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Weaning Weights in a Range Purebred Merino and Crossbred Merino x Rambouillet Flock

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Summary

The Rafter 7 Merino flock was initiated in Nevada in 1990 with the purchase of 500 purebred Rambouillet ewes. A grade-up program was initiated using Australian Merino genetics with the aim of developing a purebred Merino flock. Early in the project the Rafter 7 Merino line was created, which is approximately 5/8 Merino and 3/8 Rambouillet and has been a closed line since 1999. In a genetic selection program that includes weaning weight, weights must be adjusted for environmental factors. The present study investigated factors influencing weaning weight in 9,594 lambs.

Results show a decrease in lamb weaning weights with the inclusion of Merino blood in the lines. At weaning, rams were heavier than ewes ($P < 0.001$) and weights decreased with increased litter size ($P < 0.001$). Lambs born from 2-year-old dams had lower weaning weights than lambs born from older dams ($P < 0.01$), and lambs born from 5-year-old dams had lower weaning weights than lambs born from 3-year-old dams ($P < 0.05$). Weaning weight of lambs born from 3-, 4-, 6-, and 7-year-old dams did not significantly differ.

Multiplicative-adjustment factors for adjusting lamb weaning weights to a common sex, age of dam, and birth-rearing type were compared with values from the *Report of the National Sheep Improvement Program Technical Committee*. Adjustment factors were slightly lower for triplet ewes and rams born from a 3- to 6-year-old dam. Other adjustment factors were very similar, suggesting that adjustment factors derived from more intensive production systems are applicable to our extensive production systems as well.

Key Words: Sheep; Weaning Weight; Adjustment Factors; Merino; Rambouillet

Introduction

The Rafter 7 Merino flock was initiated in Nevada in 1990 with the purchase of 500 purebred Rambouillet ewes from two prominent breeders in the western United States. These ewes were mated via artificial insemination with imported semen from Australian Merino rams. The initial breeding objective was to develop a purebred Merino flock with Australian genetics that would be adapted to the western rangeland environment. Since females or embryos could not be imported, a grade-up program (1/2, 3/4, 7/8, 15/16 and higher Merino breeding, with 15/16 Merino being considered purebred by the world animal breeding community) was implemented utilizing semen from imported rams.

It was observed early in the project that Merino x Rambouillet F1 offspring produced approximately 70 percent more clean wool, while the weaning weight of lambs per ewe was not significantly different from purebred Rambouillet. It was decided to develop a selection line from the best 1/2 Merino ewes and a limited number of 3/4 Merino ewes and rams known as the Rafter 7 Merino line. This line is therefore approximately 5/8 Merino and 3/8 Rambouillet and has been a closed line since 1999.

In a genetic selection program, much of the variation attributable to phenotypic records is environmental and must be accounted for by use of appropriate adjustment factors, such as breed and sex (Boggess et al., 1991). Knowledge of these factors is essential for efficient management and for the accurate estimation of breeding values (Assan and Makuza, 2005). Currently, weaning weights of purebred and crossbred Merino sheep are adjusted utilizing the adjustment factors recommended by SID (1997), which were largely derived from more intensive production systems. These adjustment factors may not be appropriate for purebred and crossbred Merino sheep raised in an extensive production system. The purpose of this study was to evaluate the influence of Merino genetics on weaning weights and to evaluate factors influencing weaning weights in the Rafter 7 flock. These factors may be valid for other Merino or crossbred Merino x Rambouillet flocks as well.

Materials and Methods

Animals

Complete weaning weight records were available on a total of 9,594 animals born between 1992 and 2005. The number of records for each line and sex are given in Table 1. Since 2001, the flock genetics include only fullblood and Rafter 7 Merinos. Between 1999 and 2005, Rafter 7 lambs were sired by approximately 53 sires and fullblood Merinos by 48 sires. Of all Rafter 7 and fullblood Merino lambs, eight were born as triplets but raised as a single, 42 animals were born as triplets but raised as a twin, 176 animals were born as a twin but raised as a single, and two animals were born as a single but raised as a twin.

Management

The Rafter 7 Ranch includes approximately 3,400 acres of private property plus grazing permits on approximately 85,000 acres of Bureau of Land Management (BLM) land and 4,500 acres of U.S. Forest Service land. Approximately 250 acres of the private land are in irrigated pasture for the sheep flock and hay production. Ewes were mated via artificial insemination or in single-sire pastures from mid-November to late-December for approximately 40 days, with hay fed only when snow cover prevented grazing or available forage was inadequate. The ewes were treated for internal parasites at the onset and end of the mating season and were then managed under herder supervision on the desert rangelands until mid-March. Shearing has generally been the last week of March. Following shearing, the ewes were treated for internal and external parasites and vaccinated with an 8-way *Clostridium spp.* vaccine to provide passive immunity to their lambs through colostrum. The ewes were then branded with a unique number in scourable paint, and the ewe's ear tag and paint brand numbers were recorded.

The lambing program was based on a modified set-stocking program with up to 250 pre-lambing ewes within a breed group in a pasture that is adjacent to three vacant pastures. The ewes were not fed any supplemental feed other than an appropriate trace mineral salt pre- or post-lambing. When a ewe lambed, her paint brand number was recorded with the lambing date, and the lamb(s) were ear tagged with the appropriate numbered metal tag; the lamb's tag number and sex were recorded; and a rubber elastrator ring was applied to the tail. Any observations on ewe health, condition or status and lamb vigor were also noted on the record sheet. The ewe and her lamb(s) were then moved to one of the adjacent vacant pastures, until a pasture was determined to contain enough ewes and lambs and then another pasture was used. Only ewes with udder, milk or behavioral problems or with weak or triplet lambs, or ewes with grafted lambs, were moved to the barn for further observation or treat-

Table 1. Number of records for each line and sex.

	Rambouillet[a]	1/2 Merino[b]	3/4 Merino[c]	7/8 Merino[d]	Fullblood Merino[e]	Rafter 7 line[f]
Ewe	167	605	898	636	1028	1787
Ram	130	462	728	596	989	1568
Total	297	1067	1626	1232	2017	3355

[a] 1992 to 1994.
[b] 1992 to 1997.
[c] 1993 to 1998.
[d] 1995 to 2000.
[e] 1997 to 2005.
[f] 1999 to 2005.

ment. Some ewes were moved to shelter with their lambs during extreme weather conditions, but this practice has been used on a very limited basis. Only approximately 15 lambing pens under shelter have been provided for ewe numbers ranging from 500 to 1000 ewes during the study. Any ewes with problems at lambing were critically checked and generally culled after the lambs were weaned.

When the smaller pasture groups of lambs were approximately two weeks old, two pasture groups were mixed together. This process was continued until a maximum of three or four groups were managed from four to five weeks of age in an intensive pasture rotation system of four to six pastures per group until weaning.

At four to eight weeks of age, the lambs and ewes were treated for internal parasites, the lambs were vaccinated with an 8-way *Clostridium spp.* vaccine and a plastic ear tag, identically numbered as the small metal tag at birth, was inserted. Any physical or genetic problems were recorded at this time, such as leg and horn deformities, jaw defects, the presence of face wool and wrinkles, or being carrier of the black gene. Weaning was generally in mid-August, when the lambs were between three and four months of age. Weaning weights were recorded, along with any technician observations of physical or genetic defects. The lambs received their second treatment of *Clostridium spp.* vaccine, were treated for internal parasites, and then managed as a group on high-quality, irrigated pasture until the sexes were separated in late-September. Selection of replacement ram and ewe lambs generally occurred in late-October. Male lambs not kept for replacement or sale as rams were castrated. Surplus ewe and wether lambs were then sold.

Data handling and statistical analysis

The SAS program was used for the statistical analysis (Statistical Analysis Systems Institute, 1985). The model used to analyze the weaning weights was (Proc Mixed):

$$Y_{ijklmnop} = \mu + L_i + S_j + YOB_k + B\text{-}RType_l + AgeDam_m + WnAge_n + Dam_o + e_{ijklmnop}, \quad (1)$$

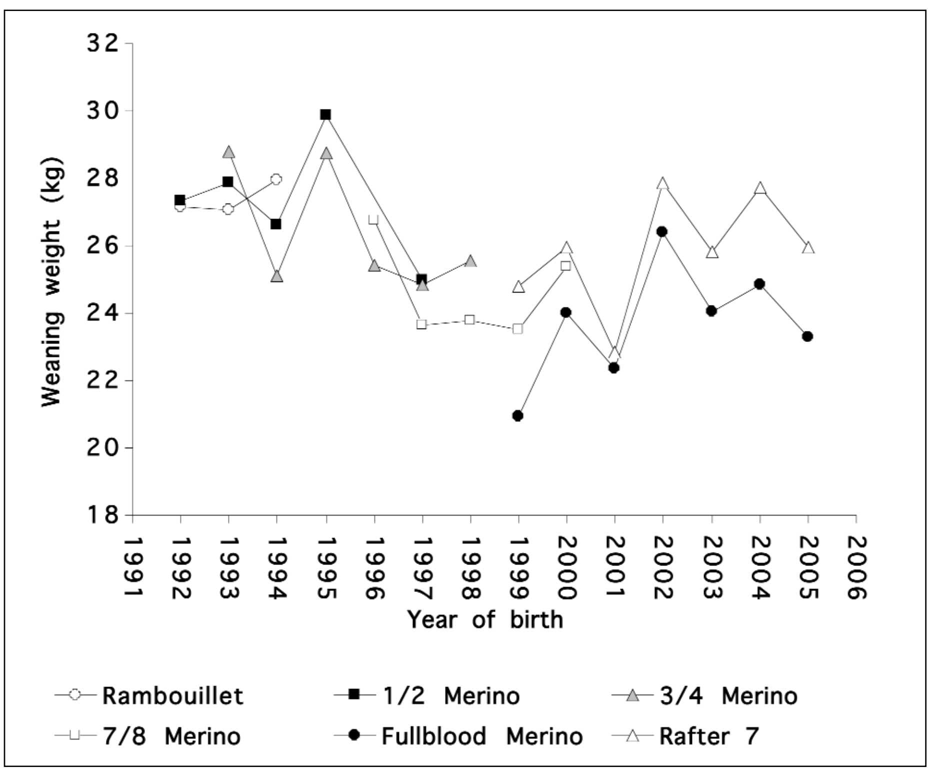
where μ = overall mean, L_i = effect of line i (1/2, 3/4, 7/8 fullblood, and Rafter 7 Merino), S_j = effect of sex j (ewe, ram), YOB_k = effect of year of birth k (1999 to 2005), $B\text{-}RType_l$ = effect of birth-rearing type l (single-single, twin-twin, triplet-triplet, triplet-single, triplet-twin, twin-single, single-twin), $AgeDam_m$ = effect of age of the dam m (2 to 7 years), $WnAge_n$ = effect of age at weaning n, and $e_{ijklmno}$ = error term of animal o, $e_{ijklmno} \sim NID(0, \sigma^2_e)$. Weaning weight measured on animal o of line i, sex j, year of birth k, birth-rearing type l, age of the dam m and age at weaning n is denoted by $Y_{ijklmno}$. All effects were considered fixed-class effects, with the exception of the effect of 'age at weaning,' which was included as a covariate effect, and the effect of 'dam,' which was considered random. Initially, the effect of the interaction between birth-rearing type and age of the dam was also included, but as this was not significant, this effect was excluded from further analysis.

Results and Discussion

Trend in weaning weight with inclusion of Merino genetics

Figure 1 presents least squares means of weaning weight for each line and each year. Only least squares means estimated from 30 or more observations are shown. Values were adjusted for the effects of model (1). In 1994, purebred Rambouillets had higher weaning weights than either 1/2 (*P = 0.0061*) or 3/4 Merinos (*P = 0.0001*). The 1/2 Merinos had a higher weaning weight than 3/4 Merinos in 1994 (*P = 0.0021*) and 1995 (*P = 0.0411*). The 3/4 Merinos had higher weaning weights than 7/8 Merinos and fullblood Merinos in 1997 (*P = 0.0156* and *P = 0.0025*, respectively) and 1998 (*P = 0.0001* and *P = 0.0065*, respectively). Weaning weight was higher in 7/8 Merinos than in fullblood Merinos in 1997 (*P = 0.0004*), 1999 (*P = 0.0001*), and 2000 (*P = 0.0085*). Rafter 7 Merinos (about 5/8 Merino) had higher weaning weights than 7/8 Merinos in 1999 (*P = 0.0001*), and had higher weaning weights than the fullblood Merino line in all years but 2001 (*P = 0.0001*). Summarized, within year, weaning weights decreased with the inclusion of Merino blood in the lines. This is in agreement with observations by Sakul et al. (1993), who observed that offspring from Targhee dams and Merino sires grew more slowly than offspring from Targhee dams and Rambouillet sires. The overall

Figure 1. Least squares means of weaning weight for Rambouillet, 1/2 Merino, 3/4 Merino, 7/8 Merino, fullblood Merino and Rafter 7 Merino lambs between 1992 and 2005.



trend in weaning weight over the entire period decreased up to 1999, with increasing inclusion of Merino genetics in the flock. Thereafter, weaning weights increased with increasing selection pressure in the flock.

Factors influencing weaning weight

Because the breeding program aimed at producing Rafter 7 and purebred Merinos, and therefore data on 1/2, 3/4, and 7/8 Merinos are limited, factors influencing weaning weight are estimated for those two lines only. Table 2 presents estimates and standard errors of factors influencing weaning weight, according to model 1, in the Rafter 7 Merino line and the fullblood Merino line between 1999 and 2005. All factors included in the model were highly significant ($P < 0.001$).

Least squares means for each level of breed, sex, birth-rearing type and age of dam are presented in Figure 2. Birth-rearing type levels with different birth than rearing type had high standard errors due to a low number of records. As expected from Figure 1, Rafter 7 Merino sheep were heavier at weaning than fullblood Merino lambs. A portion of this difference is likely due to the opportunity for increased selection pressure within the Rafter 7 Merino line during the period, whereas the primary objective in the fullblood Merino line was the increase in population size. Rams were heavier at weaning than ewes. This is in agreement with observations by Matika et al., (2003) and Assan and Makuza (2005). As can be observed in Figure 1, average weaning weights differed for each individual year but no trend could be distinguished. The effect of year reflects variation in the physical environment resulting from changes in the weather conditions, which directly affect the quantity and quality of available food resources (Matika et al., 2003).

Several studies report on the effect of birth type on weaning weight where lambs from larger litters are found to weigh less than lambs from smaller litters (e.g., Boujenane et al., 1991; Matika et al., 2003). This difference in birth weight often persists through weaning (Boujenane et al., 1991; Matika et al., 2003) as offspring have to compete for milk. In the present study, only 221 fullblood and Rafter 7 Merino lambs (4.6 percent) had a rearing type that differed from birth type. As expected, weaning weight decreased with increasing litter size. Single born-single raised had higher weaning weights ($P < 0.001$) than twin born-twin raised, which had higher weaning weights ($P < 0.05$) than triplet born-triplet raised. Lambs born and raised in a triplet litter tended to have lower weaning weights than lambs born in a triplet litter but raised in a twin or single litter ($P < 0.10$). Lambs born and raised in a twin litter had lower weaning weights than lambs born in a twin litter but raised in a single litter ($P < 0.01$).

Lambs born from 2-year-old dams had lower weaning weights than lambs born from older dams ($P < 0.01$). Lambs born from 5-year-old dams had lower weaning weights than lambs born from 3-year-old dams ($P < 0.05$). This latter observation resulted mainly from low weaning weights in 5-year-old dams in the year 2002 ($P < 0.05$; results not presented). Weaning weights of lambs born from 3-, 4-, 6- and 7-year-old dams did not significantly differ. Results are somewhat different from those presented by Matika et al. (2003), who observed an increase in weaning weight from 2-year-old ewes which peaked at four years. The observation that young dams produce smaller offspring results from the fact that they are challenged simultaneously with the drive to grow, support pregnancy and sustain lactation in a food-resource-limited situation (Rauw et al., 1999).

The phenotypic correlation between weaning weight (adjusted for the effects of line, sex, year of birth, birth-rearing type and the age of the dam) and weaning age was positive and highly significant ($r = 0.20$, $P < 0.001$). Results indicate that weaning weight increased about 133 grams per day.

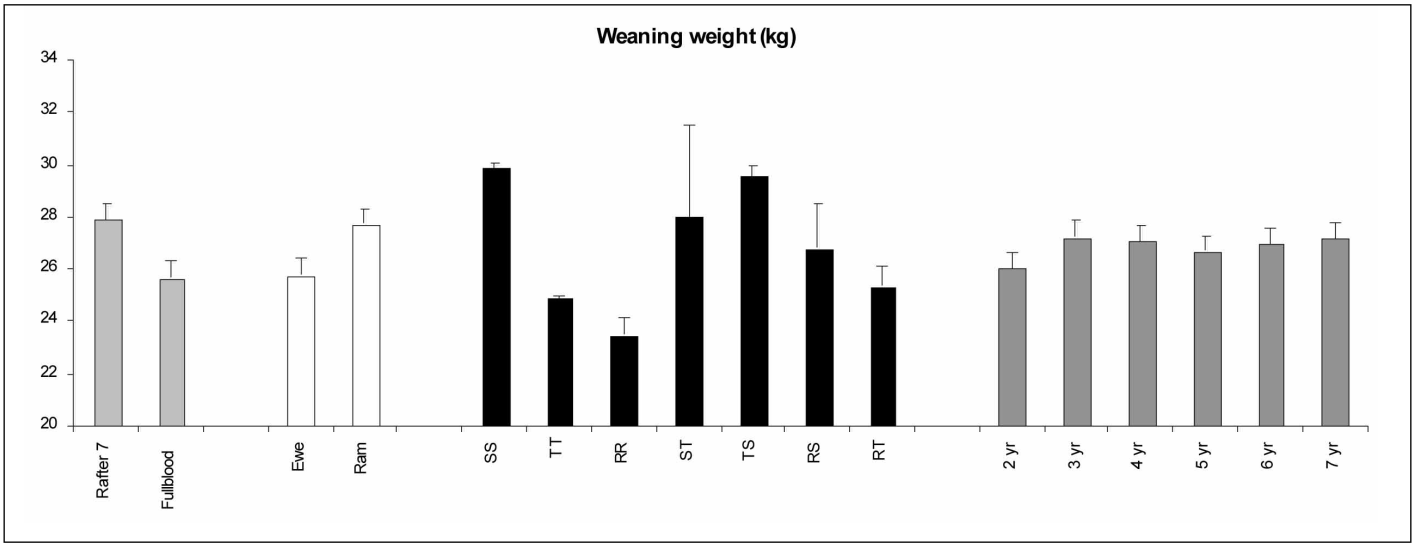
Table 3 presents multiplicative adjustment factors for adjusting lamb weaning weights to a common sex, age of dam, birth-rearing type in comparison

Table 2. Estimates (SE) of factors influencing weaning weight (kg) for each subclass.

Factor	Subclass	N	Factor estimate (SE)
Intercept		5341	8.99 (0.801)
Breed	Rafter 7 Merino	3355	0.00 (0.00)
	Fullblood Merino	1986	-1.98 (0.176)
Sex	Ewe	2804	0.00 (0.00)
	Ram	2537	1.98 (0.134)
Year of birth	1999	425	-1.17 (0.347)
	2000	583	0.287 (0.310)
	2001	1021	-2.16 (0.283)
	2002	943	2.47 (0.272)
	2003	875	0.641 (0.313)
	2004	963	1.66 (0.262)
	2005	531	0.00 (0.00)
Birth type	Single – Single	2294	5.04 (0.153)
	Twin – Twin	2746	0.00 (0.00)
	Triplet –Triplet	73	-1.38 (0.651)
	Single – Twin	2	3.15 (3.50)
	Twin – Single	176	4.72 (0.388)
	Triplet – Single	8	1.94 (1.75)
	Triplet – Twin	42	0.466 (0.791)
Age dam (yr)	2	1103	-1.14 (0.333)
	3	1193	0.0669 (0.322)
	4	1097	-0.0649 (0.322)
	5	921	-0.453 (0.325)
	6	679	-0.154 (0.333)
	7	348	0.00 (± 0.00)
Age at weaning (d)		5341	0.133 (0.00636)

N = number of animals in each subclass.

Figure 2. Least squares means (SE) of weaning weight for each subclass of the class variables breed, sex, birth-rearing type and age of dam. SS = single born-single raised, TT = twin born-twin raised, RR = triplet born-triplet raised, ST = single born-twin raised, TS = twin born-single raised, RS = triplet born-single raise, RT = triplet born-twin raised.



with values from the *Report of the National Sheep Improvement Program (NSIP) Technical Committee* (1986) for single born-single raised, twin born-twin raised and triplet born-triplet raised lambs. Values of the present study were adjusted for effects included in model 1, with the exception that 'age of the dam' was included for ages 2 and '3 to 6' only. Adjustment factors were slightly lower for triplet ewes born from 3- to 6-year-old dams. Other adjustment factors were very similar. This implies that the adjustment factors recommended by SID (1997), which were largely derived from more intensive production systems, are applicable to our more extensive production system as well.

