.83^a	0.08
Overall liking[d]	2.79^c	3.24^d	2.16^b	1.90^a	0.08
Likelihood to buy[e]	2.79^C	3.23^d	2.24^b	1.82^a	0.08

[abc] Means in a row with different superscripts differ ($P < 0.05$).
[d] 1 = Like extremely; 6 = Dislike extremely.
[e] 1 = Definitely would buy; 5 = Definitely would not buy.
[f] CON = Control.
[g] Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[h] Mexican = Coriander, paprika, garlic powder, ground pepper, cumin, salt.
[i] Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

likely to buy. Fifty-seven percent of the participants liked prime rib the most followed by Mexican (26 percent), CON (12 percent), and Italian (7 percent). When asked which they liked the least, 49 percent of consumers reported Italian followed by CON (33 percent), Mexican (11 percent), and prime rib (7 percent).

Implications

The results of this study revealed roasts from goat legs can be processed and sold at retail as a pre-cooked product, which would increase the value of these primal cuts. Certain spices have the ability to enhance overall flavor and improve palatability characteristics held in high regard by consumers. Hopefully, goat market-share could improve by marketing a pre-cooked goat product, especially one with prime rib spice that is palatable and convenient. Results from the current study are in agreement with previous research showing tenderness and flavor to be the two most important factors for determining overall eating satisfaction in red meat. These products should improve the overall eating quality of goat and appeal to a large number of new consumers because of palatability and convenience of preparation.

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Corn Supplement for Goats on Summer Rangeland or Improved Pasture

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Summary

Improved (cultivated) pastures (IP) and supplements are needed to complement rangeland-based goat production in warmer regions of North America during the hot and dry months of June through September. To address this need, growing Spanish X Boer wether kids (average 25 kg) grazing IP (primarily annual legumes and *Amaranthus retroflexus*) were compared to kids on honey mesquite native rangeland (NR-*Prosopis glandulosa* var. *glandulosa*) with an understory dominated by little bluestem (*Schizachyrium scoparium*) during the summers of 2002 and 2003 in north-central Texas, United States. Wethers within both IP and NR were supplemented with corn meal at 0 percent, 0.5 percent, or 1.0 percent BW. Herbage biomass in the IP peaked in July, whereas biomass in the NR tended to peak in August. Kids supplemented with 0.5 percent BW corn on the NR had 61percent greater average daily gains (ADG) than unsupplemented animals, whereas those on IP had to be supplemented at 1.0 percent BW corn before showing an increase in ADG (31percent) compared to unsupplemented animals. Unsupplemented wether kids on NR gained only 30.5 percent the ADG of kids fed a balanced feedlot diet (159 g ADG), while kids on IP gained 53.3 percent of those fed a balanced feedlot diet, indicating that neither forage-based system was able to provide the nutrition needed to achieve maximum gain potential. Improved pasture and corn supplement both have potential for increasing wether ADG compared to rangeland during dry, hot summer months.

Key words: Wethers, Corn Supplement, Mesquite Rangeland, Improved Forages.

Introduction

Supplementing goats with high-energy, rapidly degraded starch, such as corn, has been correlated to decreases in dry-matter intake (DMI)(Abijaoude et al., 2000). In one trial, goats fed three levels of ME kg^{-1} decreased DMI as dietary energy density increased (Lu and Potchoiba, 1989), while in another trial the addition of corn as an energy concentrate raised DMI over a forage-only diet with no differences between 30 percent and 60 percent corn diets (Islam et al., 2000). Although goats supplemented with energy concentrates exhibited decreases in forage intake as supplementation levels increased from 0 percent to 1.8 percent BW in another trial, an increase in total DMI and forage digestibility still occurred (Kawas et al., 1999).

The incorporation of legumes into small ruminant diets has been shown to increase ruminant production. Getachew et al. (1994) recorded greater herbage and CP intake and showed greater BW gain for sheep supplemented with *Macroptiloma axillare* legume hay. Likewise, Goodwin et al. (2004) and Muir and Massaette (1996) found that goat ADG was greater where legumes were present and that a greater CP of improved forage legumes allowed for greater ADG compared to animals grazing rangeland.

