Effects of Supplementation on Juniper Intake by Goats

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Abstract

The potential for winter supplementation to increase juniper intake by goats on rangelands in the Edwards Plateau region of Texas was assessed in two experiments. The first experiment evaluated the effect on juniper intake of either no supplementation (negative control) or supplementation with corn, alfalfa, or cottonseed meal fed at an isonitrogenous protein level of 1.5 g · kg body weight⁻¹ for 12 days. Redberry juniper (Juniperus pinchotii Sudw.) consumption by individually penned Spanish, Boer × Spanish, Spanish × Angora, and Angora goats was measured on days 11 and 12. Each goat received each supplement in a complete 4 × 4 Latin square design. Juniper intake increased for goats supplemented with alfalfa and cottonseed meal (P = 0.001), but not for those supplemented with corn (P = 0.944). Boer × Spanish goats did not differ in levels of consumption (P = 0.085) from the other breeds. A second study investigated the effect of either no supplementation or soybean meal supplementation on juniper consumption by free grazing Angora and Boer × Spanish goats. Forty goats were assigned to four pasture groups by breed and previously juniper intake, and randomly allocated to either the treatment (supplementation) or control (no supplementation) regime in a complete block design. After 4 days of grazing and supplementation, fecal samples were collected to estimate percent of juniper in the diet using near-infrared spectroscopy. Goats were then rotated to another pasture. Juniper intake was highest for goats supplemented with soybean meal (P = 0.034). Breed of goat did not affect intake (P = 0.240). Goats previously categorized as high juniper consumers based upon prior measurements of juniper intake ate more juniper (P = 0.003) than those classified as low consumers. This research indicates that the effectiveness of goats for biological control of juniper can be improved with a high protein, low starch supplement.

Key Words: detoxification, Juniperus, monoterpenes, prescribed herbivory

INTRODUCTION

Juniper infestation of Texas rangelands is an important dilemma because of its impact on livestock production (Taylor and Ralphs 1992), water availability and quality (Hester et al. 1997), wildlife habitat, and volatile fuels fire hazard (Taylor
Juniper species, once minor proportions of the range-
land flora, have expanded their range. Ashe juniper (Juniperus
ashei Buch.) and redberry juniper (Juniperus pinchotii Sudw.)
now occupy most soil types and vegetation communities in
central and western Texas. Because carrying capacity can be
reduced by as much as 85% in the transition from grassland to
a closed canopy cover of juniper (Ueckert et al. 1994), some
form of juniper management is essential for maintaining
rangeland productivity.

Chemical and mechanical control methods are effective but
can be cost prohibitive (Whitson et al. 1984; Lee et al. 2001).
Also there are real or perceived environmental concerns
regarding the use of chemicals (Ralphs and Bushy 1979; Johnson
1980; Bovey and Richardson 1991) and mechanical treatments
(Wright et al. 1976) for juniper management, especially on
rangeland watershed quality. Fire also is an effective juniper
management tool (Steuter and Britton 1983; Ueckert et al. 2001)
but may not be practical for every situation.

Goats have the potential to provide a cost-effective and
herbicide-free tactic to manage juniper. Goats are evolution-
arily programmed through morphophysiological and behavior-
al adaptations to consume browse (Hoffmann 1973). Observa-
tional data suggest that juniper intake typically ranges from
0%–13% when goats are foraging on pasture (Bryant et al.
using pen studies measuring juniper intake by Angora and
Spanish goats have reported maximum intake values of 33.5%
(6.7 g · kg body weight⁻¹ [BW]) of diet composition (Pritz et
al. 1997). Even though juniper species can represent an
important part of goat’s diets, the overall intake of juniper
tends to be self limited when juniper consumption is higher
than 30% of the diet (Pritz et al. 1997; Bisson et al. 2001;
Straka et al. 2004). The restriction in juniper intake appears to
be an attempt to regulate consumption of monoterpines and
avoid negative postigestive consequences of monoterpene
exposure at higher levels. Toxic monoterpines in juniper deter

goat browsing of juniper plants by reducing nutrient assimila-
tion (Riddle et al. 1999), and (or) by imposing high de-
toxification costs postabsorption (Freeland and Janzen 1974).