Out on the ranges, sheep experience significant fluctuations on both quantity and quality of forage. According to Thomas and Kott (1995), ewes commonly experience prolonged bouts where less than 50 percent of the National Research Council's (NRC) requirements are met. This results in significant amounts of weight loss, while pregnant animals in particular are supposed to gain weight (Rauw et al., 2006). Early gestation is critical for placentomal growth, differentiation, and vascularization, and fetal organogenesis (Vonnahme et al., 2006). Vonnahme et al., (2006) observed that fetuses from ewes fed a 50-percent-restricted diet were markedly lighter than those from control-fed ewes. This may influence postnatal growth and weaning weights and may have been responsible for fluctuations observed between years of birth (Figure 1). Future experiments will aim at further investigating the relationship between resource limited range conditions and offspring weaning weight.

Table 3. Multiplicative adjustment factors for adjusting lamb weaning weights to a common sex, age of dam, and birth and rearing type[a] in comparison with values from the Report of the National Sheep Improvement Program (NSIP) Technical Committee[b] (1986; between brackets).

Item	Age of dam (yr)	Single	Twin	Triplet
Ewe	2	1.04 (1.08)	1.24 (1.29)	
	3-6	1.00 (1.00)	1.18 (1.19)	1.28 (1.36)
Ram	2	0.96 (0.98)	1.14 (1.17)	
	3-6	0.93 (0.91)	1.10 (1.08)	1.19 (1.23)

[a] Values are given for single born – single reared, twin born – twin reared, and triplet born – triplet reared lambs only.
[b] Values were calculated from Targhee, Suffolk and Polypay flocks throughout the United States.

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Peanut Stover and Bermudagrass Hay for Wethers on Summer Hardwood Rangeland in North Central Texas

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Summary

Goats in the south-central United States raised on rangeland often face a mid-summer forage quantity and nutritive-value deficit that may be mitigated by feeding inexpensive hay or stover. Four wethers (Boer X Spanish goats) were assigned to wooded rangeland paddocks (eight head ha^{-1}, two replications) and supplemented with either peanut (*Arachis hypogea*) stover (10 percent crude protein (CP)) or coastal bermudagrass (*Cynodon dactylon*) hay (12 percent CP) at 0.5 percent or 2.0 percent BW with two unsupplemented paddocks as control treatments. The hay and stover were also fed to wethers *ad libitum* in a traditional feedlot and compared to a complete feed ration (four head pen^{-1}, two replications). For 10 weeks from July to September in 2002 (216 mm rainfall) and in 2003 (354 mm rainfall) average daily gains (ADG) were measured, while herbage availability, and ADF, ADL, NDF, and CP concentrations of the primary browse species were determined. Goats receiving 0.5 percent BW bermudagrass in 2002 had greater ADG than those in the control and 0.5 percent BW peanut paddocks ($P < 0.1$). There were no differences in ADG among goats fed 2.0 percent BW of bermudagrass and peanut stover or control animals in 2002. No differences in ADG were measured in 2003 when browse nutritive value was the same but quantity was 26 percent lower than 2002. Goats on the complete ration in the drylot had greater ($P < 0.1$) ADG than goats fed either hay or stover *ad libitum* both years. Goats on complete feed in the drylot had greater ($P < 0.05$) dressing percentages than animals fed either stover or hay (45 percent, 37 percent and 31 percent, respectively). Supplementing goats on hardwood range with bermudagrass hay at 0.5 percent BW improved ADG only when there were sufficient quantities of high-quality browse.

Keywords: Bermudagrass Hay; Peanut Stover; Wooded Rangeland; Daily Gain; Goats

Introduction

Stabilizing meat-goat prices (VDACS, 2006) and the introduction of Boer-goat genetics into the United States (Cameron et al., 2001), are factors contributing to an increased interest in meat-goat production. Historically, Texas meat goats have been raised almost exclusively on rangelands or in small holdings. Confined-finishing systems used for sheep and cattle in the United States are not considered effective for goats and are relatively new practices for the meat-goat industry (Machen et al., 2001). Therefore, very little information is available on the efficacy of supplementing hays or stovers (baled-crop residues) to meat goats on south-central U.S. rangeland (Machen, 2001).

Goats raised on rangelands in the south-central United States often face both forage-quantity and/or quality deficits from July through August, usually due to dry weather conditions. For example, the 30-year-average annual rainfall for Stephenville, Texas, is 762 mm (Figure 1), with July and August comprising the driest and warmest (Figure 2) months of the year (TAES, 2002). Prolonged drought conditions in the south-central United States since 1998 have led to a further reduction in forage availability and quality during July and August, resulting in economic losses for many producers (Hiler, 1998).

Supplementing or substituting browse during drought, when pasture- and rangeland-forage quantity and nutritive-value decrease, might improve goat productivity in the south-central United States. The question addressed in this study was whether the hays or stovers currently used complement rangeland browse. Studies have shown that stover or hay supplements to goats on mature grass pastures rarely increase ADG (Torto and Rhule, 1997), whereas high-CP supplements increase production, especially when the nutritive value of grass is low (Faftine et al., 1998). Supplementing goats on browse, however, can be different since browse in drought periods can still have high-nutritive value, albeit of insufficient quantity to keep animals growing (Schacht et al., 1992; Papachristou et al., 1999). In such situations, high-fiber supplements (rather than high-nutritive value material) may be more appropriate since goats consuming woodland browse select for CP but do not select against ADF concentrations (Ott et al., 2004). Browse of greater nutritive value than hays or stovers with elevated ADF concentrations may have a synergistic effect on the supplement by increasing the intake and digestibility of the hay or stover. Supplementing or substituting feed may also attenuate the impact of overgrazing on rangelands during drought months or years (Bodine et al., 2001).

This study evaluated coastal bermudagrass hay and baled peanut stover in two feeding systems for meat goats. One system was based on a hardwood rangeland, where the stover and hay supplemented or partially replaced native browse, while the other was a drylot system comparing formulated feed, hay, or stover fed *ad libitum*. The two hays selected for these trials are easily accessible to producers in the south-central United States and are being used increasingly by goat producers in the region. Critical questions addressed during the course of this study included animal performance and the efficiency of using hay or stover as goat feed, both as a sole feed, as well as in conjunction with browse in a hardwood rangeland.

Figure 1. Rainfall during 2002 and 2003 and the 30-year average at Stephenville, Texas.

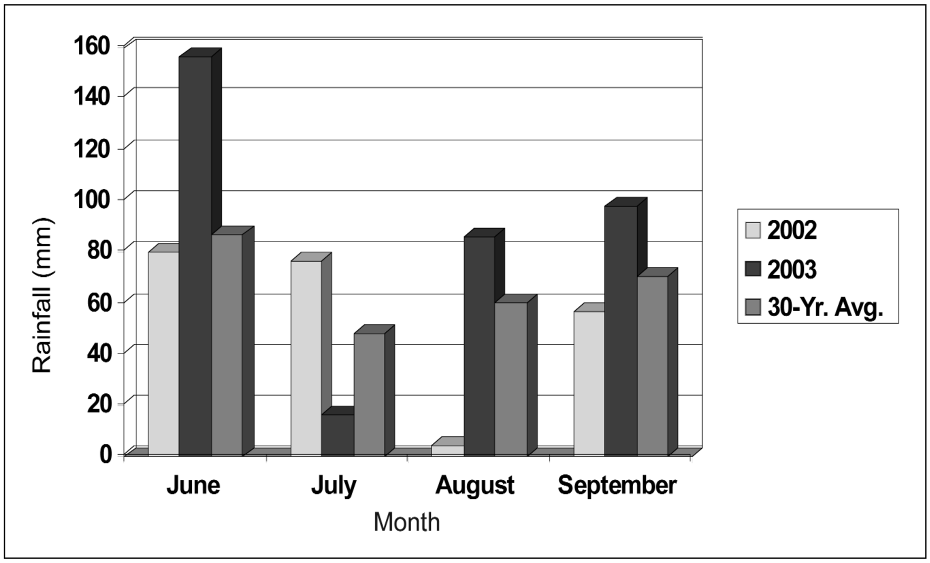
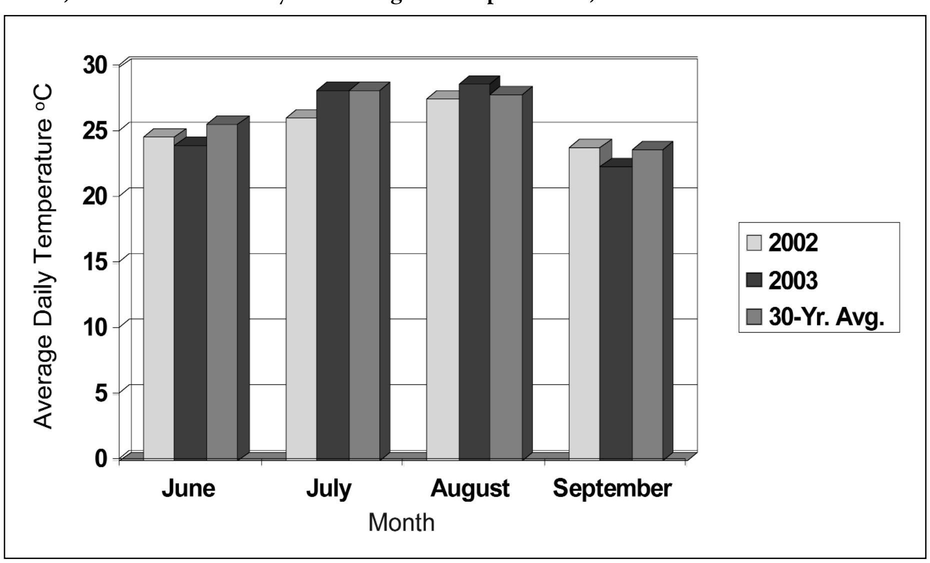


Figure 2. Average daily temperatures from June through September in 2002 and 2003, as well as the 30-year average at Stephenville, Texas.



Materials and Methods

The trial spanned the same 10-week period, from the third week in June to the second week in September, in the years 2002 and 2003. Sixty-four 5- to 6-month old Boer (75 percent) X Spanish wethers were obtained from the same Texas livestock producer each year (same four sires) and averaged 20±2 kg at the start of the trial in both years. All goats had been previously castrated and wounds were completely healed at the onset of the experiment. Ivermectin® was administered to all goats when fecal egg counts exceeded 500 g^{-1} in one or more animals (once in 2002 and twice in 2003) and antibiotics were administered to all animals when one or more showed symptoms of respiratory or intestinal distress (once in 2003). Water and salt were available throughout the trials. Seven days prior to the start of the trials, goats were weighed and randomly assigned to sixteen groups of four, assigned to the woodland trial or the drylot trial, and allowed a 7-day adaptation period.

Table 1. Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) of bermudagrass hay, peanut stover, and their refusals (dry matter basis) when fed to wether kids over two years at Stephenville, Texas.[a]

	Year	CP %	NDF %	ADF %	ADL %
Bermuda hay	2002	12.7±0.8	66.8±4.1	32.7±0.7	4.96±0.6
	2003	10.7±1.5	69.8±0.8	33.3±4.5	7.36±2.3
Bermuda hay refusals	2002	10.6±0.2	71.4±0.5	35.7±1.2	5.92±0.5
	2003	8.3±2.0	74.1±0.4	36.0±1.2	5.73±0.1
Peanut stover	2002	8.9±0.5	42.3±1.8	35.4±1.6	9.1±2.1
	2003	11.8±1.4	48.3±6.0	44.2±8.2	11.4±3.0
Peanut stover refusals	2002	6.2±0.7	55.9±6.8	46.7±3.2	6.20±0.7
	2003	7.9±2.1	56.8±3.6	45.1±8.4	7.87±3.6

[a] Means ± SE of 10 weekly samples.

Woodland trial

The trial site was a native, wooded rangeland located at the Texas Agricultural Experiment Station, Stephenville, Texas (32° 13'N/ 9° 12'W at 399 m elevation). Dominant browse species included herbaceous forbs (perennial legumes and grasses), shrubs (*Cetis* spp., 2900 stems ha^{-1}), vines (*Smilax* spp., 44000 stems ha^{-1}), and an overstory dominated by *Quercus virginiana* (800 trees ha^{-1}), *Quercus stellata* (2400 stems ha^{-1}), and *Ulmus* spp. (120 trees ha^{-1}) (Ott et al., 2004). The 30-year-average precipitation for June to September for the area is 256 mm, and rainfall for these months during the trial was 216 mm for 2002 and 354 mm for 2003. The 4.9 ha woodland was divided into ten paddocks, each approximately 0.49 ha with uniform species composition.

A group of four wethers was assigned to each of ten paddocks and supplemented with either peanut (*Arachis hypogea*) stover or coastal bermudagrass (*Cynodon dactylon*) hay (Table 1) at 0.5 percent or 2 percent of BW, with two control groups receiving no supplementation (two replications per treatment). Weekly feeding levels for each treatment were calculated from mean body weight in each paddock after a weekly weighing. Feed levels remained at that calculated amount until the following week's weighing and were then adjusted. All supplemented wethers were fed in hay troughs and refusals were collected and subtracted from the fed amounts to calculate the actual amount of hay consumed. Goats received their allotted supplementation/substitution diet once daily in the morning.

Goats were weighed using a Paul® portable small livestock scale with LCD digital readout and the mean of four wethers in each paddock used as a single data point. Data obtained was used to estimate ADG over the entire 10-week period each year. Following the weekly weighing, wethers were systematically rotated to the next paddock to ensure equal exposure to all paddocks.

One goat from each treatment/pasture and/or drylot pen was randomly selected for slaughter and carcass data collection at the end of 2003. These goats were transported to Rancher's Lamb of Texas, an abattoir in San Angelo, Texas. Shrinkage interval between penning and slaughter was 12 hours. Each carcass was tagged with the corresponding identification number, and weights were recorded prior to and following slaughter to determine dressing percentage of live weight.

Browse herbage samples were taken at three random points along the north and south diagonal transect in each paddock, thrice during the trial period: the first week of the trial, week six, and week ten. At each point, all available foliage below the browse line (1.5 m) was collected within a 1-m radius. Foliage from each point was hand-plucked to imitate how goats would browse the plants. Browse-herbage yields were reported as totals of all species combined. Because of the woodland canopy and goats' strong preference toward woody and forb species (Rodriguez and Kothmann, 1998), no attempt was made to quantify the sparse herbaceous material within the study area. Samples of hay were taken daily from the different supplementation/substitution treatments from each paddock. Refusals were collected daily before the goats received fresh supplement. Hay by type and refusals by treatment were batched by week (N = 10 yr^{-1}). Foliage, hay, and refusal collected from each paddock and drylot were placed in sample bags by type/species and dried at 55° C to a constant weight. Dried samples from each species were ground in a Wiley mill to pass a 1-mm screen and bottled for nutrient composition analyses in the laboratory.

Samples of the rangeland foliage, hays, and refusals were analyzed for concentration of N (A.O.A.C., 1990), NDF, ADF, and ADL as a percentage of dry matter (DM) (Van Soest and Robertson, 1980). Forage N concentrations were digested in an aluminum block digester (Gallaher et al., 1975) and mineral concentration of the digest was measured using semi-automated colorimetry (Hambleton, 1977) with a Technicon Autoanalyzer II. Percentage N estimates were then multiplied by 6.25 to estimate herbage CP concentration (Van Soest, 1994).

Drylot Trial

The drylot study was also located at the Texas Agricultural Experiment Station and consisted of six pens, each approximately 28 m^2 in size. Diet treatments were coastal bermudagrass, peanut stover or a commercially formulated feed (18 percent CP and 63 percent total digestible nutrients) offered *ad libitum* to four animals per pen. No additional supplement was given with the hay and no effort was made to equate CP or energy levels since the purpose was to compare pure hay or stover feeds with a balanced diet. Feeding regimes, feed sampling, laboratory analyses, as well as wether care and data collection were the same as in the woodland trial. Feed-conversion rates were calculated for the pen-fed animals (peanut, bermudagrass, and complete ration).

Statistical analyses

Each trial was analyzed as a separate experiment. The ADG values for the entire 10-week period were derived by averaging the ADG of all four wethers in each paddock or pen, with each treatment replicated twice. For carcass percent, only one wether from each paddock or pen was used as a data point, with each treatment replicated twice. Years and treatments (and years by treatment) were used as independent variables in the models when ADG values were submitted to analyses of variance, while only treatments were included in the model when analyzing carcass percent. Where appropriate, means were separated using a least significant difference (LSD) at $P < 0.10$. All other values are reported with standard deviations.

Results and Discussion

Woodland trial

Browse nutritive value for the primary species (*Ulmus* spp., *Celtis* spp., and *Quercus virginiana*) in the woodland paddocks (Table 2) was consistent between years. This supports the findings of Tolera et al. (1997) who reported that most browse species maintain their nutritive value from year to year. The primary woody species were generally of greater nutritive value than the bermudagrass hay or the peanut stover. In contrast, viney (*Smilax* spp.) and herbaceous plants (grasses) decreased in both quantity and nutritive value from the first to the second year, despite greater rainfall in the second year. This was likely because of reduced plant nutrient reserves caused by the first year's browsing of these smaller, less deep-rooted species. Crude-protein concentration of viney plants, for example, decreased by 17 percent and grasses by 22 percent from the first to the second year.

Table 2. Nutritive value of leaves from browse species consumed by goats in wooded rangeland over two years in Stephenville, Texas, pooled over weeks 1, 6 and 10 of the trial.[a]

	Year	CP %	NDF %	ADF %	ADL %
Ulmus spp.	2002	11.0±0.3	34.5±0.7	24.4±0.4	9.2±0.3
	2003	10.9±0.7	35.0±1.3	24.6±0.6	9.3±0.4
Celtis spp.	2002	9.8±0.1	39.8±0.7	27.5±6.3	9.0±0.3
	2003	9.6±0.6	39.5±1.6	27.4±2.7	8.6±1.8
Quercus spp.	2002	11.7±0.9	45.7±2.7	30.0±1.8	10.7±0.7
	2003	11.6±0.6	46.2±1.6	30.0±1.6	11.3±0.7
Smilax spp.	2002	11.7±0.4	47.5±2.3	30.5±0.4	9.6±0.5
	2003	10.6±0.5	46.7±1.7	35.0±1.9	14.8±1.5
Grasses	2002	9.5±0.8	63.5±1.3	39.0±0.4	6.0±0.7
	2003	7.2±0.3	71.9±0.9	32.3±2.4	5.7±0.4

[a] Means ± SE of 30 samples over 3 time periods.

Forage production and quality varies depending on precipitation, temperature, and grazing history (White and Richardson, 1999). In addition, plants grown at elevated temperatures generally produce lower-quality forage than plants grown under cooler temperatures (Ball et al., 2001). The average air temperature was greater in 2003 than in 2002 over the months of the trial, which may also have contributed to a decrease in the forage nutritive value. Greater air temperatures may also have caused the herbaceous plant material to mature earlier, thereby decreasing the quality of the forages (Bruinenberg et al., 2002).

Supplementation of low-quality diets can either improve intake of a basal diet (Pathirana and Orskov, 1995; Abdulrazak et al., 1997) or reduce intake (Getachew et al., 1994), depending on relative quality of the basal and supplemental feeds. Papachristou et al. (1999) suggested that woodland browse is an effective supplement to low-quality forages and that this seems to be a practical means of maintaining body weight of goats. Improvements in voluntary intake are often attributed to increased rates of forage digestion and digesta passage, which can promote improved BW gain and body condition in ruminants, such as cattle (Weder et al., 1999).

The quantity of accessible browse decreased from an estimated 991 kg ha^{-1} in 2002 to 737 kg ha^{-1} in 2003. This may explain how the 0.5 percent BW bermudagrass benefited the goats in 2002 but not in 2003 (Table 3; year by treatment interaction $P = 0.1$) due to insufficient high-quality browse in 2003 to stimulate passage rate of even small quantities of bermudagrass. Goats receiving 0.5 percent BW bermudagrass in 2002 had greater ADG than those in the control or 0.5 percent BW peanut paddocks ($P < 0.1$) while there were no differences ($P \geq 0.1$) in ADG among goats supplemented with the 0.5 percent BW bermudagrass, 2 percent BW bermudagrass, and 2 percent peanut stover in 2002. Goats receiving 0.5 percent BW peanut stover and 2 percent BW peanut stover in 2002 did not differ from animals in the control paddock.

There were no differences ($P \geq 0.1$) in wether ADG among treatments in 2003. This may be a result of decreased

Table 3. Wether kid average daily gains (ADG) on summer wooded rangeland fed bermudagrass hay or peanut stover at three different rates or in a dry lot fed solely formulated ration, bermudagrass hay, or peanut stover (year by treatment interaction *P = 0.10*).[a]

	2002	2003
	ADG g/day	
Rangeland		
Bermudagrass hay at 0.5% BW	50±1[bc]	36±1[b]
Bermudagrass hay at 2% BW	49±5[bcd]	35±2[b]
Peanut stover at 2% BW	46±6[cd]	32±3[b]
Unsupplemented control	35±1[d]	34±4[b]
Peanut stover at 0.5% BW	33±4[d]	33±3[b]
Drylot		
Complete pelleted ration	127±2[b]	82±2[b]
Peanut stover	37±5[c]	30±4[c]
Bermudagrass hay	31±5[c]	27±1[c]

[a] Means ± SE; N = 2 with 4 kids per N
[b,c,d] Values in the same year and trial differ only if followed by different letters according to a least significant difference multiple mean separation ($LSD_{0.05}$).

browse nutritive value (Table 2) and quantity in 2003 (737 kg ha^{-1}) compared to 2002 (991 kg ha^{-1}). Due to lower availability of browse in 2003, the quality of the native browse may have been insufficient to stimulate the digestibility of grass hay at both supplementation/substitution levels. First year results indicate that supplementation with bermudagrass hay at 0.5 percent BW may increase ADG over no supplementation only when there is sufficient high-quality browse, whereas greater amounts of hay may be less efficacious, by diluting the effect of high quality browse. Further research is required to determine whether increasing browse availability (achieved through lower stocking rates or by using previously unbrowsed, wooded rangeland) will improve goat ADG when bermudagrass is fed at rates greater than 0.5 percent BW.