Cowpea [*Vigna unguiculata* (L.) Walp.] is a nutritious forage when incorporated into ruminant pastures (Sharma and Singhania, 1992). Immature cowpea herbage has CP levels over 19 percent and mature cowpea provides browsing goats with 11 percent CP, 59 percent TDN, 1.4 percent calcium, and 0.35 percent phosphorus (N.R.C., 1981). Rouquette et al. (1990) found that the indeterminantly flowering cowpea cultivar 'Iron and Clay,' widely used for improved pastures in the southeastern United States, had a leaf CP level of 21 percent and stems contained 9 percent CP.

Amaranth comprise a group of hardy, herbaceous, weedy, fast-growing, pseudo-cereals that consists of about 60 species from the genus *Amaranthus* (Opute, 1979; Stordahl et al., 1999). Depending largely on soil fertility, amaranth herbage CP, at varying levels of maturity, can range over 25 percent (Stordahl et al., 1999; Whitehead et al., 2000) and produce herbage yields up to 4.5 Mg ha^{-1} within four weeks of germination (Grubben and van Sloten, 1981). *Amaranthus retroflexus* (L.), commonly referred to as redroot pigweed, grows abundantly throughout North America and is considered an invasive weed (Diggs et al., 1999). It is palatable to goats, however, and can have high nutritive value (Sleugh et al., 2001). Mba and Brams (1984) documented a seven-fold increase in consumption of *A. retroflexus* over bermudagrass hay when fed to goats and suggested that amaranth may have a higher bypass-protein value, thus leading to more efficiently used escape protein post-ruminally.

The objectives of this trial were threefold: 1) to determine if supplementing growing wethers grazing summer IP with corn increases ADG; 2) to determine if supplementing growing wethers grazing summer mesquite NR with corn increased ADG; and 3) to compare ADG of unsupplemented wethers grazing IP or mesquite NR in the summer with those fed a commercial pelleted feed.

Materials and Methods

Improved Pasture Trial

The trial took place at the Tarleton State University Experimental Farm near Stephenville, Texas, United States (32° 13'N / 9° 12'W at 399 m elevation). The soil type was a Windthorst fine, sandy loam (fine, mixed, thermic Udic Paleustalf). The soil, sampled to a 15 cm depth, had a pH of 6.3 and Mehlich III NO_3 concentration was 290 mg kg^{-1}, P was 32 mg kg^{-1}, and K 185 mg kg^{-1}. The paddock encompassed 5 ha and was divided into six 0.83 ha sub-paddocks. The soil was lightly disced, seeds were broadcast onto the surface, and packed into the soil using a roller in early April of both 2002 and 2003. Species included in the mix were: 'Iron and clay' cowpea, 'Laredo' soybean [*Glycine max* L.], and redroot pigweed at 35 percent of their individual recommended seeding rates (50, 30 and 2 kg ha^{-1} individual recommended seeding rates, respectively). Volunteer *Digitaria ciliaris* (Retz.) Koeler and *Echinochloa* spp. (barnyard grass) were also present. Urbana, "cowpea type" rhizobium inoculant was added directly to all legume seeds prior to planting. No irrigation or fertilizers were applied.