We hypothesized that the additional protein provided to goats
by winter supplementation strategies would enhance the metab-
olism of secondary compounds by providing precursors or
additional energy required for degrading the secondary com-
pounds, thus increasing the consumption of juniper. We also were
interested in a concurrent comparative evaluation of the supple-
ments provided. At an isonitrogenous level, would the other
nutritional components of the feed (i.e., degradable protein,
digestible energy) influence their efficacy? Although researchers
using pen studies with other species of animals have investigated
the effect of protein or energy supplementation in reducing
toxicity and increasing consumption of plants that have high
levels of terpenoids, results have been equivocal. Burritt
et al. (2000) reported that protein and energy supplementation
did not increase intake of sagebrush by lambs. Villalba et al.
(2002), however, reported that sagebrush intake was higher for
lambs and kid goats fed a high protein supplement. In a subsequent
study, energy and protein concentrations influenced the amount of
terpenes ingested by lambs (Villalba and Provenza 2005).

A second promising area of study is the identification and
exploitation of individual animal and breed differences in
juniper preference to increase effectiveness of vegetation
management. Individual animal variation in juniper preference
is evident (Riddle et al. 1996) and is also seen in studies
evaluating intake of other chemically defended plant species
such as blackbrush (Coleogyne ramosissima Torr.; Provenza
et al. 1990) and sagebrush (Artemisia tridentata Nutt.; Snowden
et al. 2001). Goat breeds vary in their preference for juniper
with higher levels of consumption reported for Spanish or
Spanish × Boer goats than fiber-producing Angora goats
(Warren et al. 1984; Pritz et al. 1997). The influence of animal
and breed preference for juniper might influence their response
to a supplementation program.

The objective of these two experiments was to determine the
effects of supplementation on juniper consumption by goats.
Experiment 1 compared the effects of three commonly used
winter feed supplements on juniper consumption by two breeds
and two crossbreeds of goats. Experiment 2 evaluated the
influence of breed of goat, previously measured propensity for
juniper, and protein supplement on juniper intake.

**METHODS**

**Study Site**

The study site for both experiments was the Texas A&M
University Agricultural Experiment Station at Sonora (lat
30°15’N, long 100°33’W) located in the western Edwards
Plateau region of Texas. The research station consists of
approximately 1 458 ha of rangeland composed of mixtures of
grasses, forbs, and woody species. Average growing season is
240 days and the elevation is about 632 m. Precipitation is
highly variable. Consequently, frequent droughts and occa-
sional wet years are the norm. Growing season precipitation
averaged 409 mm from 1919 to 1989 (Taylor et al. 1993).

The most common soils on the station are Tarrant silty clay
and Tarrant stony clay (members of the clayey-skeletal,
montmorillonitic, thermic family of Lithic Haplustolls, with
some Kavett silty clay soils in low-lying areas; Taylor et al.
1993). The Tarrant stony clays are the dominant soils, which
overlay a fractured limestone substrate, and are generally 15–
30 cm deep. These soils contain 5% to 70% limestone
fragments or slabs of limestone outcroppings. The topography
is typified by rolling, stony hills with slopes of 3%–4%, which
produce patterns of shallow divides, limestone outcrops, and
low lying areas of deeper soils (USDA–SCS 1972).

**Experiment 1—Pen Trial**

Experiment 1 was designed to compare the effects of three
isonitrogenous supplemental protein sources on juniper intake.
The protein sources selected for this study reflected three winter
supplements commonly used to correct seasonal forage nutrient
deficiencies. Feeding rates were compatible with recommended
supplementation levels for goats on winter rangelands (Huston
et al. 1971). Feed treatments included a negative control (NC,
no supplemental feed), corn (C), alfalfa (A), and cottonseed
meal (CSM). At the target rate, all animals were fed crude
protein (CP) to provide 0.24 g N · kg BW⁻¹ (Table 1), 100%
of their maintenance protein requirements (NRC 1981).

Two breeds and two crossbreeds of goats received four feed
treatments in a complete 4 × 4 Latin square design with four
Table 1. Crude protein (CP), degradable protein, and digestible energy contents of supplemental feed treatments offered to goats with ad libitum access to redberry juniper. DM = dry matter.

<table>
<thead>
<tr>
<th>Nutrient contents (DM basis)</th>
<th>Nutrient contents (DM basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% CP</td>
<td>Degradable protein&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>15</td>
</tr>
<tr>
<td>Corn</td>
<td>9</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>42</td>
</tr>
</tbody>
</table>

<sup>1</sup>Source for reference value for degradable protein was Dairy One (2006) Forage Lab Feed Composition Library (values not reported in NRC, 1981).

replications per treatment. Goat breeds, four animals per breed, were Angora (28.6 ± 3.4 kg BW), Spanish (33.3 ± 5.3 kg BW), Angora × Spanish (29.7 ± 2.4 kg BW), and Spanish × Boer (37.0 ± 6.8 kg BW) for a total of 16 mature (> 2 years old) nannies. Animals were individually fed and received all four treatments. The Spanish × Boer goats were larger animals, due to the Boer influence; therefore intake is reported on a g · kg BW<sup>-1</sup> basis to account for this difference.