No positive effects on ADG were observed with peanut stover supplementation or substitution compared to unsupplemented animals (Table 3), perhaps because nutrients in the stover did not complement those ingested in the browse. Warambwa and Ndlovu (1992), reported by Faftine et al. (1998), also found that peanut stover fed to goats resulted only in weight maintenance. In contrast, Manyuchi et al. (1997) found that it was possible to feed peanut stover in small amounts to improve nutrient intake when animals consumed poor quality forages. Ondiek et al. (1999) also reported improved live-weight gains in goats when legumes were used to supplement roughage-based diets, while Ahmed and Nour (1997) stated that goat production under natural, rangeland conditions would be improved by legume supplementation. Differences among these studies and our findings were likely due to the fact that the browse quantity and nutritive value in the present study were greater than poor-quality, grass basal diets used in other studies. When available in sufficient quantities in 2002, the high-nutritive value of native browse (Table 2) likely improved the digestibility of bermudagrass at the 0.5 percent BW but was insufficient to positively affect energy availability of the grass hay fed at the greater rate.

Hay or stover fed at lower rates was more efficiently consumed, since refusals were five to six times greater when hay or stover was fed at 2 percent compared to 0.5 percent BW (Table 4). There were no differences in percentage of refusals in each treatment between years. The 2 percent BW treatments of bermudagrass and peanut stover had the greatest refusal percentage (18 percent and 10 percent, respectively), indicating greater selectivity by the goats when fed greater amounts of hay or stover.

Chemical composition of the refusals was different from the fed material (Table 1). Bermudagrass hay rejected by goats was 23 percent lower in CP, 7 percent greater in NDF, 8 percent greater in ADF, and 9 percent greater in ADL concentration than the original fed hay. Likewise, peanut stover refusals were 22 percent lower in CP, 12 percent greater in NDF, 19 percent greater in ADF, and 21 percent greater in ADL concentration than the stover when fed. Feeding at 2 percent BW allowed the goats to select the feed lower in fiber components (but not CP) to complement the available native forage. Small ruminants are often better able to select specific feedstuffs based on their nutrient content,

Table 4. Percent refusal by wether kids of bermudagrass hay or peanut stover while on winter wooded rangeland or in a drylot.[a]

	2002	2003
	% refusal	
Pasture		
Bermudagrass hay at 0.5% BW	2±1[d]	4±1[e]
Bermudagrass hay at 2% BW	18±2[b]	14±3[c]
Peanut stover at 2% BW	10±2[c]	16±4[b]
Peanut stover at 0.5% BW	4±4[e]	5±4[d]
Drylot		
Peanut stover	21±4[b]	26±2[b]
Bermudagrass hay	12±2[c]	14±1[c]

[a] Means ± SE; N = 2
[b,c,d,e] Values in the same year and trial differ only if followed by different letters according to a least significant difference multiple mean separation ($LSD_{0.05}$).

spending more time searching through a large amount of vegetation for dietary items with desirable quality characteristics (Kronberg and Malechek, 1997). When feed quantities are low, however, their selectivity may be limited, explaining why goats in the 0.5 percent BW peanut stover and 0.5 percent bermudagrass paddocks consumed a greater proportion of supplement available, 98 percent and 96 percent for both years, respectively.

Goats consuming 2 percent BW peanut stover had 40 percent of their LW as carcass, greater ($P \leq 0.05$) than all other treatments (Table 5). This may be the result of the ingested peanut stover having a faster passage rate than the bermudagrass hay, resulting in lower rumen fill at the time of slaughter. At 37 percent carcass yield, goats consuming 0.5 percent BW bermudagrass and peanut stover were undifferentiated from the goats fed the control diet ($P \leq 0.05$). Animals offered 0.5 percent BW bermudagrass hay had greater carcass dressing percentages than goats fed 2 percent bermudagrass hay, again likely a result of greater rumen fill in the latter animals at time of slaughter. Although these data should be used cautiously due to low numbers of replication, conclusions are supported by Oman et al. (1999) and Warmington and Kirton (1990), who also found that nutrition can influence carcass-dressing percentage through variation in weight of gut contents.

Drylot trial

Sheridan et al. (2003) found that goats have a lower intake of concentrate diet compared to other domesticated ruminants, which may lead to poor performance in a feedlot. This did not appear to be the case in our study. On average, goats fed a complete feed ration in the drylot had over three times greater ($P < 0.1$) ADG than goats consuming *ad libitum* bermudagrass hay or peanut stover in 2003 and 2002, respectively (Table 3). These results agree with Kiesling and Swartz (1997) and Johnson and McGowan, (1998) who found that feeding ruminants a complete ration in a drylot/feedlot usually resulted in greater efficiency in gains and higher carcass scores than feeding forages alone. There were no differences ($P \geq 0.1$) in ADG between the goats receiving bermudagrass hay or peanut stover *ad libitum* in either year. It is not clear why ADG of goats on the complete ration was greater in 2002 than 2003 since nutritive value was similar, 18.6 percent CP, 39.1 percent NDF, and 25.2 percent ADF in 2002, and 18.2 percent CP, 37.9 percent NDF, and 26.0 percent ADF in 2003. Greater mean temperatures (Figure 2) and relative humidity due to greater rainfall (Figure 1) may have contributed to lower goat appetite and greater internal parasite load in 2003, but this question would need more research before reaching any conclusions.

As was the case in the woodland trial, chemical composition of the hay and stover refusals was different from the fed material (Table 1). Bermudagrass hay and peanut refusal chemical composition was similar to those measured for the woodland trial. Average refusal percentage, over both years, was 80 percent greater in the peanut stover pens compared to bermudagrass (Table 4). Goats tend to select forage with the greatest nutrient concentration: the leaves more than the stems, and the thin stems more than the thick ones (Owen et al., 1986; Narjisse, 1991; and Odo et al., 2001). This may explain the greater refusal percentage in the peanut stover pens since the stover had larger, thicker stems than did the bermudagrass hay.

Although goats in the peanut stover pens tended to consume less, there was no difference in ADG between pens, making conversion ratios of the stover more efficient than the hay. The conversion ratios for peanut stover were 14:1 in 2002 and 16:1 in 2003, while bermudagrass hay was 19:1 in 2002 and 20:1 in 2003, and the concentrate was 3:1 in 2002 and 5:1 in 2003. On a price (2003 Texas market) per LW basis, bermudagrass hay was approximately \$3.30 kg^{-1} of gain, while peanut stover cost approximately \$2.20 kg^{-1} of gain, and the concentrate was approximately \$0.66 kg^{-1} of gain.

Goats fed concentrate in the drylot in 2003 had 8 percent greater ($P < 0.05$) dressing percentage than animals fed peanut stover, which in turn, had 5.9 percent greater carcass dressing percentages than goats fed bermudagrass hay (Table 5). These results were similar to those of Kiesling and Swartz (1997) and Johnson and McGowan (1998). Results reported by McClure et al. (1994) also support the conclusion that the consumption of a balanced diet by small ruminants, in this case sheep, in feedlots resulted in greater gains and carcass scores than did the consumption of forages. The fact that goats fed peanut stover had greater dressing percentages than those fed bermudagrass hay would indicate that goats consuming bermudagrass hay had the lowest passage rate and greater rumen size at time of slaughter.

Table 5. Wether kid carcass percent on summer wooded rangeland fed bermudagrass hay or peanut stover at three different rates or in a dry lot fed solely formulated ration, bermudagrass hay, or peanut stover.[a]

	2003
	% carcass
Treatment	
Bermudagrass hay at 0.5% BW	38.5±2[c]
Bermudagrass hay at 2% BW	36.8±2[d]
Peanut stover at 2% BW	40.0±2[b]
Unsupplemented control	37.5±2[cd]
Peanut stover at 0.5% BW	37.6±3[cd]
Drylot	
Complete pelleted ration	45.0±3[b]
Peanut stover	37.0±2[c]
Bermudagrass hay	31.1±2[d]

[a] Means ± SE; N = 2
[b,c,d] Values in the same trial differ only if followed by different letters according to a least significant difference multiple mean separation ($LSD_{0.05}$).

Conclusions

The primary goal of this research was to determine whether feeding bermudagrass hay or peanut stover to goats, already a common practice in north-central Texas, affects wether ADG during summer months. Results were decidedly mixed, leaving in doubt whether or not the use of bermudagrass hay and peanut stover are effective for goats except, perhaps, in emergency situations, such as drought. The nutritive value and quantity of the woodland browse was a larger determining factor on goat ADG than the bermudagrass hay or peanut stover. Even the first year, when browse was more abundant, only smaller amounts of bermudagrass hay improved wether ADG, while greater quantities showed little benefit to ADG. Further research is needed to determine whether more abundant browse can combine with greater amounts of grass hay to further improve goat performance.

The wethers in the woodland trial exhibited good acceptance of the supplements, even though they showed little benefit from it in terms of ADG. Goats selected for finer stems, leaves, and nuts of the peanut stover while leaving thicker stems behind. This preference for the finer stems could also be seen with the bermudagrass hay. Goats in the drylot trial were even more selective in the forage material they consumed than those on rangeland, resulting in greater rates of refusal and less efficient use of the fed material.

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Growth and Carcass Characteristics in Goat Kids Fed Grass- and Alfalfa-Hay-Based Diets with Limited Concentrate Supplementation[1]

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Summary

Two experiments were conducted to evaluate the effect of feeding legume hay (alfalfa; *Medicago sativa* L.) or mixed-grass hay on ADG and carcass characteristics of growing goats. In Experiment 1, 24 Spanish kids, equally representing female, intact male and wether goats, were pen-fed *ad libitum* either chopped alfalfa (16.8 percent CP) or mixed grass hay (9.4 percent CP) (3 pens/diet) and a corn/soybean meal supplement (16 percent CP) at 1.5 percent BW for 102 d. Goats were harvested at a commercial abattoir. Average daily gain (62 vs. 37 g/d; $P < 0.01$), carcass weight (14.8 vs. 12.8 kg; $P < 0.05$) and dressing percent (52.9 percent vs. 50.4 percent; $P < 0.05$) were higher in alfalfa than grass-hay-fed goats, respectively. Backfat and percentage kidney/pelvic fat was lower ($P < 0.05$) in bucks (0.12 cm and 1.8 percent) than in does (0.17 cm and 5.7 percent) and wethers (0.22 cm and 4.0 percent). In Experiment 2, 10-month-old Boer and Boer-cross wethers (n=16) were pen-fed *ad libitum* either chopped alfalfa (15.2 percent CP) or grass hay (10.9 percent CP) for 84 days. Forage was supplemented with concentrate (16.3 percent CP) at 1 percent of BW. Carcass characteristics were determined as described for Experiment 1. Wethers fed alfalfa hay had a higher ADG (158 vs. 119 g/d; $P < 0.01$) and dressing percentage (54.0 percent vs. 52.2 percent, $P < 0.05$), but did not differ in other carcass characteristics. Alfalfa feeding improved growth rate and dressing percentage, but had no effect on other carcass characteristics, whereas sex class influenced primarily carcass-fat content.

Introduction

Goat production systems are more diverse, and markets more varied than for many of the more traditional livestock species in the United States. Finishing goats in feedlots on high concentrate diets is not a widespread practice, and goats are generally used more efficiently when utilizing browse and forage. Pen feeding of goats may achieve faster growth rates and allow for finishing at specific target weights (Lupton et al., 2007), but feedlot goats have shown only a marginal response in growth rate when dietary crude protein increased from 14 percent to 16.4 percent, or roughage content decreased with removal of cottonseed hulls from the feedlot ration (Huston and Waldron, 1996).

Goat meat has been extensively compared to lamb and mutton, and difference in flavor and aroma have been noted (Webb et al., 2005). Goats tend to be leaner (intra-muscular and back fat), have a lower dressing percentage, and higher muscle shear force values than sheep (Sen et al., 2004; Van Niekerk and Casey, 1988). Carcass composition in goats may be influenced by level of feed intake and diet composition (Warmington and Kirton, 1990), but additional information is needed on the specific effects of breed and diet on carcass characteristics.

The utilization of forages by ruminants is dependent on a variety of inter-related factors that include not only forage nutritive value, but also intake and digestibility (Reid et al., 1990). Forage type (grass vs. legume) can have a significant impact. Alfalfa not only has a higher CP concentration than most grasses, but generally has lower levels of ADF, and a greater organic matter intake and digestibility can be expected when consumed by goats compared to sheep (Coleman et al., 2003; Park et al., 1989; Reid et al., 1990). Therefore the objective of this study was to estimate the effect of the improved nutritional value of alfalfa hay compared to mixed grass hay on animal growth and carcass characteristics in young goats.

Materials and Methods

Feeding trials were conducted at the Small Ruminant Facilities of Virginia State University, Petersburg, Virginia. The first trial (Experiment 1) was conducted in fall (late August through November), while the second trial (Experiment 2) was conducted in December through March the following year. The experiments were approved by the Virginia State University Agricultural Animal Care and Use Committee.

Experiment 1

Twenty-four Spanish goat kids (16 bucklings and 8 doelings) were randomly selected from a fall kid crop at 6 months of age. Eight bucklings were surgically castrated and allowed to recover for 1 month to establish three sex classes (does, bucks and wethers). At 7 months of age animals were weighed and randomly allocated by sex class to six semi-enclosed pens (26 m^2; equipped with automated waterers) with four animals/pen (two pens per sex class). Forage-based diets consisted either of commercially produced grass (predominantly orchard grass, *Dactylis glomerata*) or alfalfa (*Medicago sativa* L.) hay and were fed to one pen per sex class.

Hay samples were analyzed for CP (total N x 6.25; Carlo-Erba Ea 1108 CHNS elemental analyzer, Fisons Instruments, Beverly, Mass.), neutral detergent fiber (NDF) and acid detergent fiber (ADF) using ANKOM procedures (Ankom Technology Corp., Fairport, N.Y.) and results are presented in Table 1. Forage (square bales) was processed through a hydraulic bale chopper prior to feeding, and cut to a particle length of 10 cm. Hay was offered at 15 percent to 25 percent over estimated daily intake and refusal removed and bunks cleaned daily prior to supplement feeding. In order to improve expected ADG and produce a harvestable product, all animals were supplemented with a cracked corn/soybean meal mixture (calculated at 16.0 percent CP and 75 percent TDN) at 1.5 percent BW, and animals had access to a trace-mineral mix with ammonium chloride. Supplement was fed in the cleaned bunks and complete consumption by individual animals was monitored (usually within 5 minutes), prior to the daily feeding of hay. Estimates of forage intake by animals temporarily placed into individual pens during the trial were 1.7 percent and 2.1 percent of BW for grass and alfalfa diets, respectively.

Body weight was recorded at 34-day intervals and supplement levels adjusted at this time. Pre-prandial blood samples were collected via jugular venipuncture at time of weighing, plasma harvested and analyzed for blood urea nitrogen (BUN) using a colorimetric technique (Sigma Diagnostic™ Test Kit Procedure No. 640).

After 102 days on trial animals were weighed at 0800 h; feed, but not water, was removed for 24 h, and shrunk BW was recorded to subsequently determine dressing percentage. Animals were transported to a commercial abattoir for harvest. Hot and cold carcass weight, ribeye area, back fat, and kidney and pelvic fat were measured, and retail cuts (shoulder, rack, loin and leg) were obtained and weighed. Data were analyzed using the GLM procedures of SAS ver. 9.1 (SAS Institute Inc., Cary, N.C.) in a model with animal as the experimental unit and forage type and sex class as main effects. Means were separated when significant ($P < 0.05$) F-values were indicated. Blood urea N data were analyzed using a repeated measures analysis.

Table 1. Nutritional values of the commercial mixed grass (predominantly orchard grass) and alfalfa hay used in the Experiment 1 and the commercial mixed grass (predominantly tall fescue) and alfalfa hay used in Experiment 2.

	Experiment 1		Experiment 2	
% (DM basis)[1]	Grass	Alfalfa	Grass	Alfalfa
CP	9.4	16.8	10.9	15.2
NDF	71.3	64.3	83.0	70.2
ADF	39.2	47.3	50.1	41.5

[1] CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber

Experiment 2

The second experiment evaluated the effect of an improved forage diet on growth performance and carcass characteristics in a breed type with a higher growth potential than the Spanish goats in Experiment 1. Animals for this experiment originated from the goat research herd of North Carolina State University. The 16 wether goats (7 Boer and 9 Boer cross) were castrated at birth, transported to Virginia State University after weaning at 90 days of age, and maintained on pasture. For the experiment the animals were weighed and randomly allocated to one of two semi-enclosed pens (44 m^2; equipped with automated waterers) at 10 months of age, with Boer and Boer-cross goats represented in each pen. Pens were fed either the grass-hay or alfalfa-hay-based diet. The mixed-grass hay in this trial was commercial, predominantly tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh], whereas alfalfa was first-cutting, commercial hay (Table 1).

Animals were offered hay at 15 percent over estimated daily intake. Forage was processed and fed as described for Experiment 1, and supplemented at 1 percent BW with a cracked corn/whole cottonseed/soybean meal concentrate (calculated at 16.3 percent CP and 73 percent TDN) that included ammonium chloride. Supplement level was reduced in this trial to allow for greater consumption of forage. Supplement was again fed in clean bunks and complete intake monitored by all animals prior to feeding hay. Animals had *ad lib* access to a trace-mineral mix. Body weight was recorded in 14-day intervals and supplement levels were adjusted at this time. Pre-prandial blood samples were collected via jugular venipuncture on days 1, 42 and 84 of the trial, and plasma harvested and analyzed for BUN using automated procedures (Ciba-Corning Express Plus Chemistry Analyzer; Ciba-Corning Diagnostics Corp., Medfield, Mass.).

After 84 days on trial, animals were weighed and harvested as described for Experiment 1. Data were analyzed for the effect of forage type on BW, ADG, and carcass characteristics with animal as experimental unit using the GLM procedure of SAS ver. 9.1 (SAS Institute Inc., Cary, N.C.).

Results and Discussion

The ADG of the Spanish goat kids in Experiment 1 was 25 g/d higher ($P < 0.01$) in the alfalfa than the grass-hay-fed kids (Table 2). In Boer and Boer-cross wethers in Experiment 2, ADG of alfalfa-hay-fed wethers was 39 g/d higher ($P < 0.01$) than the grass-fed wethers (Table 2).

In a previous feeding trial at our location, using alfalfa-hay-based diets supplemented with concentrate at 0.5 percent BW, mixed-breed goat kids had intermediate ADG (103 g/d) to those observed in the two present experiments (Turner et al., 2005). In the Turner et al. (2005) trial ADG of alfalfa-hay-fed goats was 80 percent higher than in goats fed sericea lespedeza [*Lespedeza cuneata* (Dum.-Cours.) G. Don] hay. Spanish goat kids fed alfalfa pellets (17.9 percent CP) compared to prairie-grass hay (7.4 percent CP) in another trial had marked improvement in ADG (82 vs. 0 g/d) (Wuliji et al., 2003), exceeding the difference between diets observed in the present study. In the study by Wuliji et al. (2003) ADG of alfalfa-hay-fed kids was similar to those receiving an all-concentrate diet. Mixed-breed dairy goats, slightly younger and lighter (5 months; 20 kg) than animals in Experiment 1 offered alfalfa hay (18 percent CP) had lower ADG (46 g) (Gelaye et al., 1990) than the Spanish goats fed alfalfa hay in Experiment 1 (62 g/d). In this study by Gelaye et al. (1990) goats offered rhizoma peanut (*Arachis glabrata* Benth.) hay had similar daily gains (63 g/d) to the Spanish goats in Experiment 1.

In an earlier study we observed no differences in ADG between Boer-cross and Spanish goats fed alfalfa-hay diets (Turner et al., 2005), whereas results from the two experiments here suggest otherwise, though there was no direct comparison of the breeds. Waldron et al. (1996) reported higher ADG in Boer x Spanish compared to Spanish kids when provided feedlot diets, but not when grazing rangeland. Boer-cross wethers fed sudan grass (*Sorghum vulgare*) hay diets supplemented with various legumes (3:2 grass to legume) and corn had somewhat lower ADG (75 to 95 g) (Kanani et al., 2006) than the Boer and Boer-cross wethers in the present study.

Spanish kids fed alfalfa hay had higher ($P < 0.05$) carcass weight and dressing percent, but similar ribeye area,

Table 2. Body weight, ADG, and carcass characteristics (mean±SEM) in Spanish (Experiment 1) and Boer goats (Experiment 2) fed either alfalfa or grass hay-based diets with limited concentrate supplementation.