Five 5 X 5 m wire exclosures were placed randomly along a diagonal across each paddock. Forage above-ground yield, chemical composition, and grass/legume/pigweed composition were determined each year at the beginning, middle, and end (June, July, and August, respectively) of the trial by pairing 1 m^2 samples inside (ungrazed) and outside (grazed) each exclosure. Forage was cut 3 cm above the ground, separated into grasses, legumes and pigweed, corrected for dry matter and reported on a per hectare basis. Sub-samples of each plant group from each m^2 were weighed at harvest, dried in a forced-air oven at 55° C until weight loss ceased and weighed to determine percent DM. These samples were subsequently ground in a Wiley mill through a 1-mm screen and analyzed for percent acid detergent fiber (ADF), acid detergent lignin (ADL; Van Soest and Robertson, 1980), and nitrogen (A.O.A.C., 1990). Forage N concentrations were analyzed using an aluminum block digester (Gallaher et al., 1975). The digest used was 5 g of 33:1:1 K_2SO_4:$CuSO_4TiO_2$, and the solution was digested for two hours at 400°C using 17 ml of H_2SO_4. Mineral concentration of the digestate was determined by semi-automated colorimetry (Hambleton, 1977) with a Technicon Autoanalyzer II (Technicon Industrial Systems, Tarrytown, New York). Nitrogen concentration is reported as CP, estimated as 6.25 X N (Van Soest, 1994). Crude protein combined with ADF concentrations can be used to predict forage nutritive value in cattle (Lippke and Herd, 2006) while ADL concentration, as an indigestible cell wall component, is a key predictor of cell wall degradation (Hatfield et al., 1999).

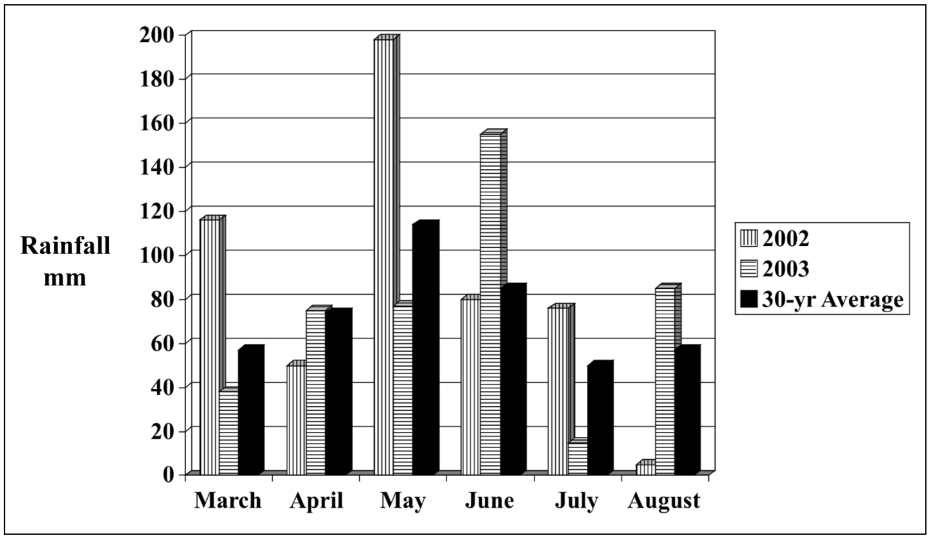
Boer x Spanish cross wethers (average 25±3 kg, 5 to 6 months old) were selected both years from the same north-central Texas meat-goat producer. Seven days prior to the start of the trial (June 1), goats were weighed and randomly assigned to IP sub-paddocks in groups of eight (9.6 goats ha^{-1}; 420 kg forage kid^{-1} average for both years). This stocking rate and herbage availability was considered to provide *ad libitum* forage that exceeded animal intake by a factor of four, thereby allowing selective grazing by the animals. Wethers in sub-paddocks (two replications each treatment) received steam-flaked corn (10.6 percent CP and 89 percent TDN) supplement at 0 percent, 0.5 percent and 1.0 percent BW. The amount of supplement was adjusted every two weeks throughout the trial after wethers were weighed and fed in troughs measuring 250 cm wide x 50 cm high that were 25 cm from the ground. Feed troughs provided over 0.5 m of linear space kid^{-1} to minimize feeding competition. Wethers in all paddocks had free-choice access to salt and water at all times throughout the trial. Average daily gains were calculated over the trial period, which ended on 6 September in 2002 (84 days) and on 4 August 2003 (52 days), when the improved forages began to senesce due to low soil moisture. The trial lasted longer in 2002 because rainfall from March through September totaled 525 mm with a drought only in August, whereas in 2003 forage became scarce in August after negligible precipitation from June 11 and a season-long rainfall total of 445 mm (Fig. 1).

