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Corn Supplement for Goats on Summer Rangeland or Improved Pasture

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Summary

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

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

Introduction

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

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

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

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

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

Materials and Methods

Improved Pasture Trial

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

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

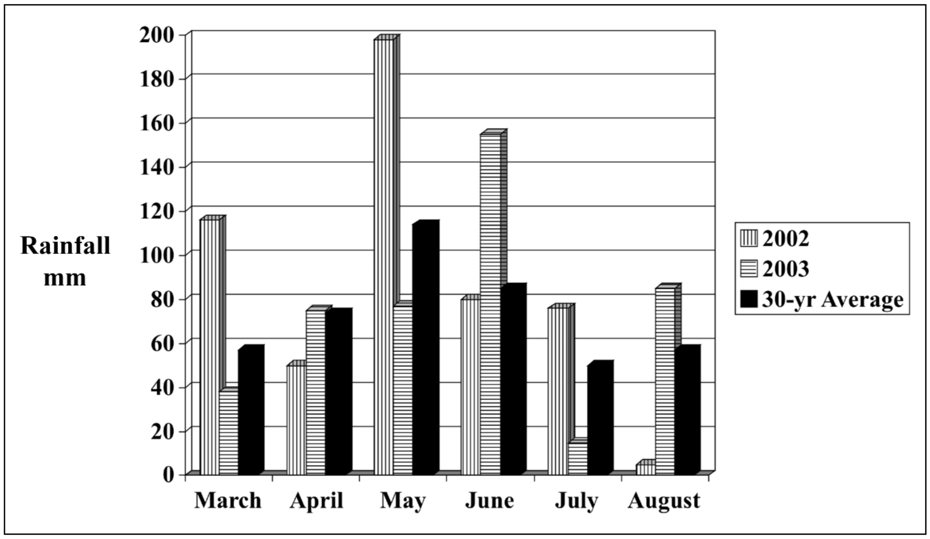
Boer x Spanish cross wethers (average 25±3 kg, 5 to 6 months old) were selected both years from the same north-central Texas meat-goat producer. Seven days prior to the start of the trial (June 1), goats were weighed and randomly assigned to IP sub-paddocks in groups of eight (9.6 goats ha^{-1}; 420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

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

Native Rangeland Trial

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

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



Comparison of Improved Pasture, Native Rangeland and Feedlot

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

Statistical Analyses

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

Results and Discussion

Improved pasture

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

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

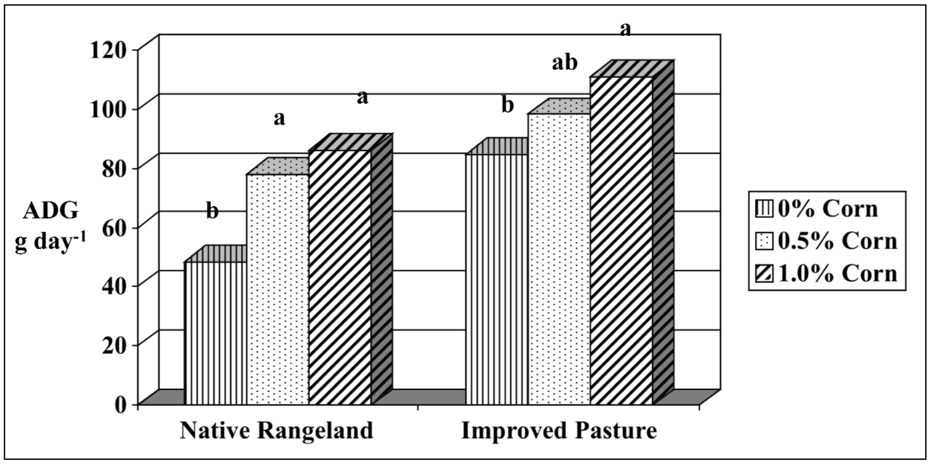


Table 1. Herbage characteristics of improved summer pasture components in June, July and August 2002 and 2003 at Stephenville, TX, USA.