	Experiment 1[1]		Experiment 2[2]	
Hay type (N of animals)	Grass (12)	Alfalfa (12)	Grass (8)	Alfalfa (8)
Starting BW, kg	21.6±1.1	21.6±0.6	37.6±1.8	36.2±1.8
Final BW, kg	25.4±1.3	27.9±0.6	47.6±1.9	49.5±2.3
ADG, g/d	37±4	62±4**	119±6	158±10**
Cold carcass wt., kg	12.8±0.8	14.8±0.4*	24.3±1.0	26.2±1.3
Dressing %	50.4±0.8	52.9±0.7*	52.3±0.5	54.0±0.4*
Ribeye area, cm^2	9.5±0.4	9.9±0.4	14.3±0.7	13.6±0.5
Backfat, cm	0.17±0.02	0.17±0.02	0.29±0.04	0.32±0.06
Kidney/pelvic fat, %	3.6±0.5	4.1±0.6	5.30±0.8	5.55±0.3
Retail cuts, %				
Shoulder	38.1±0.7	39.6±1.1	36.3±0.7	34.9±0.7
Rack	17.3±0.5	16.4±0.4	18.4±0.9	19.0±0.5
Loin	13.6±0.4	12.8±0.4	15.7±0.6	17.3±0.9
Leg	31.0±0.4	31.2±1.0	29.6±0.8	28.8±0.8

[1] Mixed-sex Spanish goat kids 7 mo of age at onset of trial; concentrate supplement at 1.5% BW

[2] Boer and Boer x Spanish crossbred wether goats 10 mo of age at onset of trial; concentrate supplement at 1% BW

*, ** Means differ between diets within experiment (* $P < 0.05$, **$P < 0.01$)

back fat and kidney/pelvic fat compared to the grass-hay-fed kids (Table 2). There were no differences in retail cut percentages between the two forage groups. In Experiment 2, the alfalfa-hay-fed Boer and Boer-cross goats also had a higher ($P < 0.05$) dressing percentage, but there were no differences between diets in any of the other carcass characteristics measured.

Goats in the two experiments reported here were harvested at different weights and age, thus not allowing a direct comparison of carcass characteristics, but carcass fat content (back fat and kidney pelvic fat) in the Boer and Boer-cross goats was considerably higher than in the Spanish goats. Similar differences between the two breeds were observed when animals were fed 80 percent concentrate feedlot diets (Oman et al., 2000), but not when grazed on rangeland at a lower plane of nutrition (Oman et al., 1999).

Increasing CP concentration of diets resulted in higher dressing percentage in wether goats (Shahjalal et al., 1992), similar to those in the alfalfa-hay-fed animals in the present study. However, Shahjalal et al. (1992) also noted an increased ribeye area, which we did not observe. No effect of increasing dietary CP on carcass characteristics was reported in intact male Tunisian goats (Atti et al., 2004). Wuliji et al. (2003) reported that ribeye area but not back fat (determined by ultrasonic measurements in live animals) was greater in alfalfa-hay-fed compared to the prairie-grass-hay-fed Spanish kids. This difference with our findings, however, is likely associated with the greater difference in BW between their groups and the lack of sensitivity of ultrasound scanning technique when used to determine the carcass measurements in goats.

There was no diet by sex class interactions on body weight, ADG, and carcass characteristics in Spanish goat kids. Sex class had no effect on body weight and ADG, or on carcass weight and dressing percentage in the Spanish goat kids in Experiment 1 (Table 3). However, ribeye area was greater ($P < 0.05$) in wethers than in does and bucks. Wethers also had greater ($P < 0.05$) back fat than bucks, with does being intermediate. Percent kidney/pelvic fat was different ($P < 0.05$) between all sex classes, being highest in does, intermediate in wethers, and lowest in bucks. Bucks had a larger ($P < 0.05$) percentage of shoulder retail cuts than does and wethers, whereas the portion of loin and leg cuts were smaller.

These results are in agreement with other studies that had reported increased fat deposition in does and wethers compared to intact bucks (Colomer-Rocher et al., 1992), but no differences in dressing percentage (Johnson et al., 1995; Mahgoub et al., 2004; Ruvuna et al., 1992). The differences observed in the proportion of retail cuts are similar to those found by Mahgoub et al. (2004) that showed a more developed forequarter, but a lower proportion of musculature in the proximal hind limb in bucks compared to does and wethers.

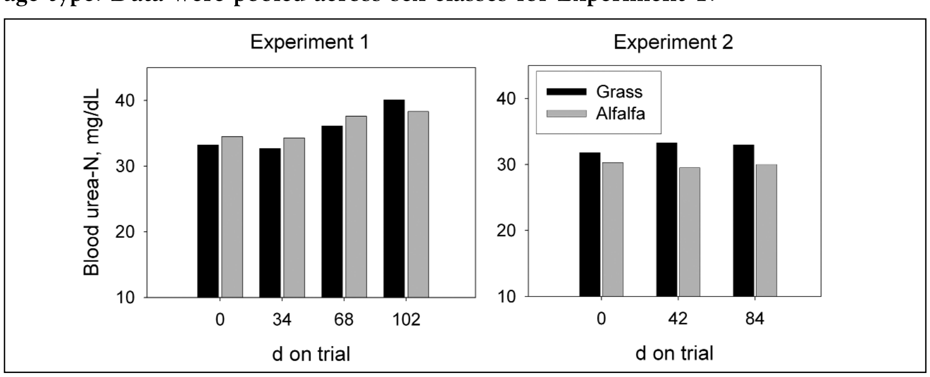
The higher-CP concentrations in the alfalfa-hay-based diets had no effect on BUN in the animals in either of the experiments (Figure 1). This contrasts earlier findings in our lab that indicated higher levels of BUN when mixed-breed goat kids were fed alfalfa hay (18.7 percent CP) compared to lespedeza hay (11.2 percent CP) (Turner et al., 2005). Sahlu et al. (1993) reported that increases in dietary crude protein in concentrate rations from 8.5 percent to 13.9 percent and 20.3 percent fed to Alpine (dairy), Nubian (meat) and Angora

Table 3. Body weight, ADG, and carcass characteristics (mean±SEM) in three sex classes of Spanish goats fed alfalfa and grass hay-based diets supplemented with concentrate at 1.5% BW (Experiment 1)[1].

Sex class (N of animals)	Bucks (8)	Does (8)	Wethers (8)
Starting BW, kg	22.4±1.3	19.9±0.5	22.6±1.2
Final BW, kg	27.3±1.3	24.9±0.9	27.8±1.4
ADG, g/d	49±6	49±6	51±8
Cold carcass wt., kg	14.1±0.8	12.9±0.7	14.5±0.9
Dressing %	51.4±0.9	51.8±0.9	51.9±1.1
Ribeye area, cm^2	9.1±0.4[b]	8.9±0.3[b]	10.9±0.4[a]
Backfat, cm	0.12±0.02[a]	0.17±0.03[ab]	0.22±0.03[b]
Kidney/pelvic fat, %	1.8±0.3[c]	5.7±0.3[a]	4.0±0.5[b]
Retail cuts, %			
Shoulder	42.4±1.1[a]	36.6±0.3[b]	37.7±0.7[b]
Rack	16.6±0.6	17.0±0.6	17.0±0.5
Loin	12.1±0.5[b]	13.5±0.5[a]	13.9±0.4[a]
Leg	28.9±1.2[b]	32.9±0.7[a]	31.4±0.5[ab]

[1] Data pooled across dietary treatments with absence of diet by sex class interactions ($P > 0.1$)
[a,b,c] Within a row, means without a common superscript letter differ ($P < 0.05$)

Figure 1. Blood urea-N concentrations in Spanish (Experiment 1) and Boer goats (Experiment 2) fed grass or alfalfa hay-based rations with some concentrate supplementation. Blood urea-N concentrations were not affected ($P > 0.05$) by forage type. Data were pooled across sex classes for Experiment 1.



(mohair) goats resulted in an associated increase in BUN from 8.3 to 22 and 33.3 mg/dL, respectively, while not affecting other blood metabolites. A rise in BUN was also reported in Spanish goats when CP increased from 8 percent to 16 percent in an otherwise iso-caloric diets (Jia et al., 1995). Differences in dietary CP levels in the present experiments were not as pronounced as those reported in these studies. Differences between studies may also have been due to the protein-to-energy ratio, as diets in the present experiments were not designed to be iso-caloric.

Conclusions

Goats responded with a consistent increase in ADG and dressing percentage to improved forage quality (alfalfa hay) in their diet. The marked differences in ADG between the hay types, regardless of level of concentrate supplementation, indicated the importance of high-quality forage in efficient meat-goat production. Results demonstrated that castration can be used as an effective tool to manipulate the fat content of goat carcasses and altered the composition of retail cuts in the carcass.

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Western Snowberry Response to Fire and Goat Browsing[1,2]

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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 western snowberry response to fire and browsing by goats. The study was conducted from 2002 through 2006 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 established on burned (fall 2001) and unburned (>30 years) sites and grazed by goats for three to five days in late June. Western snowberry foliar cover, plant height, stem density and seed production were measured each year. Annual goat browsing in late June reduced western snowberry plant height and seed production in burned and unburned sites, but did not change foliar cover. Fire also reduced plant height and seed production. Stem density remained unchanged after four years of annual goat browsing or five years post fire and was unchanged in controls. Reducing nuisance, resprouting, woody species, such as western snowberry, in grasslands is difficult, but annual goat browsing and/or combination with frequent fire (<4 years) can alter canopy structure and seed production.

Key words: Browse, Goats, Prescribed Fire, Weeds, Woody Plants

Introduction

Western snowberry (*Symphoricarpos occidentalis* Hook.) is widely distributed from Ontario to western Provinces in Canada, south to northern Missouri and west through Okalahoma, New Mexico, Utah and Washington in the United States (Johnson and Larson, 1999; Pelton, 1953). Pastureland and native prairie in the eastern Great Plains can be invaded by western snowberry, a perennial woody shrub with an expansive root system that forms dense colonies up to 200 m in diameter (Pelton, 1953). High density western snowberry infestations can severely limit grass understory growth by reducing nitrogen availability (Wilson, 2000). Weaver and Fitzpatrick (1934) found that Kentucky bluegrass (*Poa pratensis L.*) was one of the last species to die out under its canopy. Reports of local, high-density infestations, as a result of cattle not being effective in controlling western snowberry, gave rise to suggested alternative control strategies, such as the use of herbicides, mowing or browsing (Bailey et al., 1990). Our observations from the Oak Lake Field Station in eastern South Dakota and others elsewhere (Aldous, 1934; Anderson and Bailey, 1979; Fitzgerald and Bailey, 1984; Pelton, 1953) have shown that western snowberry readily resprouts after mowing or prescribed burning.

The use 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 by grazing of some unwanted woody species an attractive alternative (Magadlela et al., 1995). Cattle have generally not been effective in reducing western snowberry stem density (Bailey et al., 1990; Fitzgerald and Bailey, 1984). Goat browsing 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). Previous research has shown that goats will readily browse western snowberry (Smart et al., 2006). However, research is lacking on the combined effects of prescribed burning and goat browsing on western snowberry in the tallgrass prairie. The objective of this study was to evaluate the effects of fire and goat browsing on western snowberry cover, plant height, stem density and seed production.

Materials and Methods

Study site

The study was conducted from 2002 through 2006 at the South Dakota State University Oak Lake Field Station (230 ha), 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, 2006). Soils are of the Buse-Laghei complex (Fine-loamy, mixed udic calciborolls). Dominant vegetation is composed of cool-season grasses, such as Kentucky bluegrass, 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 minor amounts of thistle species (*Cirsium* spp.). In September 2001, a prescribed burn was conducted on upland prairie sites infested with western snowberry. The Oak Lake Field Station generally uses a fire return interval of two to four years as part of their prairie management strategy. Plots established on unburned sites had not been burned for > 30 years.

Experimental design

In April 2002, five experimental paddocks, 89 m^2, were established on upland prairie sites infested with western snowberry. Two paddocks were allotted to sites that were unburned and three paddocks were allotted to the sites that were burned the previous fall. Fifteen mature 'Spanish' female goats weighing approximately 45 kg each were randomly assigned to the five paddocks, three goats in each paddock. Paddocks were constructed using two 5 m cattle panels on each side. Browsing was conducted for three to five days in late June of 2002, 2003, 2004 and 2005 at the time of flowering. The browsing period was based on an appropriate stocking rate that would achieve approximately 50 percent utilization of herbaceous and current years' growth of woody vegetation. Removal of goats from experimental paddocks was contingent on visual inspection of the targeted utilization. Prior to the allotment of experimental paddocks, goats were pastured where they had access to grass and brush vegetation. Stocking rate ranged from 4.5 to 5.6 animal unit months (AUM) ha^{-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). Three control plots, 25 m^2, were established on each site adjacent to experimental paddocks. The experimental design was a completely randomized design with pasture considered the experimental unit. The treatment design was a 2 x 2 factorial with two sites (unburned vs burned) and two browsing treatments (browse vs control).

Vegetation measurements

Foliar cover of western snowberry 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 paddock before each grazing period. Visual estimates were made by a single observer each year. 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. Stem density of western snowberry was estimated by counting the number of living stems in each quadrat. Cover of western snowberry plants with seed set was visually estimated in October 2002 and October 2003 using the same procedure to estimate foliar cover.

Statistical analysis

The analyses were computed using PROC MIXED (SAS, 2006) with site and treatment as a 2 x 2 factorial and

Table 1. Western snowberry cover, height, and stem density followed by standard deviations in parenthesis measured in late June 2002 prior to goat browsing at the Oak Lake Field Station near Astoria, SD.

Site	Treatment	Cover	Height	Stem density
		--- % ---	--- cm ---	--- No. m^{-2} ---
Unburn	Browse	29 (2.7)	54 (10.7)	62 (7.2)
Unburn	Control	21 (2.8)	47 (4.1)	37 (8.6)
Burn	Browse	12 (5.5)	29 (1.5)	37 (17.1)
Burn	Control	12 (5.7)	34 (1.7)	33 (17.1)

years as a repeated measure. Western snowberry cover, height, and stem density means were calculated for each site and treatment by year and were standardized by subtracting the means calculated in 2002 (Table 1). The autoregressive 1 model (SAS, 2006) was used to adequately account for error correlation among years for western snowberry cover, height, and stem density. Percentage cover of western snowberry plants with seed means were calculated for site and treatment in 2002 and 2003. The compound symmetry model (SAS, 2006) was used to adequately account for error correlation among years. Least squares means were separated using the PDIFF option (SAS, 2006) and considered statistically significant at the 0.10 probability level.

Results and Discussion

Cover

Goat browsing or no browsing (control) in late June 2002, 2003, 2004 and 2005 on sites differing in burn history, unburned (>30 years) or burned (fall 2001), resulted in no significant differences (*P* = 0.902) in western snowberry cover. There was a significant (*P* = 0.006) quadratic response in cover between years (Fig. 1) which indicates that climatic influences (Table 2) are important drivers in foliar cover expression. Since western snowberry is a cool-season shrub, cool temperatures and above normal precipitation would favor leaf and twig growth in May and June. This was the case in 2003 and 2004 compared with 2005 and 2006 (Table 2) and is consistent with foliar cover responses in Figure 1. Similar cover resulting from browsing in the burned and unburned sites may be related to stimulated changes in canopy structure (stem density, plant height, and stem branching). Pelton (1953) described the age distribution of stems from two western snowberry colonies in Minnesota that were recently burned (<6 years) and unburned (>13 years). The recently burned colony had a high proportion of stems that were > 4 years old, while the unburned colony had a skewed distribution of younger stems to fewer, older stems up to 13 years old (Pelton, 1953). We observed older western snowberry plants from the unburned sites to have leaf foliage concentrated in the upper branches of the plant. Perhaps, goats stimulated "leafing out" from buds lower in the canopy by their browsing of the upper portions. Xu (1998) demonstrated this effect through moderate and heavy clipping of planeleaf willow (Salix planifolia var. planifolia Prush), which produced more leaf and twig biomass than unclipped or lightly clipped plants.

Plant height

Western snowberry plant height was inconsistent over years between site and treatment as indicated by a significant (*P* = 0.099) year x site x treatment interaction (Fig. 2). Western snowberry plant height in burned-control plots linearly increased (*P* = 0.086) over years compared to annual goat browsing, which maintained a lower plant height (Fig. 2A). The opposite occurred in the unburned site, where plant height in control plots remained unchanged compared to a significant linear decrease (*P* = 0.045) in the browsed plots (Fig. 2B). This was most likely a result of the older, unburned-controls being at a long-term equilibrium, since it had not been disturbed for >30 years compared to the burned-controls (Fig. 2C). Goat browsing reduced plant height in unburned sites because they removed the upper portion of the plant canopy, while in the burned sites, stems were younger and actively recovering from the 2001 fire (Fig. 2D). Our results (Fig. 2A) support observations by Pelton (1953) and Anderson and Bailey (1979) that western snowberry plant height returns to control levels after a few years following a disturbance, such as burning. Pelton (1953) observed an average stem height of 75 cm for 20 locations in Minnesota, which ranged from 40 to 110 cm. Our sites tended to be closer to 40 cm (Table 1). In Canada, Bailey et al. (1990) reported after five seasons of cattle grazing in early to mid-June, plant height was reduced by 30 cm in grazed treatments. Their greater reduction (30 cm vs 11 cm in our study) could be related to larger grazing animals (cattle vs goats) causing more trampling and stem breakage at similar stocking rates.

Figure 1. Western snowberry cover difference from 2002 with standard errors bars averaged across site and treatment for 2003-2006 (*P* = 0.005) at the Oak Lake Field Station near Astoria, SD.

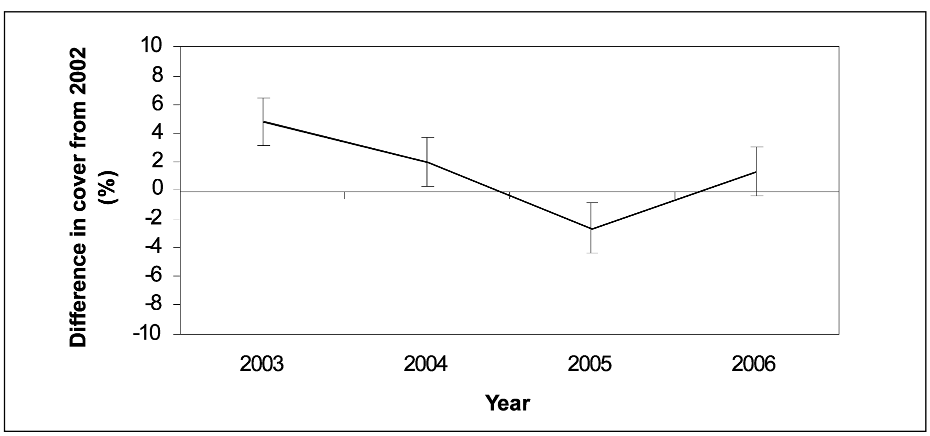


Table 2. Mean monthly temperature (°C) and total monthly precipitation (mm) for the Oak Lake Field Station during April through August 2003-2006 (USDC, 2006).

	Year				
Month	2003	2004	2005	2006	30-yr mean
		Mean Monthly Temperature			
		°C			
Apr	8	8	9	9	7
May	12	12	12	14	14
Jun	17	16	20	19	19
Jul	21	20	22	23	22
Aug	22	17	20	21	20
Sep	14	17	18	13	15
		Precipitation			
		mm			
Apr	38	40	44	73	68
May	124	162	125	53	92
Jun	85	109	160	60	109
Jul	80	65	76	4	99
Aug	27	58	66	177	85
Sep	105	125	208	153	53
Annual	492	635	833	572	685

Stem density

Stem density of western snowberry was inconsistent over years between site and treatment as indicated by a significant (*P*=0.047) year x site x treatment interaction (Fig. 3). Changes in stem density between the browse and control treatments in burned sites were consistent and not significant over time (Fig. 3A), while the browse and control treatments in the unburned sites often had opposite responses or inconsistent changes in magnitude in stem density over years (Fig. 3B). In the absence of goat browsing, the stem density was significantly greater in unburned than in burned sites (Fig. 3C) and most likely was related to the difference in past disturbance history (years since last fire). After four years with goat browsing, with or without recent burning, stem density was higher in the unburned sites compared to the burned sites (Fig. 3D). Several researchers have demonstrated that western snowberry stems are easily killed by fire but that it resprouts readily (Anderson and Bailey, 1979, Anderson and Bailey, 1980; Pelton, 1953). In addition, the stem density after a single fire usually increases two to three times that of controls (Anderson and Bailey, 1979; Pelton, 1953). In our study, we were not able to assess the direct difference between stem density prior to the burn and one year after the burn. However, the unburned control sites had a higher stem density over time (Fig. 3C) than the burned control sites which indicates that the burn indirectly had a negative impact on stem recruitment.

Seed production

Goat browsing reduced the cover of western snowberry plants with seed similarly between burned and unburned sites, whereas the control in the unburned sites had twice ($P < 0.01$) the cover of plants with seed than the control in the burn sites (Fig. 4). Burning in fall 2001 killed the stems and in spring of 2002 the height of new stems was significantly less than the unburned sites (Fig. 3B). Therefore, the difference in seed production was probably caused by a reallocation of carbohydrates toward stem development at the expense of seed production in the burned sites. Our data supports the direct relationship between plant height and the number of fruits per stem discovered by Pelton (1953). Browsing was successful in reducing seed production because the grazing period was at the time when western snowberry

Figure 2. Western snowberry plant height difference from 2002 with standard error bars for year x site x treatment interaction ($P = 0.099$); A) comparison of control and browse treatments in the burned sites , B) comparison of control and browse treatments in the unburned sites, C) comparison of controls, and D) comparison of browsing at the Oak Lake Field Station near Astoria, SD.