Carcass measurements were reported from a preliminary experiment conducted in 2000 (Weiss, 2001). In Weiss' (2001) trial, treatments were identical to those described in the present study, except that two distinct age classes were studied within the IP treatments. Age class 1 started the experiment post-weaning at approximately 5 to 6 months of age with a mean weight of 25.5 kg; age class 2 started the experiment post-weaning at 3 to 4 months of age and mean BW of 17.5 kg. Four animals closest to each treatment mean were selected from each class, treatment and experiment to collect carcass data. At approximately 24-hours-post-slaughter, carcasses were evaluated for mass (chilled), adjusted fat thickness (mm), carcass length (measured from the point of the hock to the point of the shoulder), leg circumference (at the base of the tail), and shrink [1 – (chilled carcass weight / warm carcass weight) X 100]. Quality grade (preliminary USDA standards) characteristic for lamb was used to assess a subjective carcass-conformation score. From the pre-slaughter and post-slaughter weights collected, percent yield and shrink were calculated.

Native Rangeland Trial

A second, contemporary trial followed much of the same procedure as the IP experiment but was located in a native paddock adjacent to the IP paddock. Only differences from the IP trial are outlined below. Soil analysis for the NR showed a pH of 7.5, Mehlich III NO_3 concentration at 11 mg kg^{-1}, P at 4 mg kg^{-1}, and K at 306 mg kg^{-1}. Soil differences between the IP and NR are due to historical amendments to the IP over years of cultivation. The NR vegetation represented typical north-central Texas grassland with an open overstory of *Prosopis juliflora* var. *glandulosa* (Torr.) Cockerell (honey mesquite) and an herbaceous layer dominated by *Bromus* spp., *Schizachyrium scoparium* (Michx.) Nash (little bluestem), and *Poa arachnifera* Torr. (Texas blue grass). Forage samples were selected in the same way but were divided only into grass and forb components. The NR paddock totaled 3 ha and was divided into six 0.5 ha sub-paddocks, with two sub-paddocks randomly assigned to each of the three corn supplement levels. Wethers were stocked in sub-paddocks in groups of four (eight goats ha^{-1}; two-year average of 130 kg forage on offer per kid over trial period).Carcass characteristics in the Weiss (2001) NR trial were measured only on class 1 wethers (approximately 5 to 6 months of age with a mean BW of 25.5 kg).

Figure 1.Monthly (2002 and 2003) and 30-yr average rainfall during the trial at Stephenville, TX USA.



Comparison of Improved Pasture, Native Rangeland and Feedlot

A comparison of ADG and carcass characteristics was made among wethers in the control groups of the IP, NR and two pens (six animals of the same origins in each pen) fed a balanced commercial pelleted feed in a feedlot. This ration contained 14.2 percent CP, 63 percent total digestible nutrients, 17 percent ADF, was balanced for mineral and vitamin requirements (Weiss, 2001) and used corn and soybean meal as primary ingredients. All trials took place simultaneously on adjacent land (comparable ambient conditions) but stocking rates differed as did forage or feed on-offer. This is therefore a general comparison of feeding systems rather than feeds.

Statistical Analyses

Animal performance data (dependent variables) consisted of ADG and carcass measurements and was subjected to analysis of variance (ANOVA). The IP and NR systems supplemented with corn were treated as separate experiments since stocking rates and forage on offer differed. Years and corn supplement were included as independent variables in the models. A separate ANOVA was also carried out on data comparing the IP control, NR control, and feedlot feeding systems (adjacent land, same years, and same wether pool). Forage species composition, total forage DM yield, and forage chemical composition data were utilized as supportive data only, with only standard deviations reported. An alpha value of $P \leq 0.05$ was selected for the determination of statistical significance throughout the manuscript and least significant difference ($LSD_{0.05}$) was utilized to separate treatment means for the ADG and carcass data.