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

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

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

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

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

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

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

Native Rangeland

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

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

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

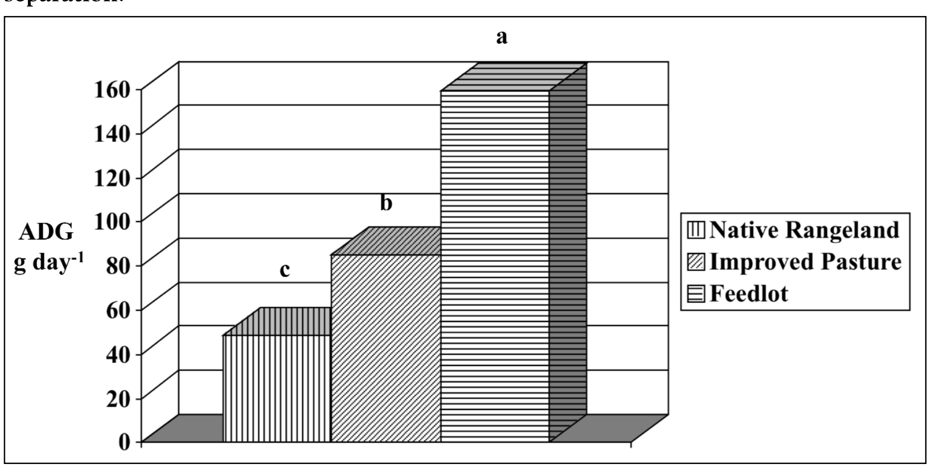
	June		July		August	
	Grass	Forb	Grass	Forb	Grass	Forb
			kg herbage ha^{-1}			
2002						
Ungrazed	869±323	532±270	2048±1637	980±706	1919±2356	1124±573
Grazed	---	---	1829±591	800±800	1771±1544	1033±1024
			g ADF kg^{-1} herbage			
Ungrazed	430±33	344±24	452±28	358±16	442±14	380±34
Grazed	---	---	437±37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

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

Pasture, Rangeland and Feedlot

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

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



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

Conclusions

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

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

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

References

Abijaoude, J.A., P. Morand-Fehr, J. Ressier, P. Schmidely, and D. Sauvant. 2000. Influence of forage:concentrate ratio and type of starch in the diet on feeding behaviour, dietary preferences, digestion, metabolism, and performance of dairy goats in mid lactation. Animal Science 71:359-368.

Aiken, G.E. 2002. Cost of steer weight gain to rate of supplementation with ground corn on bermudagrass pasture. Agronomy J. 94:1387-1392.

A.O.A.C. 1990. Official Methods of Analysis, Association of Official Analytical Chemists. 15th Ed. Volume One. 976.06, pp. 72-74.

Diggs, Jr., G.M., B.L. Lipscomb, and R.J. O'Kennon. 1999. Shinner & Mahler's flora of north central Texas. BRIT, Fort Worth, TX., 1626 pp.

Gallaher, T.J., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for plant and soil analysis. Soil Science Society of America. Proc. 39:803-806.

Getachew, G., A.N. Said, and F. Sundstol. 1994. The effect of forage legume supplementation on digestibility and body weight gain by sheep fed a basal diet of corn stover. Animal Feed Science and Technology 46:97-108.

Goodwin, J.D., J.P. Muir, R.D. Wittie, and T.F. Brown. 2004. Goat weight gains and forage selectivity in mixed grass-forb silvo-pastoral systems. Small Ruminant Research 52:53-62.

Grubben, G.J.H. and D.H. van Sloten. 1981. Genetic Resources of Amaranths: a global plan of action. International Board for Plant Genetic Resources, Food and Agric. Org., Rome, 57 pp.

Hambleton, L.G. 1977. Semiautomated method for simultaneously determination of phosphorus, calcium, and crude protein in animal feeds. J. Association of Official Analytical Chemists 60:845-852.

Hatfield, R.D., J. Ralph, and J.H. Grabber. 1999. Cell wall structural foundations: molecular basis for improving forage digestibilities. Crop Sci. 39:27-37.