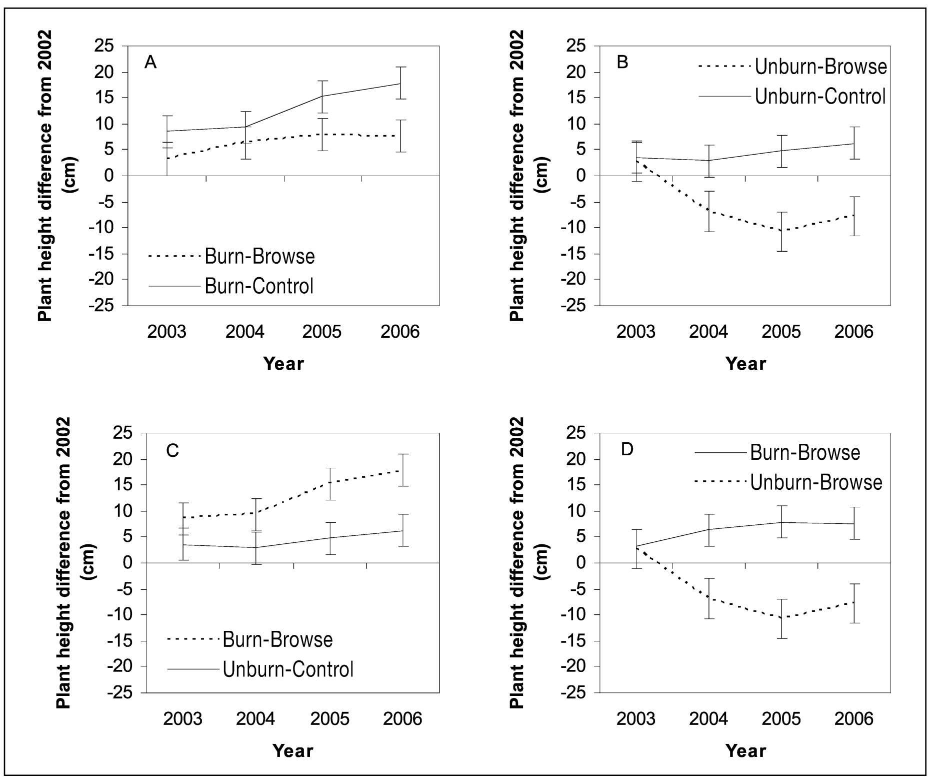
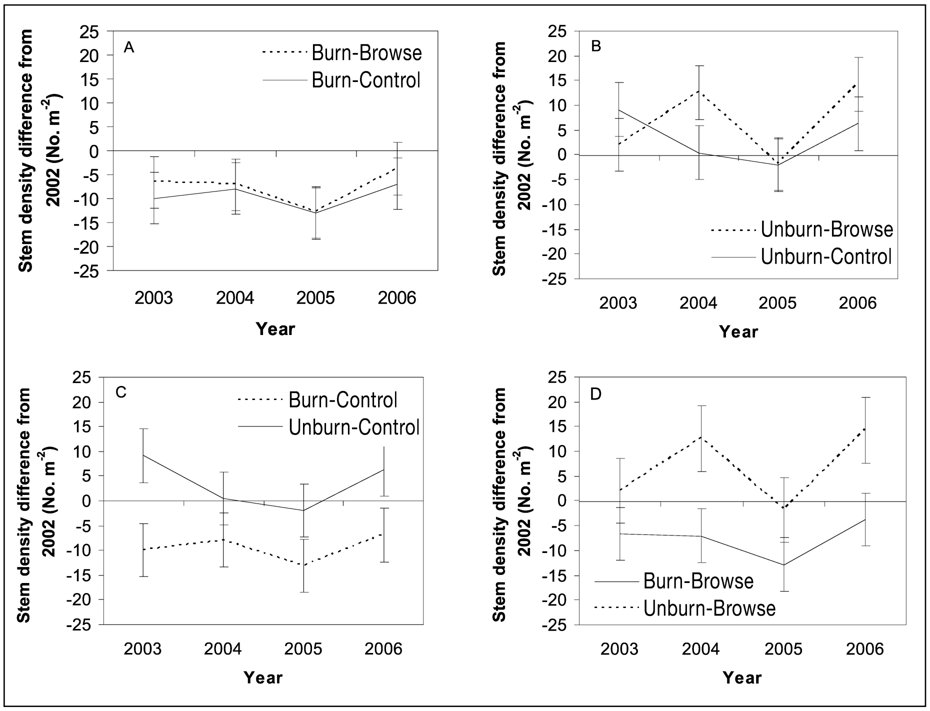


Figure 3. Western snowberry stem density difference from 2002 with standard error bars for year x site x treatment interaction ($P = 0.047$); A) comparison of control and browse treatments in the burned sites, B) comparison of control and browse treatments in the unburned sites, C) comparison of controls, and D) comparison of browsing at the Oak Lake Field Station near Astoria, SD.



was flowering and regrowth after browsing was directed toward its leaf canopy. The significance of stopping seed development probably has little direct influence on new recruitment of plants within the colony as vegetative propagation is its primary way of sustaining stem density and foliar cover (Pelton, 1953). However, stopping seed production would prevent the spread of seed by wildlife to uninfested areas.

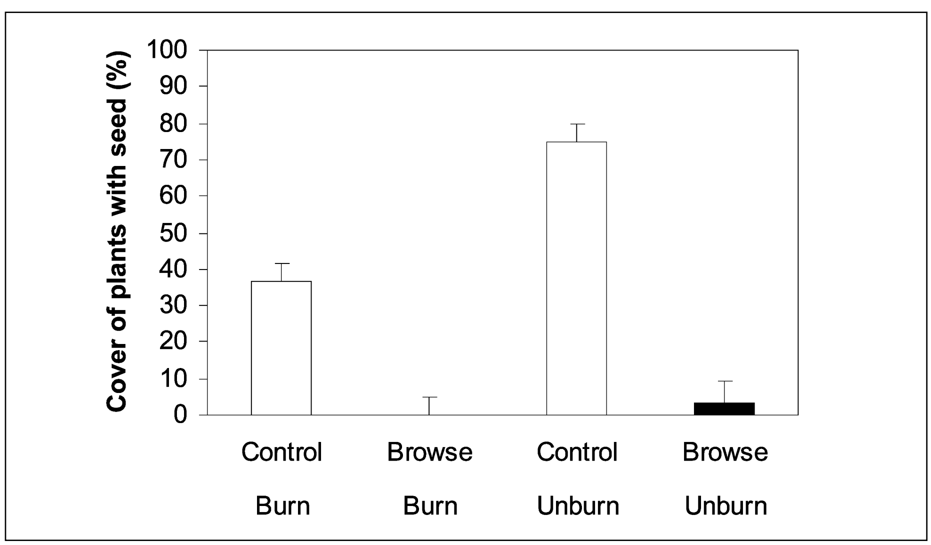
Historical perspective

In the early 1830s, explorer Joseph Nicolet documented that this region had abundant grazers, such as Bison (*Bison Bison*) and Elk (*Cervus canadensis*) and browsers, such as mule deer (*Odocoileus hemionus*), white tailed deer (*Odocoileus virginianus*) and Pronghorn (*Antilocapra americana*) (Bray and Bray, 1993). Coupled with abundant and diverse herbivores, Native Americans used burning to alter their environment to enhance the vegetation for food, basketry, weapons and wildlife manipulation (Anderson, 2005; Higgins, 1986). Since the time of settlement, fire in the northern tallgrass prairie has been suppressed and wildlife populations of browse species such as mule deer and pronghorn are virtually nonexistent. In addition, there is general consensus that western snowberry increases under overgrazing (Pelton 1953). Our data supports that reintroducing a disturbance (fire or browsing) can alter canopy structure (cover, height, density) of western snowberry. Without a disturbance, older western snowberry colonies reach an equilibrium characterized by taller, denser structure. We contend that historically (prior to European settlement) western snowberry colonies in the northern tallgrass prairie would have resembled a more shorter, less dense canopy structure like the burned-browsed paddocks.

Conclusions

Annual goat browsing in late June reduced western snowberry plant height and seed production, but resulted in no change in foliar cover. Stem density was altered by fire and browsing, with lower density reported in burned-browsed sites. Fire also reduced the plant height and seed production. Anderson and Bailey (1980) demonstrated that annual burning severely reduced western snowberry canopy cover and biomass but minimally reduced stem density. Older western snowberry colonies, such as those in our unburned sites, have not burned because of lack of adequate fuel loading to carry a fire. Pretreatments, such as mowing or other disturbance to open up the canopy, may be necessary. We conclude that single browsing events during the growing season were enough of a disturbance to reduce western snowberry plant height and seed production. Stem density was reduced by a combination of fire and grazing, however single grazing events alone actually stimulated western snowberry stem density in infested grasslands.

Figure 4. Cover of western snowberry plants with seed and standard error bars for site x treatment interaction ($P = 0.013$) averaged over fall 2002 and 2003 at the Oak Lake Field Station near Astoria, SD.



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Superovulation in Sheep: Number and Weight of the Corpora Lutea and Serum Progesterone[1,2]

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Summary

To determine similarities and differences between non-superovulated and superovulated ewe models, data collected from several experiments (1989 through 2005) were analyzed. Mature non-pregnant non-superovulated (n = 91) or superovulated (n = 299) Western range-type ewes were used for evaluation of luteal function. To induce superovulation, ewes were injected twice daily with FSH on days 13 to 15 of the estrous cycle. At corpora lutea (CL) collection on day 5 or 10 of the estrous cycle, the number of CL was determined. For selected ewes, the CL were weighed and blood samples were collected for determination of progesterone (P4) concentration in serum. Each year, a similar ($P > 0.1$) number of ovulations/ewe was induced by FSH treatment (range from 12.4 ± 2.0 to 20 ± 2.5/year). Superovulated ewes had greater ($P < 0.001$) number of CL than non-superovulated ewes (16.2 ± 0.5 vs. 1.9 ± 0.1). Weight of CL on day 5 of the estrous cycle was similar for superovulated and non-superovulated ewes (252.2 ± 4.1 vs. 224.7 ± 15.6 mg/CL), but on day 10, weight of CL from superovulated ewes was less ($P < 0.05$) than from non-superovulated ewes (379.9 ± 4.0 vs. 598.7 ± 18.5 mg/CL). Luteal tissue mass per ewe was greater ($P < 0.001$) for superovulated than non-superovulated ewes on days 5 (3.7 ± 0.4 vs. 0.5 ± 0.1 g) and 10 (6.1 ± 0.5 vs. 1.2 ± 0.1 g) of the estrous cycle. Serum P4 concentration on day 5 of the estrous cycle did not differ statistically ($P > 0.1$) for superovulated vs. non-superovulated ewes (2.3 ± 1.1 vs. 1.3 ± 0.1 ng/ml), but on day 10 tended to be greater ($P < 0.06$) in superovulated than non-superovulated ewes (5.8 ± 1.3 vs. 3.8 ± 0.3 ng/ml). When P4 concentration in serum was expressed per g of luteal tissue mass, values were similar for non-superovulated and superovulated ewes on days 5 and 10 of the estrous cycle. Moreover, all P4 values were greater ($P < 0.05$) on day 10 than on day 5 of the estrous cycle. Thus, despite some differences in CL number and CL weight, the major function of the CL, P4 production does not seem to be altered in superovulated ewes compared with non-superovulated ewes. Therefore, these data indicate that our superovulated ewe model may be used for studies of luteal function.

Keywords: Superovulation, Corpora Lutea, Serum Progesterone, Ewe

Introduction

Assisted reproduction technologies (ART) have been used in agriculture for many decades to increase reproductive potential of domestic farm animals (Gordon, 1997, 2005; Grazul-Bilska, 2004). In sheep, use of these techniques can help enhance reproductive efficiency (Cognie et al., 2003). Superovulation protocols allow one to take advantage of the relatively short gestation length of sheep and utilize the ewe to her fullest potential (Gordon, 1997; Gonzales-Bulnes et al., 2004).

Superovulation was developed approximately 55 years ago and has been implemented in sheep research and production (Driancourt and Fry, 1992; Gordon, 1997, 2005). Treatment with FSH or pregnant mare serum gonadotropin (PMSG) causes multiple follicles to develop followed by ovulation and creation of multiple corpora lutea (CL). Thus, the superovulated ewe had 5 to 27 CL (Stormshak et al., 1963; Hild-Petito et al., 1987; Jablonka-Shariff et al., 1993; Gonzales-Bulnes et al., 2004), and peripheral progesterone (P4) concentration was greater in superovulated than non-superovulated ewes (Stormshak et al., 1963; McClellan et al., 1975). However, morphology of CL was similar for superovulated and non-superovulated ewes (McClellan et al., 1975; Hild-Petito et al., 1987). Furthermore, superovulation did not affect circulating P4 concentration when expressed per mg of luteal tissue, basal P4 secretion by small and large luteal cells, and P4 concentration in luteal tissues (Stormshak et al., 1963; Hild-Petito et al., 1987). Hild-Petito et al. (1987) also demonstrated that small luteal cells differ in size and responsiveness to LH in superovulated compared to non-superovulated ewes. Our study was designed to further determine similarities and differences of CL development and function in superovulated vs. nonsuperovulated ewe models, and to provide additional information about these two models.

The aims of this study were to determine the number and weight of CL and serum P4 concentration in superovulated vs. non-superovulated ewes across several years.

Materials and Methods

Animal Treatment and Tissue Collection

The Institutional Animal Care and Use Committee at NDSU approved all animal procedures in this study. From 1988 to 2005 mature, non-pregnant, Western range-type ewes (n = 390) of mixed breeds (predominantly Targhee x Rambouillet) were used for several experiments during breeding season (September through January) to evaluate luteal function. A portion of ewes was non-superovulated (n = 91), and a portion of ewes was superovulated (n = 299). To induce superovulation, ewes were injected twice daily (morning and evening) with FSH-P (FSH with 10 percent luteinizing hormone) purchased from Schering (Kenilworth, NJ; 1989 through 1994; n = 128 ewes) or Sioux Biochemical (Sioux Center, IA; 1996 through 2005; n = 171 ewes) on days 13 (5 units/injection, day 0 = estrus), 14 (4 units/injection) and 15 (3 units/injection) of the estrous cycle (total dose = 24 units) to induce superovulation (Grazul-Bilska et al., 1991, 2001). Standing estrus (day 0 of the estrous cycle) was determined by using vasectomized rams. Ewes were fed a ration of mixed forage and cracked corn which was designed to meet the nutritional requirement for non-pregnant ewes (NRC, 1985), and had free access to a salt-mineral mixture and to water.

At CL collection on days 5 or 10 of the estrous cycle, each CL was dissected from ovarian tissues separately, and number of CL was determined for all non-superovulated (n = 91) and superovulated (n = 299) ewes. Individual CL were weighed for a portion of non-superovulated (n = 86) and superovulated (n = 87) ewes. Blood samples were collected for selected non-superovulated (n = 24) and superovulated (n = 15) ewes on days 5 and 10 of the estrous cycle to determine serum P4 concentration.

Progesterone RIA

Progesterone concentrations in extracted serum were measured as previously reported (Jablonka-Shariff et al., 1993; Vonnahme et al., 2006). Sensitivity of the assay was 12.5 pg/tube. The intra- and inter-assay coefficients of variation ranged from 3.4 percent to 6.4 percent, and from 7.1 percent to 12.6 percent, respectively.

Statistical Analysis

Data were analyzed using the general linear model (GLM) procedure of SAS (SAS, 2006), and presented as means ± SEM throughout the manuscript. When the F-test was significant ($P < 0.05$), differences between specific means were evaluated by using least significant differences test (Kirk, 1982).

Results

From 1989 to 2005, similar ($P > 0.1$) number of ovulations/ewe, measured by the CL number, was induced using both FSH preparations (Figure 1). Source of FSH did not affect number and weight of CL. A similar number of ovulations ($P > 0.1$) was

Figure 1. Mean number of FSH-induced ovulations/ewe, measured by the number of CL, from 1989 to 2005 (number in each bar indicates the number of superovulated ewes in a specific year).

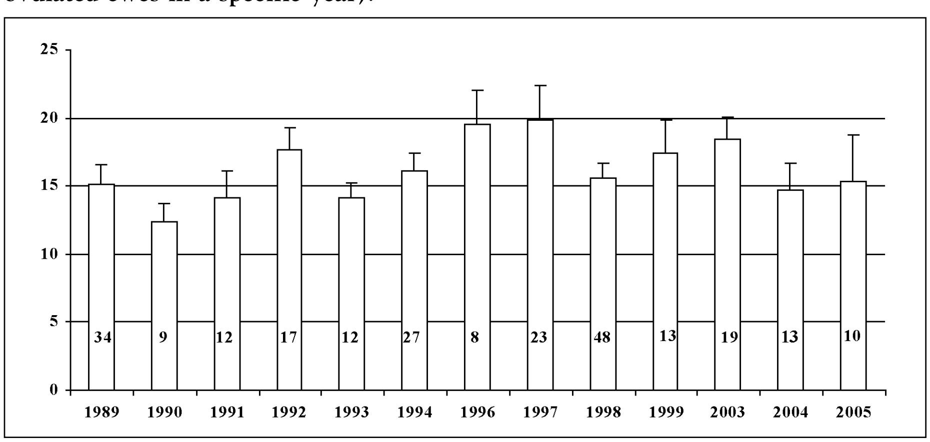


Table 1. The effects of superovulation on number and weight of the CL on days 5 and 10 of the estrous cycle.

	Non-superovulated	Superovulated
Number of CL	1.9 ± 0.1[a] (n = 91 ewes)	16.2 ± 0.5[b] (n = 245 ewes)
Weight of individual CL (mg)		
Day 5	224.7 ± 15.6 (n = 39 CL)	252.2 ± 4.1 (n = 443 CL)
Day 10*	598.7 ± 18.5[c] (n = 123 CL)	379.9 ± 4.0[d] (n = 936 CL)
Luteal tissue mass/ewe (g)**		
Day 5	0.46 ± 0.06[a] (n = 24 ewes)	3.74 ± 0.37[b] (n = 29 ewes)
Day 10*	1.20 ± 0.05[a] (n = 62 ewes)	6.12 ± 0.49[b] (n = 58 ewes)

[a,b] $P < 0.001$; [c,d] $P < 0.05$; means ± SEM with different superscripts differ within a row.
* $P < 0.05$; means ± SEM for CL weight and luteal tissue mass on day 10 are greater than on day 5 of the estrous cycle within a column.
** Luteal tissue mass is a sum of weight of all CL from individual ewe.

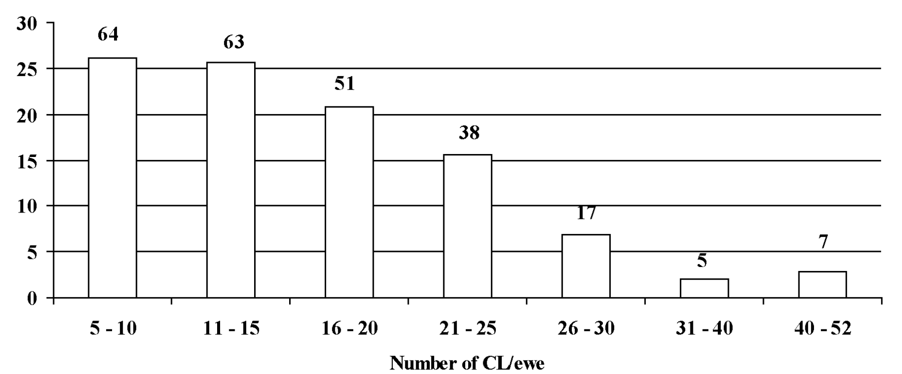
achieved when sheep were treated with FSH-P from Schering or Sioux Biochemical (15.3 ± 0.7 and 16.9 ± 0.8 CL per ewe, respectively). Therefore, data for these two FSH preparations were combined for further analysis.

The number of CL and the weight of each CL for non-superovulated and superovulated ewes on days 5 and 10 of the estrous cycle are presented in Table 1. The number of CL per ewe was greater ($P < 0.001$) in superovulated ewes than non-superovulated ewes (Table 1). The percentage of non-superovulated ewes with 1, 2, 3 or 4 CL was 30 percent (n = 27), 56 percent (n = 51), 9 percent (n = 8), and 5.5 percent (n = 5), respectively. The number of CL for superovulated ewes which responded to FSH-treatment (n = 245), ranged from 5 to 52/ewe; 88 percent of ewes had 5 to 25 CL, and 12 percent had 26 to 52 CL (Figure 2). On day 5 of the estrous cycle, the weight of the individual CL was similar for non-superovulated and superovulated ewes. But on day 10, individual CL weight from the non-superovulated ewes was greater ($P < 0.05$) than from the superovulated ewes (Table 1). Total luteal tissue weight per ewe was greater ($P < 0.001$) for superovulated than non-superovulated ewes on days 5 and 10 of the estrous cycle (Table 1). The individual CL weight and total luteal tissue weight per ewe were greater on day 10 than on day 5 of the estrous cycle for both non-superovulated and superovulated ewes (Table 1).