Results and Discussion

Improved pasture

The effect of corn supplements on ADG in the IP (Fig. 2) did not change with years, indicating a stable response over a year that had near-normal precipitation (2003) and another (2002) that exceeded the 30-year average by 20 percent for the trial period (Fig. 1). This stability in response to supplement was apparent even though forage yields varied between years (Table 1). July legume yields increased fourfold from 2002 to 2003, while the amaranth yields were reversed. Reasons for this are unclear but could be related to plant species response to climate differences between years. High 2002 July rainfall (Fig. 1) and low stocking rates for forage on-offer explain why grazed grass yields were not lower than ungrazed, but further research on relative palatability of forage species to goats is needed to explain why grazed legume and amaranth out-produced these species in ungrazed exclosures. Chemical composition of the whole-plant sward components varied much less than yields over years, with legumes generally greater in value than the amaranth and all declining with time.

Figure 2. Average daily gains (ADG) of young wethers grazing summer mesquite-dominated native rangeland or improved pastures and supplemented with rolled corn grain at 0, 0.5, or 1.0% BW (pooled over two years). Columns within groupings headed by different letters differ (*P* = 0.05; SE for rangeland = 10; SE for improved pasture = 12) according to a least significant difference range separation.

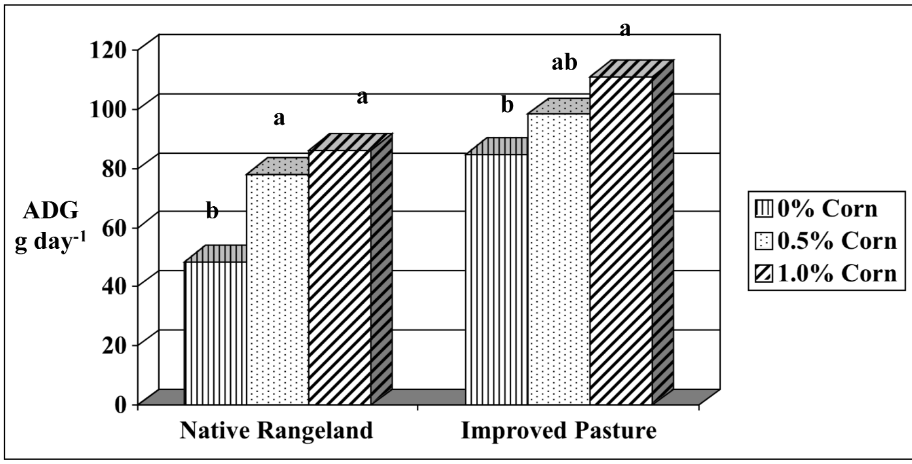


Table 1. Herbage characteristics of improved summer pasture components in June, July and August 2002 and 2003 at Stephenville, TX, USA.

	June			July			August		
	Grass	Legume	Amaranth	Grass	Legume	Amaranth	Grass	Legume	Amaranth
				kg herbage ha^{-1}					
2002									
Ungrazed	122±100	384±166	2559±967	793±848	521±532	3399±3017	622±905	427±522	2576±3161
Grazed	---	---	---	746±1218	793±817	3644±4377	1171±1216	1171±522	3274±3575
				g ADF kg^{-1} herbage					
Ungrazed	317±10	275±18	364±35	356±103	374±36	440±28	426±27	398±22	495±26
Grazed	---	---	---	381±61	342±15	435±12	432±72	391±27	493±24
				g ADL kg^{-1} herbage					
Ungrazed	35±6	48±4	50±5	54±2	66±9	69±8	56±6	74±6	95±7
Grazed	---	---	---	45±4	60±2	79±10	55±4	75±8	95±7
				g N kg^{-1} herbage					
Ungrazed	20.8±1.0	27.9±2.7	10.8±1.7	15.0±1.5	25.9±3.7	11.0±0.6	10.5±1.0	22.6±3.9	9.5±1.6
Grazed	---	---	---	19.4±8.2	25.5±5.9	10.5±2.4	10.1±1.0	21.1±1.3	7.9±1.4
2003									
Ungrazed	153±238	381±243	490±314	110±246	2325±1793	960±1284	0	3736±1589	2203±2884
Grazed	---	---	---	83±82	2085±1040	772±857	0	3057±1879	1011±1091
				g ADF kg^{-1} herbage					
Ungrazed	322±29	217±27	218±45	386±24	386±20	445±5	---	408±27	415±89
Grazed	---	---	---	362±11	362±22	447±4	---	414±35	491±25
				g ADL kg^{-1} herbage					
Ungrazed	37±2	35±5	25±6	63±2	68±2	76±3	---	71±2	79±6
Grazed	---	---	---	42±3	65±4	65±11	---	75±9	80±5
				g N kg^{-1} herbage					
Ungrazed	32.2±0.2	42.0±1.4	32.5±7.2	14.4±3.4	24.9±1.0	9.6±1.9	---	22.3±2.2	10.0±2.2
Grazed	---	---	---	20.2±3.4	27.0±1.8	10.7±3.5	---	22.8±1.7	8.2±1.6