Islam, M., H. Abe, F. Terada, K. Iwasaki, and R. Tano. 2000. Effects of levels of feed intake and inclusion of corn on rumen environment, nutrient digestibility, methane emission and energy and protein utilization by goats fed alfalfa pellets. Asian-Australian J. Animal Sciences 13:948-956.

Johnson, D.D. and C.H. McGowan. 1998. Diet/management effects on carcass attributes and meat quality of young goats. Small Ruminant Research 28:93-98.

Kawas, J.R., W.H. Schact, J.M. Shelton, E. Olivares, and C.D. Lu. 1999. Effects of grain supplementation on the intake and digestibility of rangeland diets consumed by goats. Small Ruminant Research 34:49-56.

Lippke, H. and D.B. Herd. 2006. Foragval: Intake and gain by cattle. http://forage.tamu.edu/foragval/default.asp (verified 6 August, 2006). Texas Agricultural Research Station, Uvalde TX.

Lu, C.D. and M.J. Potchoiba. 1989. Feed intake and weight gain of growing goats fed diets of various energy and protein levels. Agricultural Research and Extension Progress. American Institute for Goat Research Scientific Paper Number OKLP-107, p. 1751-1759.

Mba, E.O. and E. Brams. 1984. The growth pattern and protein content of *Amaranthus retroflexus*. Forage Research in Texas. Texas Agricultural Experiment Station, College Station, TX. CPR 4253, p. 227-233.

Muir, J.P. and E.S. Massaete. 1996. Effect of physical restriction and supplementation with *Leucaena leucocephala* on goat growth. Small Ruminant Research 23:103-108.

N.R.C. 1981. Nutrient requirements of goats: angora, dairy and meat goats in tropical and temperate climates. National Academy Press, Wash. D.C., 18 pp.

Opute, F.I. 1979. Seed lipids of the grain amaranths. J. of Exp. Bot., 30:601.

Ott, J.P., J.P. Muir, and L. Simms. 2002. Effect of peanut meal or corn hominy on wethers pastured on coastal fertilized with high or low levels of N. Sheep and Goat, Wool and Mohair Research Reports, September, 2002. Consolidated Progress Report, Texas Agricultural Research Station, College Station, TX USA, p. 70-76.

Rouquette, Jr., F.M., G.R. Smith, M.J. Florence, C.L. Gilbert, and R.P. Gillespe. 1990. Establishment of cowpeas in a bermudagrass sod. Tex Agric. Exp. Sta. Overton Tech. Rep. 90-1, p. 6-12.

Schacht, W.H., J.R. Kawas, and J.C. Malechek. 1992. Effects of supplemental urea and molasses on dry season weight gains of goats in semiarid tropical woodland, Brazil. Small Ruminant Research 7:235-244.

Sharma, C.D. and D.L. Singhania. 1992. Performance of cowpea (*Vigna unguiculatea (L) Walp*) genotypes for fodder traits. Annals of Arid Zone 31:65-66.

Sleugh, B.B., K.J. Moore, E.C. Brummer, A.D. Knapp, J. Russell, and L. Gibson. 2001. Forage nutritive value of various amaranth species at different harvest dates. Crop Science 41:466-472.

Stordahl, J.L., C.C. Sheaffer, and A. DiCostanzo. 1999. Variety and maturity affect amaranth forage yield and quality. J. Production Agriculture 12:249-253.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. Second Edition, Cornell University Press, Ithaca, NY, 476 pp.

Van Soest, P.J. and J.B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. *In.* W.J. Pigden et al. (ed.) Standardization of Analytical Methodology for Feeds: Proc. Int. Workshop, Ottawa, ON. 12-14 Mar. 1979. Rep. IDRC-134e. Int. Dev. Res. CTR., Ottawa, ON. Canada, and Unipub, New York, pp. 49-60.

Weiss, S.A. 2001. Energy supplement for finishing goats on native savannah or cultivated warm-season pasture. Thesis. Tarleton State University, Stephenville, TX., 68 pp.

Whitehead, W.F., T.H. Terrill, B.P. Singh, and S. Gelaye. 2000. Amaranth productivity and nutrient composition in central Georgia. Fort Valley State University. Fort Valley, GA., http://www.eap.mcgill.ca/CPAT_1.htm.