Serum P4 concentrations, and P4 secretion expressed per g of luteal tissue mass in non-superovulated and superovulated ewes is presented in Table 2. Serum P4 concentrations were similar for non-superovulated and superovulated ewes on day 5 of the estrous cycle. However, on day 10 of the estrous cycle, serum P4 concentration tended to be greater ($P < 0.06$) in superovulated than non-superovulated ewes (Table 2). When P4 secretion was expressed per g of total luteal tissue mass per ewe, P4 values were similar for non-superovulated and superovulated ewes on days 5 and 10 of the estrous cycle. In addition, all P4 values were greater on day 10 than on day 5 of the estrous cycle for both non-superovulated and superovulated ewes.

A proportion of ewes (overall 18.1 percent; n = 54) did not respond to FSH induction of superovulation, which was manifested by the presence of one to four CL after FSH treatment. During years 1988 to 1994 (when FSH-P from Schering was used) and during years 1995 to 2005 (when FSH-P from Sioux Biochemical was used) lack of superovulatory response to FSH treatment was similar ($P > 0.1$) between these two FSH preparations (13.2 percent ± 2.8 percent and 19.5 percent ± 3.1 percent, respectively).

Figure 2. Percentage of superovulated ewes (n = 245) with multiple CL (number above bar indicates number of sheep).



Discussion

Our study demonstrated no differences in number of CL in response to superovulation treatment with FSH from two different sources/preparations. Furthermore, the response to superovulatory treatment was consistent throughout 17 years of FSH application in our research program. Thus, these FSH preparations were equally active for induction of superovulation. The purified FSH preparation is optimal when it includes less than 10 percent LH (Donaldson, 1991; Boscos et al., 2002) because the ratio of FSH:LH is critical for the development of preovulatory follicle and ovulation (Donaldson, 1991; Senger, 2003; D'Alessandro et al., 2005). Therefore, in this study we used the FSH preparations containing less than 10 percent LH.

In this study, the number of CL ranged from one to four (average 1.9) and from to 5 to 52 (average 16.2) for non-superovulated and superovulated ewes, respectively. Similar average numbers of CL per superovulated ewe were

Table 2. The effects of superovulation on progesterone (P4) concentration in serum (ng/ml) on days 5 (n = 12 for non-superovulated and n = 5 for superovulated) and 10 (n = 12 for non-superovulated and n = 10 for superovulated) of the estrous cycle.

		Non-superovulated	Superovulated
P4 (ng/ml)			
	Day 5	1.28 ± 0.13	2.32 ± 1.06
	Day10**	3.82 ± 0.33 [a]	5.75 ± 1.26 [b]
P4 (per g of luteal tissue)*	Day 5	0.22 ± 0.02	0.27 ± 0.05
	Day 10**	0.68 ± 0.04	0.87 ± 0.26

* Calculated by dividing P4 concentration in serum by luteal tissue mass per ewe.
** $P < 0.001$; means ± SEM for P4 values on day 10 are greater than on day 5 of the estrous cycle within a column.
[a,b] $P < 0.06$; means ± SEM with different superscripts differ within a row.

reported in other studies using a multiple FSH-treatment protocol (Stormshak at al., 1963; Amiridis et al., 2002; Ammoun et al., 2006; Mossa et al., 2006; Veiga-Lopez et al., 2006). However, when lower doses of FSH (e.g., 2.5 to 10 units), or one injection of FSH or PMSG were used, number of CL varied from one to six (Boscos et al., 2002; Riesenberg et al., 2001; Hild-Petito et al., 1987). Thus, number of CL after induced superovulation depends on dose and type of hormone used (e.g., FSH or PMSG); frequency of treatment; and also time of treatment related to the stage of the estrous cycle. Furthermore several factors, including variations in follicular (e.g., number of follicular waves or follicle sizes) and hormonal (e.g., level of peripheral pituitary and ovarian hormones) dynamics in individual ewes, may contribute to variability in the CL number/ewe after FSH treatment (Driancourt, 2001; Riesenberg et al., 2001; Amiridis et al., 2002; Cognie et al., 2003; Gonzales-Bulnes et al., 2004). However, this subject requires additional study.

In the present study, the weight of individual CL and serum P4 concentration in superovulated ewes were similar to non-superovulated ewes on day 5 of the estrous cycle. However, on day 10 of the estrous cycle, CL weight was less in superovulated than non-superovulated ewes, but serum P4 concentration was greater in superovulated than non-superovulated ewes. Similar CL weight for non-superovulated and superovulated ewes on day 10 of the estrous cycle, but greater serum P4 concentrations in superovulated than non-superovulated ewes has been demonstrated by Hild-Petito et al. (1987). In contrast, Stormshak et al. (1963) reported lower CL weight of individual CL in superovulated compared to non-superovulated ewes throughout the estrous cycle. These discrepancies in CL weight and P4 concentration are likely due to the different superovulation protocol used in these studies. In fact, superovulation was induced using PMSG followed by hCG treatment by Hild-Petito et al. (1987) but using multiple injections of ovine pituitary extract followed by hCG treatment by Stormshak et al. (1963). Thus, superovulation protocols may affect not only the number of CL, but also weight of CL.

On day 5 of the estrous cycle, the CL is still rapidly growing and differentiating (Jablonka-Shariff et al., 1993), therefore, differences in CL weight or serum P4 concentrations could not be observed during the early luteal phase for non-superovulated and superovulated ewe models. By day 10, when the CL reaches its fully functional and differentiated stage, differences in weight and serum P4 concentrations for non-superovulated and superovulated ewes were observed. Thus, as compared to non-superovulated ewes, when multiple CL (i.e., more than four) are developing in superovulated ewes, growth seems to be limited, and they fail to achieve their typical weight. Furthermore, it seems that because there are more CL on the superovulated ovary that they had less room to grow and consequently grew smaller to approximately 0.6x of the size of individual CL found on non-superovulated ovaries. Additionally, reduced luteal weights on day 10 of the estrous cycle in superovulated ewes is likely associated with control of luteal function by LH (Niswender and Nett, 1994). Since greater luteal tissue mass can produce more P4, as observed in our and other studies (Amiridis et al., 2002) in superovulated ewes, P4 through negative feedback may inhibit LH secretion, which in turn may limit growth of the CL. However, this concept requires further investigation.

When P4 secretion was expressed per g of luteal tissue mass, P4 values were similar for superovulated and non-superovulated ewes on days 5 and 10 of the estrous cycle. Similar observations were reported by Hild-Petito et al. (1987) for the CL from day 10 of the estrous cycle. Furthermore, Stormshak et al. (1963) demonstrated that luteal P4 concentration was similar for superovulated and non-superovulated ewes. Thus, total luteal tissues in superovulated ewes secrete amounts of P4 similar to non-superovulated ewes, which is likely due to tight control by LH. Furthermore, it has been demonstrated that CL structure and luteal function measured by P4 secretion and *in vitro* unresponsiveness of large luteal cells to LH and dbcAMP treatment were similar for non-superovulated and superovulated ewes (McClellan et al., 1975; Hild-Petito et al., 1987). We have also demonstrated in several studies, that luteal cells from superovulated ewes responded to LH or dbcAMP stimulation by increasing P4 secretion in vitro (Grazul-Bilska et al., 1991, 1995, 1996). However, the mean cell diameter and LH stimulation of P4 secretion by small luteal cells differed between superovulated and non-superovulated ewes (Hild-Petito et al., 1987). Therefore, these data indicate that despite some differences, function of CL reflected by P4 secretion in superovulated ewes is similar to function of CL in non-superovulated ewes.

Several other studies demonstrated that peripheral P4 concentrations were enhanced in superovulated ewes during several stages of the estrous cycle (Stormshak et al., 1963; McClellan et al., 1975; Hild-Petito et al., 1987; Amiridis et al., 2002). Furthermore, Amiridis et al.

(2002) showed a positive relationship between number of CL and serum P4 levels on day 5 of the estrous cycle. In our study, positive correlations were also observed between P4 secretion and CL number and luteal tissue mass for combined data for days 5 and 10 of the estrous cycle. This clearly demonstrates that the amount of P4 circulating in the blood is relative to the total luteal tissue mass. However, as discussed above, secretion of P4 is likely limited by LH and possibly other factors in superovulated ewes.

In this study, approximately 18 percent of ewes did not respond to the FSH treatment as indicated by presence of only one to four CL. In agreement with our data, Cognie (1999) reported that about 20 percent of ewes did not respond to superovulatory treatment. It has been hypothesized that a lack of superovulatory response to FSH by some ewes is due to a heterogeneity in the morphological features of the ovulatory follicles or to the number of small antral follicles present in the ovaries when FSH treatment was initiated (Draincourt, 2001; Cognie et al., 2003). Also season, breed, and nutritional treatments may all contribute to the variability of responsiveness to FSH treatments (Cognie, 1999). Future studies should be undertaken to determine why a relatively large proportion of ewes does not respond to the FSH-treatment.

Summary

In summary, this study demonstrated that 1) a consistent number of ovulations measured by the number of CL was induced across 17 years of using the FSH treatment; 2) the number of CL was greater in superovulated than non-superovulated ewes; 3) weight of individual CL was similar on day 5 but less on day 10 in superovulated than non-superovulated ewes; 4) serum P4 concentration was similar on day 5 but greater on day 10 in superovulated than non-superovulated ewes; 5) P4 secretion expressed per g of luteal tissue mass was similar on days 5 and 10 for superovulated and non-superovulated ewes, and 6) 18 percent of ewes did not respond to FSH treatment in our superovulation protocol. Thus, variation in number of CL and weights of luteal tissue between non-superovulated and superovulated ewes did not significantly affect P4 secretion when expressed per g of luteal tissue mass. Therefore, this superovulated ewe model is a reasonable model for the study of luteal function and is also helpful for generating larger amounts of luteal tissue per animal for use in complex studies of the CL function.

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Cash Versus Contract Marketing in the U.S. Lamb Industry[1]

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Summary

Lamb operations in the United States are experiencing unfavorable market conditions, such as declining breeding inventories, stagnant domestic lamb consumption, and increasing competition from imported lamb. To more effectively compete, some operations may turn to nontraditional marketing arrangements, such as use of contracts, to purchase and sell lambs. To determine the extent of alternative marketing arrangements (AMAs) use in the U.S. lamb industry, we conducted a nationally representative mail survey of lamb producers and feeders. We received 302 completed surveys (53 percent weighted response rate). The survey collected information on purchases, sales and pricing methods, reasons why operations use their choice of marketing arrangements, and operation characteristics. We compared small and large operations, as well as Eastern and Western U.S. operations. Primarily U.S. lamb operations use cash-marketing methods to purchase and sell lambs. However, there appears to be a slight trend away from auction markets toward other types of cash-market transactions, such as direct trade. Large operations are more likely to use AMAs than small operations. Likewise, Western U.S. operations are more likely than Eastern operations to use AMAs. Large operations use AMAs to reduce risk, while small operations use AMAs to sell their lambs at higher prices.

Key Words: Alternative Marketing Arrangements, Contract, Lambs, Sales

Introduction

The U.S. lamb industry faces many challenges, including decreasing inventories of breeding sheep, stagnant domestic lamb consumption levels, and increasing competition from imported lamb (USDA/National Agricultural Statistics Service (NASS), various years; USDA/Economic Research Service (ERS), 2006). From 1970 through 2004, breeding sheep and ewe inventories declined from 31 million sheep to 8 million sheep. Between 1990 and 2004, annual domestic lamb consumption fell from 1.4 pounds to 1.1 pounds per person (USDA/ERS, 2006), while lamb imports increased from 40.7 million pounds to 180.9 million pounds.

To overcome these challenges, the industry will have to adapt to changing market conditions. One such adaptation might be in the use of nontraditional marketing arrangements to purchase and sell lambs. Muth et al. (2005) suggested that contracts offer advantages to both lamb producers and packers by offering incentives for higher-quality meat. Williams and Davis (1998) further contend that contracts allow packers to operate near capacity and help stabilize inventories.

Types of Marketing Arrangements Used in the Lamb Industry

Lamb producers (or lambing operations) have three options for marketing lambs—selling feeder lambs to feedlots, retaining ownership through contract feeding, or feeding feeder lambs and selling the fed lambs directly to packers for slaughter (Bastian and Whipple, 1998). Lamb feeders, in turn, purchase lambs from lamb producers and sell fed lambs to packers.

Marketing arrangements are the methods by which lambs are transferred through successive stages of production and marketing. There are two categories of marketing arrangements: cash (or spot) and alternative. In this paper, cash- or spot-market transactions refer to transactions that occur immediately or "on the spot." These include auction barn sales; video or electronic-auction sales; sales through order buyers, dealers, and brokers; and direct trade. The terms "cash market" and "spot market" are used interchangeably, and might also be referred to as "traditional" marketing. Alternative-marketing arrangements (AMAs) are all possible alternatives to the cash or spot market. In the lamb industry, these include arrangements such as forward contracts, marketing agreements, packer owned, custom feeding, and custom slaughter. Forward contracts and marketing agreements generally use some type of formal contracts for the agreement and are the most commonly used AMAs for purchasing and selling lambs. As described by Brester et al. (2007), the types of AMAs are as follows:

- Forward contract: Oral or written agreement between a buyer (packer) and seller for future purchase of a specified quantity of lambs at either a fixed or base price more than two weeks before delivery or kill date.
- Marketing agreement: An ongoing, long-term oral or written agreement between a buyer and seller, where the buyer agrees to purchase lambs under specific terms.
- Packer owned: Lambs are owned by the packer and fed for slaughter at either a custom feedlot or a packer-owned or packer-controlled feedlot (or company-owned farms).
- Custom feeding: Providing feeding services for a fee (lambs are owned by producer or by a packer).
- Custom slaughter: Providing slaughter services for a fee (lambs are owned by producer or feeder).

The key dimensions of marketing arrangements include the ownership method for lambs (i.e., sole ownership, shared ownership, or owned by another entity) and the type of pricing and valuation methods. The pricing method provides additional information about transactions by specifying how the price was determined (e.g., individual negotiations or formula pricing). If formula pricing is used, a base price used in the formula must be specified. In the case of packer ownership or other types of transfers within a company, an internal transfer pricing method is used. The valuation method further defines the transaction type by indicating how the price was applied (per head, per-pound live weight, or per-pound carcass weight). Carcass-weight valuation might be based on a grid that offers premiums or discounts based on weight range and carcass quality grade.

Purpose

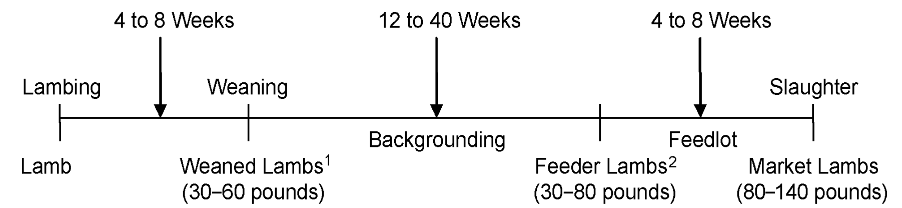
The purpose of this study was to compare use of cash-marketing methods with AMAs in the lamb industry. In this paper, we describe methods used by lamb operations in the United States to sell market-fed lambs through both traditional (i.e., cash) and alternative (i.e., contract) marketing arrangements. We also describe the reasons why operations use their choice of marketing arrangements. Finally, we discuss implications of using AMAs in the lamb industry.

Although AMAs can be used at any stage of the marketing chain, we focus our analysis on the feeder lamb production and feeding stage. To provide a better understanding of how lambs are marketed, we first provide a brief summary of lamb production.

U.S. Lamb Industry Background

The specific stages of slaughter lamb production in the United States include feeder-lamb production, backgrounding, feeding, packing, and processing or breaking (i.e., cutting carcasses into primal, subprimal, and other meat cuts). In some cases, all of these stages are distinct production stages. However, production, backgrounding, and feeding are often combined at the livestock-production stage, and packing and breaking are often combined at the meat-production stage. Most sheep can only be bred during specific times of the year, so the majority of lambs are born in the spring. Newborn lambs will remain with ewes for four to eight weeks before they are weaned (Figure 1). After weaning, lambs can be sent directly to a feedlot, or they may be backgrounded to increase body mass and then sent to a feedlot for finishing. Most lambs in the United States are grain-fed, leading to a milder flavor of meat (American Lamb Board, 2007). The weight of finished market lambs varies, but the average live weight is 135 pounds. Lambs sold for consumption in ethnic markets are lighter, with the average live weight ranging from 60 to 80 pounds. Finished lambs are sent to a packer for slaughter, where they are inspected and usually quality graded by USDA. The production stages have remained relatively unchanged over time, but an increase in vertical integration within the industry has prompted several stages to be per-

Figure 1. Lamb production timeline. Lamb production time varies depending on the type of meat desired.



[1] Lambs sold for slaughter after weaning are sometimes referred to as milkfat lambs.
[2] Some feeder lambs are sold for slaughter after being backgrounded and are referred to as market lambs.

formed by a single entity or producer-owned cooperative (Boland et al., 2007).

Lamb production occurs in all 50 states; however, flock sizes vary significantly by geographic location. Large flocks are typically located in the western part of the United States, where large tracts of land are available for grazing. In 2002, there were 6.68 million sheep raised on slightly more than 64,000 operations (USDA/NASS, Various years). As with lamb producers, lamb packers are located throughout the country. However, most facilities are located strategically near lamb feeders, consumers, or both. The amount of meat produced per animal slaughtered has increased steadily. Between 1990 and 2003, the average live weight of federally inspected slaughter lambs and sheep increased by 10 pounds. During the same period, average lamb carcass weight increased from 64 pounds to 68 pounds (USDA/ERS, 2006). About 70 percent of the carcass weight is saleable cuts, with fat and bones making up 30 percent (Boland et al., 2007).

Materials and Methods

To collect data on lamb operations' use of marketing methods, we administered a national, voluntary survey of lamb producers and feeders. The survey was administered by mail, with initial and follow-up contacts made by telephone to encourage response. Additional detail regarding questionnaire development, sampling procedures, survey administration, and data analysis follows.

Questionnaire Development

The questionnaire was designed to collect information on the use of different types of purchasing methods, sales methods, and pricing methods for lambs; terms of purchase and sales methods (e.g., contract length); reasons for using the cash market or alternative purchase and sales methods; and operation characteristics (e.g., number of employees, annual sales). In addition, we asked respondents to indicate how their marketing practices have changed during the past three years and their expectations for how they may change over the next three years. The questionnaire was pretested and reviewed. Our pretest procedures included a review of the survey instrument using a standardized instrument review methodology and telephone interviews with five lamb producers and feeders. The draft survey instrument was reviewed by peer reviewers and Grain Inspection, Packers, and Stockyards Administration staff. The survey instrument was subsequently revised based on those reviews.

Sampling Methods

We used the most current Dun & Bradstreet (D&B) database to construct the survey sampling frame for lamb producers and feeders. The D&B database provides detailed financial and other information for businesses in the United States. The initial sampling frame included operations with a primary Standard Industrial Classification code of 0214, "sheep and goats," and the following subcategory codes: sheep, lamb feedlot, sheep-feeding farm, and sheep-raising farm. We excluded operations without reported revenue or number of employees from the sampling frame because our previous experience using the D&B database suggests that most such business units are not currently operating. We stratified the sample by size, using annual revenue as the size criterion, so that we could report results by size of operation.

We took a census of the 80 largest operations (annual revenue greater than $200,000) and a sample of operations from the remaining population (small operations with annual revenue less than or equal to $200,000). The sample design specified a sample size that was expected to yield precision of +/- 5 percent or better for estimates of all proportions.

Based on the total population of 1,267 lamb producers and feeders in the D&B database, the starting sample size was 727 operations (647 small operations with annual revenue less than or equal to $200,000 and 80 large operations with annual revenue greater than $200,000). The eligibility rate for small operations was lower than anticipated; many operations were no longer in business or did not produce lambs. Thus, we drew and used a reserve sample of 129 small operations to have a final sample size of 776 small operations and 80 large operations.

Survey Administration

We conducted the full-scale data collection from November 2005 to February 2006. To maximize the response rate, we used a multimodal survey approach, incorporating many of the procedures recommended by Dillman (2000). We contacted sampled business units by telephone to screen for eligibility and to identify the target respondent, mailed the self-administered questionnaire to target respondents via Federal Express, mailed a reminder postcard, and made a series of telephone calls to nonrespondents to encourage participation. During the data collection period, we operated a toll-free survey help line and email address that respondents could contact to request assistance when completing the questionnaire.

We received 302 completed surveys; 120 operations were eligible but did not complete the survey (i.e., nonrespondents); 215 operations were ineligible (e.g., operations that were out of business or did not produce or feed lambs); and for 219 operations we were unable to determine their eligibility for the survey. We calculated response rates (respondents / [nonrespondents + respondents]) by size strata using the initial sampling weights adjusted for unknown eligibility so that cases with unknown eligibility were distributed between eligibles (nonrespondents) and ineligibles in the same proportions that existed among cases with known eligibility. Ineligible operations were excluded from response rate calculations. The response rate was 58 percent for large operations and 53 percent for small operations.