Table 2. **Carcass characteristics of wethers (N = 4) fed corn meal at 0, 0.5, and 1.0% body weight while on improved pasture or native grass-dominated rangeland. (Adapted from Weiss, 2001)**

	Carcass chilled	Dressing	Shrink[1]	Leg circumference	Fat thickness	Carcass length	Conformation[2]
	kg	%		mm		cm	
Improved Pasture							
0% Corn	34.8	40.2	1.0	47.8	0.055	97.7	2.68
0.5% Corn	32.6	43.3	0.8	47.8	0.078	97.6	2.63
1.0% Corn	34.7	42.3	0.9	49.0	0.081	96.9	3.63
4 month (17.5 kg)	26.0[b]	42.9[b]	1.0	46.4[b]	0.580[b]	93.7[b]	2.28[b]
6 month (25.5 kg)	32.6[a]	44.4[a]	0.9	51.8[a]	0.100[a]	101.9[a]	4.81[a]
Native Rangeland							
0% Corn	29.4	42.4	1.0	48.3	0.056	96.9	2.20
0.5% Corn	32.5	41.7	0.9	50.4	0.063	99.2	3.00
1.0% Corn	31.4	44.9	0.9	50.6	0.072	98.0	3.75
Feedlot vs. Pasture							
Improved Pasture	34.8[b]	40.2[b]	1.0	47.8[b]	0.055[b]	97.7	2.68[b]
Native Rangeland	29.4[c]	42.4[b]	1.0	48.3[b]	0.056[b]	96.9	2.20[b]
Feedlot	44.6[a]	48.7[a]	1.0	54.1[a]	0.125[a]	98.9	7.75[a]

[1] 1 – (chilled carcass weight / warm carcass weight) X 100
[2] 1 = very poor; 10 = excellent
[abc] Values in the same column groups followed by different letters differ (*P* = *0.05*) according to a least significant difference range separation.

Grazed amaranth in August, mostly residual stem, averaged over both years, was especially low in nutritive value: 492 g ADF kg^{-1}, 88 g ADL kg^{-1}, and 8.1 g N kg^{-1}, 12 percent greater, 22 percent greater, and 31 percent less, respectively, than average July values.

Weiss (2001) found no discernable effect of corn supplementation on any of the carcass characteristics (Table 2). In the present study, however, the 1 percent BW corn supplement increased ADG 31 percent over the control sub-paddocks (Fig. 2) but no difference was apparent between the two supplement rates. These results contrast with a study in which finishing wethers on dormant coastal bermudagrass (37 g ADF kg^{-1}; 13 g CP kg^{-1}) improved ADG as corn supplement increased (Ott et al., 2002). In that study, wethers supplemented with corn at 1.5 percent BW improved ADG 60 percent over those supplemented at 0.75 percent BW. Our results also contrast with those from a cattle study in which steers, despite showing a positive response to daily corn supplement equivalent to 0.5 percent BW while on improved warm-season grass pasture, did not continue improving ADG as supplement level increased (Aiken, 2002).

Weiss (2001) found older (6-month-old) wethers in the IP system had 3.5 percent greater dressing percent and 72 percent greater surface fat thickness than younger (4-month-old) animals (Table 2). The leg circumference, carcass length and conformation values were likewise greater.