Each trial was 12 days long, with the first 10 days representing a preconditioning period. Each day of the trial, supplemental feed treatments were offered individually from 0800 to 1200 hours. Refusals were collected and weighed, and intake of supplemental feed calculated. Nutrient values for supplements and juniper were calculated using reference values (NRC 1981; Huston et al. 1981; Dairy One 2006).

Fresh juniper foliage was harvested daily at 0800 from a 61-ha pasture. One redberry juniper tree per day was randomly selected to provide juniper to all goats for the day’s feeding period. From 0900 to 1400 hours, goats were offered redberry juniper ad libitum by attaching branches in an upright position in each pen. Branches of juniper offered as feed were weighed before and after each feeding period. Corrections for moisture loss were made by weighing branches similar to the ones offered but not grazed at the same time as the grazed branches. Juniper intake was determined by averaging consumption on days 11 and 12 and calculated on a g · kg BW<sup>-1</sup> basis.

Statistical Analyses. Independent variables were breed type (Spanish, Angora, Spanish × Angora, Spanish × Boer), and treatment (control, corn, alfalfa, and cottonseed meal). Juniper intake, expressed on a g · kg BW<sup>-1</sup> basis, was the dependent variable. Goats were fed individually and considered replicates. Analysis of variance was conducted using PROC GLM (SAS 2002). Interactions were tested and found not to be significant, so a reduced model was used that included only main effects. Orthogonal contrasts of treatment effects for juniper intake, nutrient content of juniper, and total nutrient content of diet ingested were as follows: 1) NC vs. C, A, CSM; 2) C vs. A, CSM; and 3) NC, C vs. A, CSM. Orthogonal contrasts for comparisons of nutrient content of the supplements were as follows: 1) C vs. A and CSM, and 2) A vs. CSM. Mean separation of other main effects was determined using protected (P < 0.05) least significant differences. The data are presented as least squares means.

Experiment 2—Grazing Trial
The effects of a soybean meal (SBM) supplement, goat breed, and propensity to graze juniper, on juniper intake by free-grazing goats was investigated during a 16-day period in midwinter. Soybean meal was used instead of cottonseed meal to prevent another secondary metabolite, gossypol, from possibly interacting with other allelochemicals and affecting consumption of juniper. Goats were selected to represent high and low juniper intake. Classification of goats was based on genetic merit for percentage juniper in the diet, which was estimated using a separate animal model for each breed (Walker et al. 2007). The Angora predictions used 778 records from 577 goats and the meat goat predictions used 239 records from 176 goats. Percentage juniper in the diet of goats for calculating genetic merit was estimated using near-infrared spectroscopy (NIRS) predictions of fecal samples collected when they were free-grazing on juniper-infested pastures. The range of juniper in the diet for the high groups was 24% to 41% and the low group 0% to 20%.

Immediately prior to initiation of this experiment, the goats were grazed on an 8-ha, juniper-free enclosure for 10 days and fecal samples were collected on the last day of that period to provide fecal material devoid of juniper to aid in fecal NIRS calibration.

Goats were then preconditioned to juniper by grazing on a 16-ha, juniper-infested pasture for a period exceeding 10 days before separating them into four treatment pastures. Ten goats were assigned to each pasture by breed and intake group as follows: pasture 1, high Angora; pasture 2, low Angora; pasture 3, high Boer × Spanish; pasture 4, low Boer × Spanish. Animals within pasture group were allocated randomly to either the treatment (supplementation) or control (no supplementation) regime. The 10 goats in each breed or consumer group were rotated between pastures to reduce pasture bias. Each group grazed each pasture for 4 days.

Goats within a pasture grazed freely together but received their supplementation treatment individually. For supplementation, goats were herded to a collection area and placed in individual stalls at 1000 hours for a 3-hour period and then released back to the pasture. Stalls were 0.6 × 1.8 m, constructed from welded wire panels. Soybean meal (47.5% CP) was fed to half the animals at a rate of 0.33% BW · day<sup>-1</sup>. Unsupplemented animals remained penned for this period as well. The supplemental feeding rate was calculated to provide 0.24 g N · kg BW<sup>-1</sup> · day<sup>-1</sup>, which is equivalent to the level of nitrogen supplement in Experiment 1. Feed was weighed for each individual animal and any orts remaining after the feeding period were also weighed so that reported feed intake could be adjusted to take refusals into account.