Data Analysis

The preparation of survey data sets involved developing survey weights, data editing, data preparation, and data coding. We developed all statistical estimates by applying appropriate survey weights that reflect the number of eligible operations. To do this, we computed initial sampling weights by size stratum, calculated adjustment factors by size stratum for unknown eligibility, and calculated poststratification adjustment factors by weighting class to compensate for nonresponse. Nonresponse adjustments ensure that, within each weighting class, respondent weights sum to the population counts of eligible operations. These adjustments can help reduce nonresponse bias to the extent that respondents within weighting classes are homogeneous (Lohr, 1999).

Questionnaires were edited to resolve data errors prior to data entry. The edited questionnaires were double keyed (i.e., 100 percent verification) into a database for quality control purposes. To resolve item nonresponse errors, we used logical imputation for some questions to assign a value to a missing response item based on responses to other questions.

While the study was national in scope, we did consider regional differences. We analyzed use of sales methods, pricing methods, and valuation methods by geographic location, comparing Eastern versus Western states. Western states included Alaska, Arkansas, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Louisiana, Minnesota, Missouri, Montana, North Dakota, Nebraska, New Mexico, Nevada, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. All other states were classified as Eastern states.

All analyses were conducted using SAS, a statistical analysis software tool that takes sample design into consideration when computing variances (SAS, version 9.1). We computed weighted proportions for questions in which respondents could select one or more responses from a list of responses, and computed weighted means for questions that required a numeric response from respondents. In addition to the point estimates for means or proportions, we also calculated interval estimates (i.e., the 95 percent lower and upper confidence intervals [CIs]). To determine whether differences in estimated weighted means and proportions were statistically significant, we calculated *P*-values using the Student *t* distribution.

Results and Discussion

Of the 302 operations that completed surveys, 267 were small operations and 35 were large operations. Because few operations purchased lambs, we primarily focus our discussion on methods for selling lambs.

Operation Characteristics

As shown in Table 1, most operations identified themselves as lamb pro-

Table 1. Characteristics of lamb producer and feeding operations.

Question	Weighted percentage of operations	Lower bound of 95% CI[1]	Upper bound of 95% CI
Type of operation[2]			
Producer	93.6	90.8	96.4
Feeder or feedlot	22.3	17.5	27.0
Other (wool producer, seedstock producer)	4.8	0.0	2.8
Total gross sales for lambs during past year			
Less than $99,999	85.8	82.4	89.2
$100,000 to $499,999	9.8	6.8	12.9
$500,000 or more	4.3	0.3	2.5
Total gross sales for all farm outputs during past year			
Less than $99,999	78.7	74.5	82.9
$100,000 to $499,999	12.3	8.5	16.0
$500,000 or more	9.0	2.7	6.4
Age of owner[3]			
Less than 45	6.8	3.0	8.6
46 to 55	26.1	20.8	31.4
56 to 65	31.2	25.6	36.8
Older than 65	35.9	30.1	41.7
Education level of owner[3]			
Less than high school graduate	3.7	1.4	6.0
High school graduate/GED	18.1	13.4	22.8
Some college or technical school/no degree	29.4	23.9	35.0
College graduate	32.6	26.9	38.2
Postgraduate	16.2	11.7	20.7

[1] CI = confidence interval.
[2] Respondents could select multiple responses.
[3] For respondents in which the owner completed the survey.

ducers (i.e., lambing operations) (94 percent), while fewer operations identified themselves as lamb feeder or feedlot operations (22 percent). Thus, some lamb producers also have feeding operations. The mean area of a lamb operation encompasses 11,239 acres. Although the mean area is quite large, the average operation only employs three full-time employees, two part-time employees, and three seasonal employees. Eighty-six percent of operations reported annual gross lamb sales of less than $99,999, and 96 percent had total annual gross lamb sales of less than $499,999.

For most operations, the owner completed the questionnaire (92 percent). Of these, almost all respondents are more than 45 years of age and nearly one-half have a college degree (Table 1). About half of their annual household income is derived from off-farm sources, so many lamb producers rely on other sources of income.

For operations that reported having lambs in inventory on January 1, 2005, the mean inventory level was 962 lambs (Table 2). However, two-thirds of operations had fewer than 100 lambs, and 17 percent had 500 or more lambs. Most lambs are born in the spring, thus inventory levels on January 1 were likely at a relatively low level for the calendar year. Inventory levels of ewes and rams were much lower than for lambs, with mean levels of 479 and 16, respectively. Ewe and ram inventories declined by 53 percent from 1990 to 2005 (USDA/NASS, various years), although this may be partly the result of increased breeding herd efficiency (Brester et al., 2007).

The majority of lamb operations can be characterized as independent businesses that do not participate in alliances or certification programs. Less than 13 percent of lamb operations participate in certification programs that certify livestock breed, carcass, or meat characteristics. Eleven percent of lamb operations participate in some type of alliance, defined as a relationship formed by two or more industry participants to meet common production or marketing objectives and to improve information flows.

Table 2. Inventory of U.S. lamb operations as of January 1, 2005[1].

Question	Weighted mean	Weighted percentage of operations	Lower bound of 95% CI[2]	Upper bound of 95% CI
Lamb inventory				
1–99	962.3			
100–499		66.5	60.3	72.6
500–1,999		16.5	11.3	21.6
2,000–9,999		7.7	4.2	11.3
10,000 or more		7.1	4.3	9.9
		2.2	0.4	4.1
Ewe inventory				
1–99	478.7			
100–499		64.8	59.3	70.2
500–1,999		18.7	14.1	23.4
2,000 or more		9.4	6.0	12.8
		7.1	5.2	9.0
Ram inventory				
1–99	15.6			
100–499		95.6	93.8	97.4
500 or more		4.4	2.6	6.2
		0.0	NA[3]	NA

[1] Lamb inventories are highest in the spring, after the new crop is born. Thus, inventory levels on January 1 are likely at their lowest levels.
[2] CI = confidence interval.
[3] NA = Not applicable.

Lamb Purchase Methods

Relatively few of the operations surveyed purchased lambs. This is because most respondents are lambing operations or feeders that self-produce their feeder lambs or only custom feed. Operations that purchase lambs bought an average of 10,368 lambs during the past year, but more than half of these operations purchased fewer than 500 lambs (Table 3). Cash market transactions dominated lamb purchases. For 83 percent of the operations that received lambs, all lambs received were through cash market transactions. During the past year, 49 percent of lamb purchases were through direct trade, 22 percent through auctions, and 13 percent through dealers/brokers (data not shown). The remaining purchases were through an AMA. Specifically, 5 percent were delivered for custom feeding, 7 percent of purchases were through forward contracts or marketing agreements, and 4 percent were purchased using other methods. While overall use of the cash market has remained constant over the past few years, the prevalence of specific arrangements is changing slightly. Over time, use of auctions decreased slightly compared with 3 years ago, while direct trade increased. The most frequently cited pricing methods were individually negotiated pricing and public auction. Only 8 percent of lambs were purchased under a written agreement. Because the number of lamb operations that use AMAs for purchasing lambs is very small, we cannot characterize their reasons for using them based on the survey responses.

Lamb Sales Methods[5]

Operations that sold feeder lambs sold an average of 561 feeder lambs

[5] The data collected in this study cannot be compared to Mandatory Price Reporting data that were collected by USDA's Agricultural Marketing Service under the Livestock Mandatory Reporting Act of 1999. Under Mandatory Price Reporting, data are only collected from lamb packers that annually process more than 75,000 lambs (i.e., the six largest lamb packers), whereas our study sampled small and large operations. Furthermore, the level of detail collected and the aggregation of data differ between the two sets of data.

Table 3. Quantities of lamb purchased and sold by lamb producer and feeder operations.

Question	Weighted mean	Weighted percentage of operations	Lower bound of 95% CI[1]	Upper bound of 95% CI
Number of lambs received or purchased during past year	10,368.4			
1–99				
100–499		42.4	24.4	60.3
500–1,999		13.5	0.6	26.3
2,000–9,999		14.1	1.5	26.6
10,000 or more		12.1	0.0	24.2
		18.0	5.1	31.0
Number of feeder lambs sold or shipped during past year	561.4			
1–99		58.0	49.4	66.6
100–499		23.1	15.4	30.9
500–1,999		9.9	4.8	15.0
2,000 or more		9.0	5.1	12.8
Number of slaughter lambs (less than 105 pounds liveweight) sold or shipped during past year	137.3			
1–99		80.9	73.8	88.0
100–499		14.8	8.1	21.4
500–9,999		4.4	0.9	7.8
10,000 or more		0.0	NA[2]	NA
Number of slaughter lambs (105 pounds liveweight or more) sold or shipped during past year	2,217.9			
1–99		67.4	60.1	74.6
100–499		12.7	7.3	18.1
500–1,999		8.4	4.1	12.8
2,000–9,999		8.3	4.2	12.4
10,000 or more		3.3	0.6	5.9

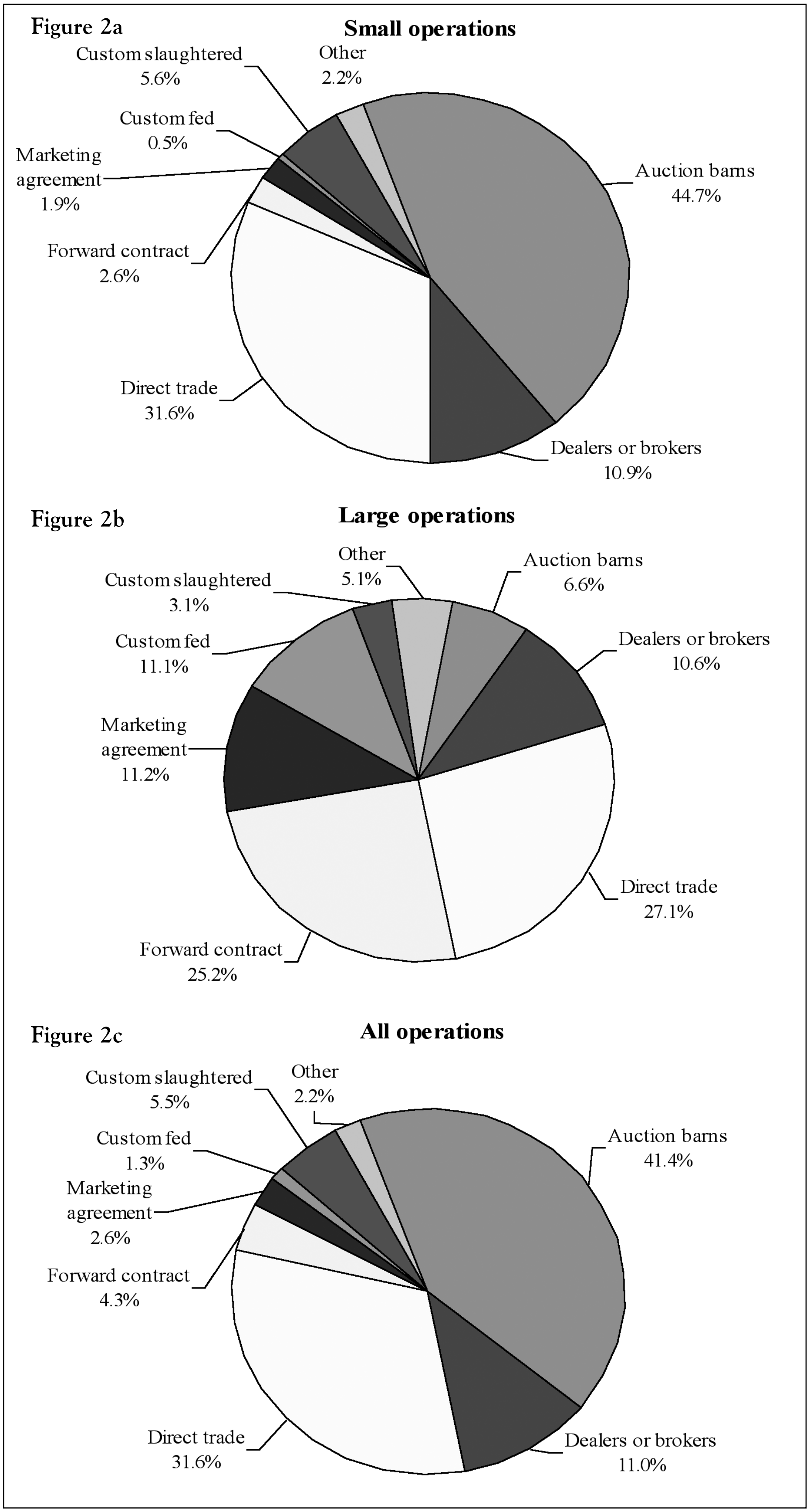
[1] CI = confidence interval.
[2] NA = Not applicable.

(Table 3). Operations that sold slaughter lambs sold an average of 137 lambs weighing less than 105 pounds live weight, and 2,218 slaughter lambs weighing 105 pounds or more. Almost 70 percent of operations sold fewer than 100 slaughter lambs weighing at least 105 pounds during the past year. Thus, the majority of lamb operations is small and primarily sells slaughter lambs.

Approximately 41 percent of sales were through auction markets, 31 percent through direct trade, and 11 percent through a dealer or broker (Figure 2). About 15 percent of lambs were sold or shipped through some type of AMA; specifically, 4 percent of lambs were sold using forward contracts, 3 percent using marketing agreements, and less than 1 percent using packer fed/owned or internal transfer. One percent of lambs were custom fed and 5 percent were custom slaughtered. Thus, most lambs were sold through cash market transactions (auction barns, dealers/brokers, and direct trade), with small operations (87 percent of lambs sold) having a much greater reliance on the cash market compared with large operations (44 percent of lambs sold) ($P < 0.0000$). Nearly 81 percent of small operations and 36 percent of large operations sold all their lambs through cash market transactions during the past year ($P < 0.0000$). Eastern and Western operations had similar usage of the cash market, with 80 percent and 76 percent using only the cash market, respectively. More than half of lambs sold by Eastern operations were sold using auctions, whereas direct trade and auctions both accounted for about one-third of lambs sold by Western operations. AMAs are slightly more popular among Western operations than Eastern operations (18 percent of lambs sold versus 10 percent, respectively). The survey collected information on respondents' expected use of cash markets versus AMAs over time (three years ago compared with three years in the future). The use of auctions appears to be on a slight decline, while the use of direct trade and forward contracts is increasing slightly. Overall, use of AMAs is expected to increase by 2 percent over the next three years.

Two pricing methods dominate lamb sales: public auction bids (57 percent of operations) and individually negotiated pricing (51 percent) (Table 4). Responses to the survey indicate that, in three years, public auctions and individual negotiations will continue to dominate, but the use of auctions is expected to decrease slightly while use of individual negotiations is expected to increase. Producers identified an average of four auctions operating within a 200-mile radius of their locations, which has essentially remained unchanged over the past three years. The majority of auctions closest to their operations have sales at least weekly. As shown in Table 4, small operations (60 percent) were more likely than large operations (15 percent) to use public auction bids to determine prices for lambs ($P < 0.0000$). Large operations primarily used individually negotiated pricing (61 percent), followed by formula pricing (21

Figure 2. Methods used for selling or shipping lambs (weighted mean, percentage of head). Small operations are more likely to use the cash market, while large operations are more likely to use alternative marketing arrangements.



percent).[6] For operations using formula pricing with a grid, most prices were based on an average price paid by packers for lambs (39 percent). USDA-reported prices, retail prices, and other market prices also were used as bases for formula pricing. The top three pricing methods used by both Eastern and Western operations were individually negotiated pricing, public auction bids, and formula pricing. However, 72 percent of Eastern operations used public auction bids compared with 47 percent of Western operations.

For operations that sell slaughter lambs, the most frequently cited valuation method for both small and large operations was live weight valuation, as detailed in Table 4. Respondents expected similar use of each valuation method in three years. However, more than one-half of large operations sold lambs on a carcass weight basis with grid pricing, compared with only 5 percent of small operations ($P = 0.0027$). In comparing valuation methods among regions, Western operations used carcass weight valuation (with and without a grid) more frequently than Eastern operations (32 percent and 11 percent of operations, respectively). Nearly twice as many Eastern operations (31 percent) used per-head valuation compared with Western operations (17 percent) in the past year ($P = 0.0461$).

For more than one-half of lambs sold during the past year, the seller reported paying transportation costs (Table 4). Small operations paid to transport more of their lambs compared with large operations (54 percent versus 32 percent of transactions) ($P = 0.0176$). Less than 7 percent of all lambs were sold under a written agreement, although this was much higher for large operations (25 percent of transactions) compared with small operations (5 percent of transactions) ($P = 0.0225$). For lambs sold under a preexisting agreement, the agreement was typically less than six months. Most deliveries (66 percent) under agreement occurred within seven days, and 16 percent were delivered within eight to fourteen days. Large operations scheduled deliveries farther in advance than did small operations.

[6] Respondents could indicate multiple pricing methods used; thus, totals sum to more than 100 percent.

Table 4. Use of and terms of sales methods for lamb operations, by size.

Question	Small	Large	All
Pricing methods used for selling lambs during the past year (weighted percentage of operations)[1]			
Individually negotiated pricing	50.6	60.6	51.3
Public auction	60.2	15.2**	57.1
Sealed bid	2.3	9.1	2.8
Formula pricing	7.7	21.2†	8.7
Internal transfer	0.4	6.1	0.8
Custom fed	1.5	18.2*	2.7
Custom slaughtered	12.0	9.1	11.8
Other	2.0	3.0	2.0
Valuation methods used for selling slaughter lambs during the past year (weighted percentage of operations)[1]			
Per head	24.6	13.3	23.9
Liveweight	76.1	53.3	74.7
Carcass weight, not dependent on grid value	13.4	26.7	14.3
Carcass weight, dependent on grid value	4.5	53.3**	7.5
Lambs sold during the past year in which the seller paid for transportation (weighted mean, percentage of head)	54.2	32.3*	52.4
Lambs sold during the past year under a written agreement (weighted mean, percentage of head)	5.1	24.8*	6.8
Length of agreement or contract (oral or written) for lambs sold during the past year (weighted mean, percentage of head)			
Sales not under agreement or contract	86.8	37.5**	82.6
Less than 6 months	7.9	43.2**	10.9
6 to 11 months	3.4	2.6	3.3
1 to 2 years	0.6	0.0	0.6
3 to 5 years	0.6	12.0†	1.6
6 to 10 years	0.0	0.0	0.0
More than 10 years or evergreen	0.6	4.7	1.0
Lead time of delivery order for lambs sold during the past year (weighted mean, percentage of head)			
Less than 7 days	68.7	33.4*	65.6
8 to 14 days	16.4	16.4	16.4
15 to 21 days	2.5	9.5	3.1
22 to 30 days	6.6	8.4	6.7
1 to 2 months	4.2	11.6	4.8
More than 2 months	1.7	20.7*	3.4

[1] Respondents could select multiple responses.
** Difference between large and small operations is statistically significant at the 0.01 level.
* Difference between large and small operations is statistically significant at the 0.05 level.
† Difference between large and small operations is statistically significant at the 0.10 level.

Reasons for Use of Traditional versus Alternative Sales Methods

The survey collected information on lamb operations' top three reasons for using traditional or alternative marketing arrangements to sell lambs. Table 5 shows reasons why operations used only cash market transactions to sell their lambs, and Table 6 shows reasons why operations used AMAs to sell their lambs. Interestingly, operations using only the cash market and those using AMAs both identified selling lambs at higher prices as a reason for using their respective methods. This may indicate that operations in each category are making optimal choices based on their own operations and local markets and thus receive higher prices by using their best option.

Greater independence, selling at higher prices, and reduced cost of selling were the three most cited reasons for using only the cash market. Small and large operations had similar reasons for only using the cash market for selling lambs. For both small and large operations, the most frequently cited reason was that the cash market "allows for independence, complete control, and flexibility of own business," although more large operations cited this reason than small operations ($P = 0.432$). Many large operations also expressed that the cash market enhances their ability to benefit from favorable market conditions.

Operations that sell lambs through AMAs believe that they can sell at higher prices, secure a buyer, and reduce risk exposure. Additionally, more than one-third of operations feel that using AMAs allows them to sell higher-quality lambs. Small and large operations had somewhat different reasons for using AMAs for selling lambs. Large operations were more concerned about reducing risk, while small operations were more interested in selling at higher prices. Seventy-two percent of small operations versus 53 percent of large operations mainly used AMAs to sell lambs at higher prices. Sixty-five percent of large operations versus 32 percent of small operations mainly used AMAs to reduce risk exposure.

Table 5. Lamb operations' reasons for only using cash market for sales, by size[1] (weighted percentage of operations).

Reason	Small	Large	All
Allows for independence, complete control, and flexibility of own business	59.8	84.6**	60.7
Can sell lambs at higher prices	44.2	46.2	44.3
Reduces costs of activities for selling lambs	33.7	23.1	33.3
Enhances ability to benefit from favorable market conditions	32.2	46.2	32.7
Does not require identifying and recruiting long-term contracting partners	16.6	15.4	16.5
Does not require managing complex and costly contracts	16.1	23.1	16.3
Allows for adjusting operations quickly in response to changes in market conditions	15.1	38.5	15.9
Reduces risk exposure	15.1	15.4	15.1
Allows for sale of higher-quality lambs	14.1	0.0**	13.5
Facilitates or increases market access	11.6	0.0**	11.1

[1] Respondents were asked to select three reasons.
** Difference between large and small operations is statistically significant at the 0.01 level.
* Difference between large and small operations is statistically significant at the 0.05 level.