Native Rangeland

The greater precipitation and its more even distribution (Fig. 1) over time (especially important during July) in 2002 resulted in greater NR forage yields than in 2003 (Table 3). This difference between years, however, did not result in variable wether ADG between years, indicating that forage quantity, even in the less productive year, was sufficient to provide adequate selection to the animals. Therefore it appears nutritive value, rather than quantity, limited ADG responses. Grass forage on-offer tended to decline gradually from July to August, while forb yield increased, a reflection of annual winter grasses dying out in mid-summer and deep-rooted forbs resisting dessication as summer progressed. Nutritive value of the forage species, especially grass N concentration, was lower in the NR than in the IP, but these tended to decline less in the NR from July to August, as rainfall decreased because the primary native forage species were perennials and more deeply rooted.

Weiss (2001) found no measurable differences in carcass characteristics among the three levels of corn supplementation (Table 2). Low nutritive value of the native forage (Table 3), however, did result in a 61percent increase in wether ADG for the NR 0.5 percent corn treatment over control animals compared to no difference between the same two treatments in the IP trial (Fig. 2). No differences in ADG were apparent between the 0.5 and 1.0 percent corn treatments in the NR trial. These results contrast with those of Schacht et al. (1992) who, when comparing energy and protein supplements to a balanced protein-energy supplement for goats on low-quality rangeland, found that protein or energy by themselves did not improve ADG as much as protein and energy combined. Schacht

Table 3. Herbage characteristics of mesquite native rangeland in June, July and August 2002 and 2003 at Stephenville, TX, USA.

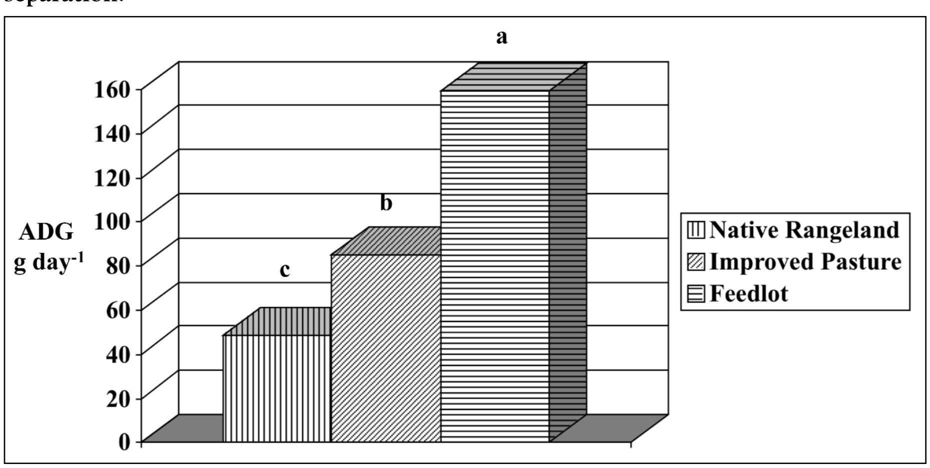
	June		July		August	
	Grass	Forb	Grass	Forb	Grass	Forb
			kg herbage ha^{-1}			
2002						
Ungrazed	869±323	532±270	2048±1637	980±706	1919±2356	1124±573
Grazed	---	---	1829±591	800±800	1771±1544	1033±1024
			g ADF kg^{-1} herbage			
Ungrazed	430±33	344±24	452±28	358±16	442±14	380±34
Grazed	---	---	437±37	375±20	428±34	401±35
			g ADL kg^{-1} herbage			
Ungrazed	59±9	72±7	64±5	81±10	66±4	92±4
Grazed	---	---	59±7	84±10	73±8	103±23
			g N kg^{-1} herbage			
Ungrazed	10.8±3.5	18.7±4.0	9.5±2.5	14.2±3.0	8.7±3.8	11.8±3.2
Grazed	---	---	10.5±3.5	16.0±4.3	9.6±3.7	12.6±3.6
2003						
Ungrazed	304±222	322±223	970±1479	213±198	371±400	425±249
Grazed	---	---	453±452	166±195	318±317	383±250
			g ADF kg^{-1} herbage			
Ungrazed	374±26	218±45	430±11	355±57	431±44	347±72
Grazed	---	---	427±16	364±55	445±24	340±48
			g ADL kg^{-1} herbage			
Ungrazed	41±6	25±6	49±4	62±19	49±7	78±15
Grazed	---	---	55±10	78±15	51±6	72±16
			g N kg^{-1} herbage			
Ungrazed	13.8±2.4	32.5±7.2	7.4±0.1	17.0±4.2	7.5±2.2	14.2±4.4
Grazed	---	---	8.1±0.2	15.4±4.9	8.6±3.7	15.3±3.6