After four days in a pasture, fecal samples for NIRS estimation of percentage juniper in the diet were collected manually at 1600 hours using a 20-mm–wide and 200-mm–long speculum (Total Reproduction, North Ryde, New South Wales, Australia).
Previous research (Whitworth 2002) indicates that a 4-day period is required for fecal spectra to adequately represent botanical composition of the diet (i.e., supplement treatment). Twenty pellets from each goat were collected for the fecal sample. Sampling was repeated in this manner after 4 days in each new pasture.

**Laboratory Analysis.** Fecal samples were dried in a forced air oven at 55°C for 12 hours, ground in a cyclone mill to pass through a 1 mm screen, and conditioned for 24 hours in an environment with constant temperature and humidity (21°C and 65%, respectively). Samples were then packed into sample cells with a near-infrared transparent quartz cover glass. Cells were scanned 32 times using a Foss scanning reflectance monochromator (model 6500, NIRSystems, Inc., Silver Springs, MD). Reflected energy (log 1/R) was measured and averaged over the 32 scans and recorded at 2-nm intervals from 1 100 to 2 500 nm.

Percentage juniper in the diet was estimated with a previously developed modified partial least squares calibration equation (Whitworth 2002; Walker et al. 2007). The calibration data were from feeding trials conducted in 1999 and 2002 that used diets with known percentages of juniper and a variety of background forages (Whitworth 2002), plus feces collected in 2003 and 2004 from goats grazing rangeland areas similar to the study pastures in this study from which all juniper had been removed (i.e., these represented diets with 0% juniper). This equation has an \( R^2 \) = 0.88 and a standard error of cross validation of 6.4 percentage units (Walker et al. 2007). When this equation was used to predict diets from an independent feeding trial with known levels of juniper, treatment differences were readily detected and were similar to actual difference in levels of juniper fed (Walker et al. 2007).

**Statistical Analysis.** Independent variables were breed (Angora and Boer × Spanish), previous juniper consumption category (high and low), supplementation (soybean meal and control), and pasture (1, 2, 3, and 4). The dependent variable was percent dietary juniper and the error term was goat within previous treatment did not exert a carry-over effect (Table 2). Analyses of variance were conducted using PROC MIXED (SAS 2002). Experiment 2 was a randomized complete block design with supplement, breed, and juniper consumption category as fixed treatment effects and pasture and date as blocking effects. Goats were fed and pasture and date as blocking effects. Goats were fed and Supplement treatment affected juniper intake \( (P = 0.005) \), Supplement treatment affected juniper intake \( (P = 0.005) \), Table 2). Alfalfa and cottonseed meal increased juniper intake compared to control and corn supplementation diets \( (P = 0.001, \) Table 3). There was no difference in juniper intake between the negative control and corn \( (P = 0.944) \). Because of feed refusals, intake levels for the supplements were different from target values; however, intakes of CP were not different \( (P = 0.075) \) among the supplemented groups (Table 3). Intake of digestible energy (DE) was higher for the corn treatment than for alfalfa and cottonseed meal \( (P < 0.001) \), and there was no difference between alfalfa and cottonseed meal for DE intake. Intake of degradable protein (DP) was lower for the corn treatment compared to alfalfa and cottonseed meal \( (P = 0.002) \), with no difference between the latter two treatments \( (P = 0.573) \).

**RESULTS**

**Experiment 1—Pen Trial**

Results did not vary by trial \( (P = 0.819) \), indicating that previous treatment did not exert a carry-over effect (Table 2).

**Table 2. Summary of 4 × 4 Latin square ANOVA to response variable \( g \cdot kg BW^{-1} \) juniper consumption. Degrees of freedom \( (df) \), \( F \) values, and \( P \) values are shown. Bold values indicate \( P \) value < 0.05 and italicized value indicates \( P \) value > 0.05 and < 0.10.**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Goat (breed)</th>
<th>Trial</th>
<th>Breed</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juniper intake ( g \cdot kg BW^{-1} )</td>
<td>df</td>
<td>12</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>( F )</td>
<td>4.08</td>
<td>0.31</td>
<td>2.36</td>
<td>4.88</td>
</tr>
<tr>
<td>( P )</td>
<td>0.0003</td>
<td>0.8186</td>
<td>0.0850</td>
<td>0.0053</td>
</tr>
</tbody>
</table>

Individual goats within breed varied in juniper intake \( (P < 0.001) \) but intake by breed did not differ \( (P = 0.085) \). Spanish × Boer, Angora × Spanish, and Spanish goats consumed 11.95 ± 10.16, 10.39 ± 4.66, 6.52 ± 5.46, and 6.39 ± 3.77 \( g \cdot kg BW^{-1} \) of juniper, respectively.