Nearly 81 percent of small operations compared with 36 percent of large operations sold all their lambs through cash market transactions during the past year. It may be more difficult for small operations to participate in AMAs because it is more costly for packers to negotiate with many small operations relative to fewer large operations. Compared with large operations, small operations are more likely to incur transportation costs, less likely to use written contracts, and more likely to schedule delivery less than two weeks ahead for lamb purchases and sales.

The cash market dominates Eastern and Western sections of the United States, with both sets of producers selling more than 80 percent of their lambs through cash methods. The use of auctions is more popular in the East, while Western operations are more likely to use both auctions and direct trade to sell lambs. Greer and Ward (2000) and Ward (2001) found similar results in their analyses of lamb sales data from 1996. Western operations use AMAs more than Eastern operations, although this may be a reflection of operation size differences between the two regions. Williams and Davis (1998) found that large-range operations, more common in the West, primarily use contracts to sell lambs, whereas smaller-flock operations, located in the East, prefer to use auctions and other cash methods.

Conclusion

The U.S. lamb industry primarily uses the cash market to purchase and sell lambs. Lamb operations believe that the cash market allows them to be independent, with complete control and flexibility over their business. Lamb operations prefer to act on their own, with few employees and little involvement in alliances or certification programs.

In procuring lambs, there appears to be a slight trend away from auction markets toward other types of cash market transactions, such as direct trade. This trend of moving away from auctions is also evident in selling lambs. Although the results are relatively minor and are not statistically significant, the survey data do show a trend that is worth noting.

Using the cash market to sell lambs was more widespread among small operations than among large operations.

Table 6. Lamb operations' reasons for using AMAs for sales, by size[1] (weighted percentage of operations).

Reason	Small	Large	All
Can sell lambs at higher prices	72.0	52.9	66.5
Secures a buyer for lambs	48.0	41.2	46.0
Reduces risk exposure	32.0	64.7*	41.4
Allows for sale of higher-quality lambs	40.0	29.4	37.0
Reduces price variability for lambs	20.0	17.6	19.3
Reduces costs of activities for selling lambs	16.0	17.6	16.5
Facilitates or increases market access	12.0	5.9	10.2

[1] 1Respondents were asked to select three reasons.
* Difference between large and small operations is statistically significant at the 0.05 level.

Lamb producers and feeders expect small increases in their use of AMAs when selling fed lambs in the future. This increase can have several implications for the industry. Operations using AMAs find that they can maintain market access, reduce risk, and get rewarded for high-quality lambs. The use of AMAs is one of the few risk-management tools available to operations, because there is no futures market for lambs. Use of marketing methods for ensuring higher- or more consistent-quality lambs may enable U.S. operations to more effectively compete with increasing foreign imports.

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Winter Grazing Systems for Gestating Ewes

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Summary

Four winter-feeding systems for gestating ewes were investigated over a 3-year period. The systems investigated were: 1) low-density corn; 2) high-density corn; 3) fescue regrowth; and 4) round-baled hay. Effects on ewe performance and winter-feed costs were determined. An average of 118 mature (3 to 7 year old) Hampshire x Dorset ewes (avg initial BW = 91.6 kg) were used each year. Each of the wintering-grazing treatments was replicated by two fields, and the hay treatment was replicated by two drylot pens. The low- and high-density corn treatments were planted to achieve densities of approximately 54,000 and 91,000 corn plants/ha, respectively. Each replicate corn field was 0.4 ha and contained 12 ewes. The stockpiled fescue treatment consisted of replicate fields of 0.8 ha, each containing 12 ewes. For the hay treatment, first-cutting fescue hay was offered free choice in replicate drylot pens of 23 ewes each. Ewes grazing low-density corn gained the most weight (10.9 kg), those grazing stockpiled fescue lost 1.8 kg and those grazing high-density corn and eating fescue hay in drylot were intermediate (7.7 and 5.9 kg, respectively; $P < 0.01$). Carrying capacity of both corn density treatments was similar. Stockpiled fescue pasture supported only 20 percent of the carrying capacity of the corn fields ($P < 0.01$). Grazing corn (both planting densities) resulted in feed costs of 19¢/d and 23¢/d for the low- and high-planting densities, respectively. Estimated costs for feeding fescue hay were 21¢/d. Grazing stockpiled fescue was lowest at 17¢/d. In conclusion, winter-grazing standing corn or stockpiled fescue were effective and economical feeding strategies to meet the nutritional needs of gestating ewes.

Key words: Ewes, Grazing, Corn, Fescue

Introduction

Feed costs represent approximately two-thirds of all production costs for a sheep enterprise (Dickerson, 1978). More than half of all feed costs are expended during the winter to provide harvested winter feed to breeding animals (Rayburn, 2000). Traditionally, producers feed hay to ewes when grass is not available. Hay is often an expensive source of feed to meet caloric requirements (Loerch, 1996). Stock-piled forage, that is set aside for winter grazing offers, some potential to reduce hay needs and reduce winter feed costs (Schoonmaker et. al., 2003). However, the availability and yield of stock-piled forages is compromised by weathering, as well as snow and ice cover. Grazing standing corn may provide an opportunity to reduce winter feed costs and meet the nutrient requirements of the flock. More than half of the energy in the corn plant is contained in the grain (NRC, 1985). Grain is less susceptible to weathering losses than forages (Schoonmaker et. al., 2003). Furthermore, corn plants have a high profile and access by grazing animals would not be restricted by snow or ice. The optimum management system for corn grazing by sheep has not been identified. Optimum grazing management, corn fertilization rates, hybrids, planting dates, and planting density are unknown. The objective of this research was to determine the effects of four winter-feeding systems on ewe performance and winter-feed costs.

Materials and Methods

This research was conducted at The Ohio State University Sheep Center at the Ohio Agric. Research and Development Center, Wooster, OH. The trial was conducted from early January to mid-March (average 72 d) in 2002, 2003, and 2004. The treatments investigated were: 1) low-density corn; 2) high-density corn; 3) fescue regrowth, and 4) round-baled hay. Each treatment had two replicates per year. An average of 118 mature (3 to 7 year old) Hampshire x Dorset ewes (avg initial BW = 91.6 kg) were used each year. Ewes were 8 d to 43 d in gestation when the experiments were initiated each year. Each of the wintering-grazing treatments was replicated by two fields, and the hay treatment was replicated by two drylot pens. The 118 ewes were randomly allotted to eight outcome groups of appropriate size, and the outcome groups were allotted to treatment replicates. The low- and high-density corn treatments were planted to achieve densities of approximately 54,000 and 91,000 corn plants/ha, respectively. Corn fields were fertilized with 68 kg of N/ha applied in two applications. Each replicate corn field was 0.4 ha, and electric fence was used to divide each field into 10 paddocks for strip-grazing. All ewes were fed a corn-silage-based diet for 14 d before the experiment began. Those randomly selected to go on corn treatments were adjusted to corn grain by feeding 0.1, 0.2, 0.3, and 0.45 kg of corn, respectively, on the four days immediately preceding turnout in the corn fields. Twelve ewes were allotted to each of the four corn replicates (48 ewes with 12 ewes per 0.4 ha corn field). Ewes grazed each paddock for 7 d to 14 d and were moved to their next paddock when all corn grain was consumed. Due to the abundance of feed in each replicate, ewes rarely required all 10 paddocks in the 0.4 ha fields to complete the 72 d trial. Amount of area actually grazed was quantified and used to calculate ewe grazing days per hectare. The stockpiled fescue treatment consisted of replicate fields of 0.8 ha each. Forage in these pastures was mob grazed the first week of August each year and forage regrowth was stock-piled for winter grazing. Each replicate was fertilized with 56 kg of N/ha the first week of August. The fescue treatments were investigated over two years (2003 and 2004). Twelve ewes were allotted to each replicate, and fields were strip grazed with the aid of electric fence. Ewes were given access to a new forage strip approximately every 7 d. For the hay treatment, first-cutting fescue hay was offered free choice in two replicate drylot pens. Each pen contained 23 ewes.

Ewes were weighed, and body condition scored initially and every 14 d during the trial. Body condition score was on a 1-to-5 scale with 1 being emaciated and 5 being obese. Fescue-pasture samples were collected in ungrazed areas at the initiation and end of the trial. The samples were obtained by use of a 61 x 61 cm metal square that was randomly tossed 6 times for each replicate. All forage within the square was hand clipped and composited. After collection, forage samples were dried, ground, and analyzed for DM, CP, NDF, and ADF (AOAC, 1996). For corn treatments, plants/ha and grain yield (kg/ha) were determined by counting the number of plants in a 730 cm distance within a row, and multiplying that number by 1000 to give plant density. Grain yield was calculated using the yield component method (Univ. of Illinois, 2005) by measuring 730 cm in 6 randomly selected rows and collecting every fifth ear to count average kernel rows and average number of kernels per row. Yield equals ear number x average row number x average kernel number divided by 90. The total kilograms of DM/ha were determined by randomly cutting, drying, and weighing 6 plants/ha in each corn replicate and multiplying by the actual plant density determined for each replicate. After collection, these corn-plant samples were ground and analyzed as described above for forage samples.

Feed costs were calculated for all four systems based on average-commodity prices and yields during the three-year trial (2002 to 2004). The kilograms of corn grain present in the corn paddocks was estimated as described above, and the grain was valued at $0.079/kg of grain at 86 percent DM. Fescue pasture was valued at $86/ha. Hay was valued at $0.088/kg and supplemental corn was priced at $0.079/kg on an as-fed basis.

Data were analyzed according to the PROC GLM procedures of SAS ver. 9.1 (SAS Institute Inc., Cary, NC). The model included the effects of treatment, year, and treatment x year. Treatment means were separated by PDIFF protected by a significant ($P < 0.05$) F-value. Each replicate was the experimental unit for all analyses.

Results and Discussion

Target corn-plant density for the low-density corn was 54,361 plants/ha. Actual density varied from 49,419 in

Table 1. Estimated plant density and corn yield of low and high planting density treatments.

Item	Low density	High density
Year 1		
Plants/ha	49,419	88,955
Year 2		
Plants/ha	56,420	110,163
kg/ha	7975	10,413
Year 3		
Plants/ha	55,597	77,010
kg/ha	6,095	6,654

Table 2. Yield and chemical composition of low and high density corn plants, fescue pasture, and fescue hay dry matter.

	Corn density			
Item	Low	High	Fescue pasture	Fescue hay
DM/ha, kg				
Initial	9,808	10,394	712	--
Final	8,118	8,519	484	--
CP, %				
Initial	7.9	8.7	14.4	10.6
Final	8.1	7.9	13.8	--
NDF, %				
Initial	51.3	56.3	69.9	72.2
Final	52.8	49.1	70.8	--
ADF, %				
Initial	22.4	24.3	37.2	40.7
Final	24.2	23.5	39.4	--

Year 1 to 56,420 plants/ha in Year 2 (Table 1). More variation was observed for the high-density-corn treatment. The target was 91,416 plants/ha, and the range observed was from 77,010 in Year 3 to 110,163 in Year 2. Germination rate or inaccurate settings on the planter may have contributed to this variation. Grain yield was not recorded in Year 1. Low-density corn had a yield of 7,975 and 6,095 kg/ha for Years 2 and 3, respectively. High-density corn had a yield of 10,413 and 6,654 kg/ha for Years 2 and 3, respectively. Lower yields in Year 3 were likely due to lack of rain in the summer of 2004. Dry-matter yield and nutrient content of corn plants, fescue pasture, and fescue hay are shown in Table 2. The corn fields (both treatments) averaged about 10,000 kg of DM/ha in January at the start of the trial. In mid-March ungrazed areas averaged about 8,294 kg of DM/ha. This difference could be attributed to weathering losses. Stockpiled fescue pastures only had 7.3 percent as much DM (712 kg DM/ha) as the cornfields initially. By mid-March, only 484 kg of DM/ha was available for grazing. Schoonmaker et. al. (2003) and Kallenbach et. al. (2003) reported herbage mass of stockpiled fescue was approximately 2,000 kg DM/ha when measured in November. Hagsten et. al. (1976) investigated supplemental-nutrient needs for ewes grazing stockpiled fescue. Estimated-forage available was not reported, and their grazing period was from December until February. These authors used a winter-stocking rate of 5 ewes/ha, whereas the fescue -stocking rate in our trial was 15 ewes/ha. In the present trial, crude-protein content of corn plants was lower than fescue pasture, while the fescue hay was intermediate. Values showed little change between early January and mid-March. This is typical of other reports for change in protein content of stockpiled fescue over time (Kallenbach et. al., 2003; Schoonmaker et. al., 2003). Protein values of corn and forages in the present trial were adequate to meet the needs of ewes in gestation (NRC, 1985). Fiber (NDF and ADF) values were lower for corn plants than for both sources of fescue (pasture and hay) and as with protein, they did not change over the course of the trial. Ewe-gain data (averaged over all three years) are presented in Table 3. Ewes grazing low-density corn gained the most weight during the 72-d trial (10.9 kg), those grazing stockpiled fescue lost weight (1.8 kg), and those grazing high-density corn or fed fescue hay in drylot were intermediate (7.7 and 5.9 kg, respectively; $P < 0.01$). We could not find reports in the literature about the efficacy of grazing unharvested corn plants as a source of winter feed for sheep or cattle. Wedin and Jordan (1961) evaluated corn plants as a source of forage for summer grazing lambs, but this was done before grain development occurred. Grazing of corn stalks after grain harvest is a common practice and represents an important strategy to reduce winter-feed costs (Hitz and Russell, 1998; Sulc and Tracy 2007).

There was a treatment x year interaction ($P < 0.05$) for body condition score change (Figure 1). In Year 1, ewes grazing low-density corn had a greater

Table 3. Effects of winter feed source on ewe body weight change.

	Corn density				
Item	Low	High	Fescue pasture	Fescue hay	SEM
Initial wt, kg	91.6	91.6	91.6	91.6	0.1
Final wt, kg	102.5^{a}	99.3^{b}	89.8^{c}	97.5^{b}	1.0
BW change, kg	10.9^{a}	7.7^{b}	-1.8^{c}	5.9^{b}	1.1

^{abc} Means with different superscripts within rows differ ($P < 0.01$).

Fig. 1 Effect of winter feeding system and year on body condition score change. Year x treatment interaction ($P < 0.05$). Bars with different superscripts differ ($P < 0.05$).

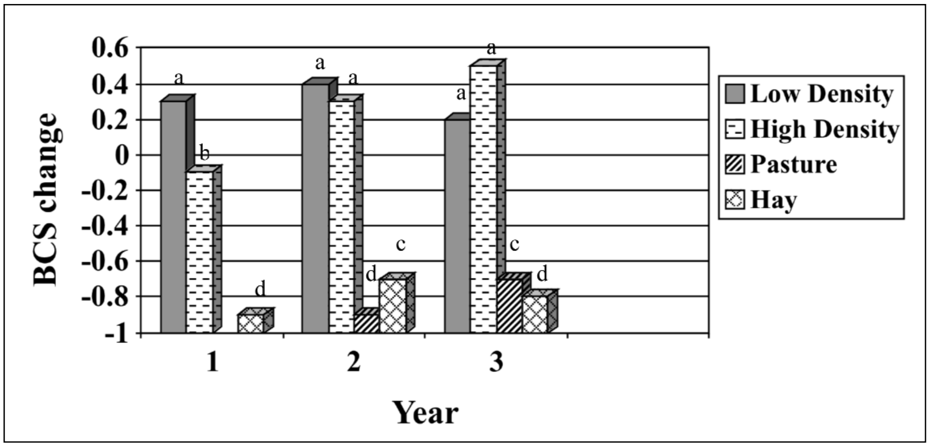
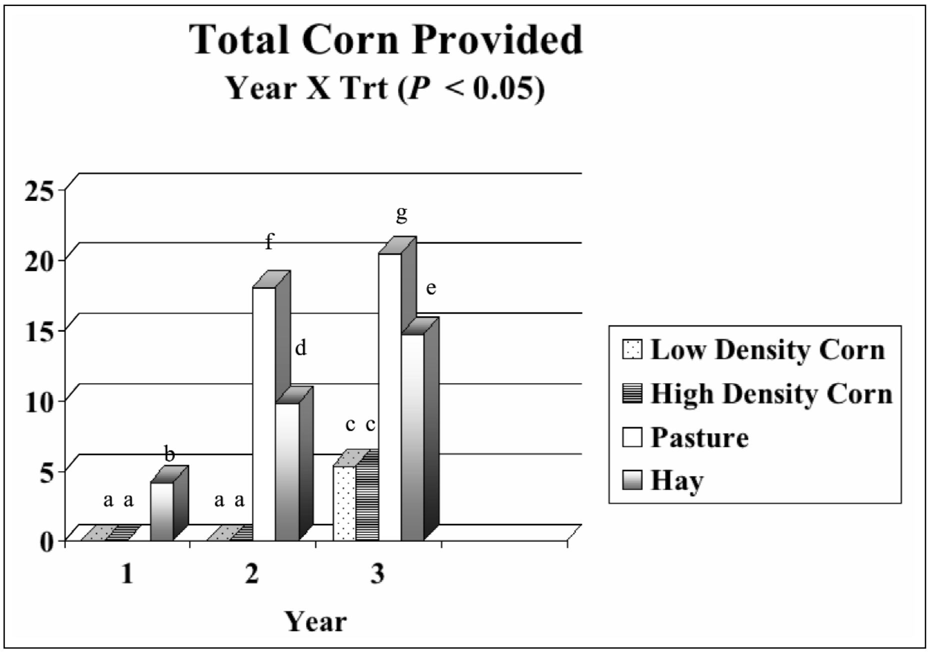


Fig. 2 Effect of winter feeding system on amount of supplemental corn DM provided per ewe during the 72-d trial. Year x treatment interaction ($P < 0.05$). Bars with different superscripts differ ($P < 0.05$).



increase in condition score than those grazing high-density corn, but in subsequent years, condition-score change was similar between corn treatments. Ewes grazing stockpiled fescue or fed fescue hay lost from 0.7 to 0.9 units of body condition (Figure 1). Emergency/supplemental corn grain was provided when deemed necessary (obvious lack of feed available or loss in body weight) and there was a treatment x year interaction ($P < 0.05$) for total supplemental corn grain provided (Figure 2). For the corn-grazing treatments, no supplemental-corn grain was provided in Years 1 or 2; a total of 5 kg of corn DM/ewe was provided in Year 3 due to adverse weather conditions. These ewes were moved to a barn for 5 days due to rain followed by a period of -17° C weather. Ewes grazing fescue pasture were supplemented with 18.1 kg to 20.4 kg of corn DM/ewe during the trial to prevent undesirable losses in weight and body condition score. Hagsten et. al. (1976) has reported the advantages of supplementing ewes grazing stockpiled-fescue pastures during late gestation with the major advantage being a reduction in winter-feed costs. In an attempt to maintain weight and body-condition score, ewes fed fescue hay in the present trial were supplemented with 4.1 kg, 9.5 kg, or 15 kg of corn DM during Years 1, 2, and 3, respectively. Effects of winter-feed source on ewe carrying capacity are shown in Table 4. Ewes in drylot consumed an average of 2.3 kg of hay DM/d. Carrying capacity of ewes grazing both corn-density treatments was similar. For both systems, a hectare of corn would have supported 100 ewes for about 30 days (Table 4). Stockpiled-fescue pasture supported only 20 percent of the carrying capacity of the corn fields ($P < 0.01$, Table 4). The DM yield data presented in Table 2 supports the lower carrying-capacity calculation for stockpiled fescue. Feed costs were calculated for all four systems, and data are provided in Table 5. When grazed corn was valued based on value of the average grain yield/ha for each planting density ($556/ha for low density and $674/ha for high density planting), daily feed costs were $0.190/ewe and $0.228/ewe for low- and high- density corn, respectively. If these corn paddocks were valued based solely on the cost to plant the crop ($370/ha), grazing corn (either planting density) resulted in calculated feed costs of $0.127/d. Estimated costs for feeding fescue hay were $0.212/d. Grazing stockpiled fescue was lowest at $0.168/d. These cost estimates are dependent on feed-cost assumptions outlined above and would vary depending on commodity price fluctuations.

Table 4. Effect of winter feed source on carrying capacity.

Item	Corn density		Fescue	Fescue	
	Low	High	pasture	hay	SEM
100 Ewe d/ha	29.2[a]	29.5[a]	5.9[b]	--	0.3
Hay DM, kg/d	--	--	--	2.3	--

[ab] Means with different superscripts within rows differ($P < 0.01$).

Table 5. Effects of wintering systems on daily feed costs ($/ewe).

Feedstuff	Corn density Low	Corn density High	Fescue pasture	Fescue hay
Grazing[a]	.190	.226	.146	--
Hay[b]	--	--	--	.201
Corn[c]	--	--	.022	.011
Total	.190	.226	.168	.212

[a] Fescue pasture was valued at $86/ha and grazed corn was valued based on value of the average grain yield for each planting density ($556/ha for low density and $674/ha for high density planting).
[b] Hay was valued at $0.088/kg (as fed basis).
[c] Corn was priced at $0.079/kg (as fed basis).

Conclusion

In conclusion, compared to traditional hay feeding, winter-grazing standing corn or stockpiled fescue, plus emergency corn supplementation, were effective strategies to meet the nutritional needs of ewes during the first two-thirds of gestation. Grazing stockpiled fescue resulted in the lowest daily feed costs.

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