and his co-authors speculated that goats were able to select high-quality diets on the Brazilian rangeland and that their total diet did not become more digestible with supplementation. It appears that, in contrast to our study, the balanced supplement in the Brazilian study improved ADG simply because it was more digestible and, in effect, replaced rangeland forage in the diet. In the NR study, palatable brushy browse was not common (the wethers only rarely selected mesquite leaves) and the forbs were of lower quality than in the Brazilian study.

Pasture, Rangeland and Feedlot

Intensive feedlot systems tend to produce larger goat carcasses with greater dressing percentages compared to systems less restrictive on movement but equal in nutritive value (Johnson and McGowan, 1998). This was the case if we compare the control treatments of the IP and NR trials (adjacent land, same years, and same source of wethers) with that of wethers fed a commercial pelleted feed (Fig. 3). This allows for a comparison of feeding systems rather than specific feeds. Feedlot wethers gained at 3.3 times the rate of the unsupplemented rangeland animals and 1.9 times the rate of the control animals in the improved pasture. In the Weiss (2001) study, feedlot-wether-dressing percentages were 12 percent greater (six units) than the IP or NR animals, while

Figure 3. Average daily gain (ADG) of young wethers on summer mesquite native rangeland, improved pasture or fed complete ration diets in feedlots from June to August (pooled across two years). Columns headed by different letters differ (*P* = 0.05; SE = 12) according to a least significant difference range separation.



fat thickness was 127 percent greater, even though this was still only 0.125 mm (Table 2). Leg circumference and subjective conformation values were also greater in the feedlot animals, further indicating that wethers responded positively to the balanced feed in the feedlot.

Conclusions

Supplementing corn to wethers at 0.5 percent BW improved gains when animals grazed rangeland of relatively poor nutritive value (an increase of 29.5 g ADG) but less so when they grazed improved pasture (13.6 g ADG improvement). However, increasing that supplement to 1.0% BW in either system did not increase ADG relative to the 0.5 percent treatment, perhaps because energy requirements had already been met. In the case of the IP, greater amounts of supplement were needed to elicit a positive ADG response relative to unsupplemented wethers, but profit margins may be smaller compared to the large response to lower supplement rates for wethers on grass-dominated rangeland.

In the improved pasture, amaranth chemical composition relative to nutritive value declined more rapidly over the season than did either grass or legume sward components, indicating that, although very productive and palatable early in its growth cycle, it quickly lost its value as leaves dropped. In a mixture, especially with a deeper-rooted, less precocious legume, this limitation might be mitigated. The wide disparity in yields of both the legume and amaranth components between the two years due to differing growing conditions would also support the use of species mixtures in improved annual pastures for goats.

Unsupplemented wethers on the IP gained at far greater rates than did those on NR, indicating that improved summer pasture may have potential for the southern U.S. goat industry if returns on the investment are attractive. Markets that demand larger carcasses at younger ages and pay a premium for these may encourage the greater use of IP for goat production. However, a comparison of unsupplemented wethers on IP and NR to those in a feedlot shows that kids are not reaching their maximum growth potential in either the NR or the IP. It also indicates that goats gain well in feedlot situations, a conclusion further supported by improved dressing percentages. Whether feedlots can be utilized economically to finish goats vis-à-vis slower-developing animals on pasture or rangeland, however, needs to be studied.

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