**Experiment 2—Grazing Trial**

Juniper intake by goats on pasture was increased 4.6 percentage units \( (P = 0.03) \) by soybean meal supplementation (Table 4). These results support the data from Experiment 1 in which protein supplementation also increased juniper intake.

Goats classified as high consumers ate more juniper \( (6.7 \% \) than low consumers. Difference in juniper intake between high and low consumers was slightly greater than differences in juniper intake between supplemented and control groups. Breed of goat did not affect intake \( (P = 0.24) \). There were no interactions between supplementation and category of goat or breed of goat \( (P = 0.10) \). The highest level of intake was by supplemented high consumers \( (31.44 \% \) of diet), followed by unsupplemented high consumers \( (26.84 \% \) of diet), supplemented low consumers \( (24.73 \% \) of diet), and unsupplemented low consumers \( (20.09 \% \) of diet).

**DISCUSSION**

**Protein**

This study showed that protein supplements increased juniper consumption by goats. Previous studies evaluated supplementation of sheep and found similar results, where intake of big sagebrush, another monoterpenedefended plant, was higher.
The increased intake of monoterpenes in goats receiving supplemental protein (Villalba et al. 2002) The increased intake of monoterpenes in goats receiving supplemental protein (Villalba et al. 2002). The increased intake of monoterpenes in goats receiving supplemental protein (Villalba et al. 2002). The increased intake of monoterpenes in goats receiving supplemental protein (Villalba et al. 2002).

The importance of degradable protein (DP) in contrast to total protein on detoxification capacity remains unclear. In our results, as percentage DP in the supplement increased, juniper intake increased. This remains an interesting area for future investigation. It is possible that the effect on microbial fermentation and/or higher levels of microbial protein reaching the abomasum provides a better source of amino acids for incorporation into oxidative enzymes required for increased detoxification capacity. The literature regarding protein supplementation and mixed function oxidase activities (Anderson et al. 1982; Guengerich 1995) describes results from studies done with monogastric animals, and does not take into account the effect of fore-stomach fermentation on the availability of protein substrates.

### Table 3. Effects of supplemental feed on intakes of juniper, crude protein (CP), degradable protein (DP), and digestible energy (DE) in the diets of goats in a pen study.

<table>
<thead>
<tr>
<th></th>
<th>Supplement</th>
<th>SE</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of goats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juniper intake (g · kg BW⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP (g · kg BW⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement</td>
<td>—</td>
<td>1.265</td>
<td>0.03</td>
</tr>
<tr>
<td>Juniper</td>
<td>0.418</td>
<td>0.082</td>
<td>0.035</td>
</tr>
<tr>
<td>Total</td>
<td>0.418</td>
<td>0.123</td>
<td>0.000</td>
</tr>
<tr>
<td>DP (g · kg BW⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement</td>
<td>—</td>
<td>0.065</td>
<td>0.042</td>
</tr>
<tr>
<td>Juniper</td>
<td>0.121</td>
<td>0.024</td>
<td>0.035</td>
</tr>
<tr>
<td>Total</td>
<td>0.121</td>
<td>0.070</td>
<td>0.000</td>
</tr>
<tr>
<td>DE (Mcal · kg BW⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement</td>
<td>—</td>
<td>0.003</td>
<td>0.002</td>
</tr>
<tr>
<td>Juniper</td>
<td>0.017</td>
<td>0.003</td>
<td>0.033</td>
</tr>
<tr>
<td>Total</td>
<td>0.017</td>
<td>0.004</td>
<td>0.001</td>
</tr>
</tbody>
</table>

1Orthogonal contrasts for comparisons of juniper dietary contribution and total diet: 1 = NC vs. C, A, and CSM; 2 = C vs. A and CSM; 3 = NC and C vs. A and CSM
2Orthogonal contrasts for comparisons of supplement: 2 = C vs. A and CSM; 3 = A vs. CSM. Maintenance requirements are as follows: CP = 1.7 g · kg BW⁻¹; DP = 1.2 g · kg BW⁻¹; DE = 0.053 Mcal · kgBW⁻¹ (NRC 1981).

The importance of degradable protein (DP) in contrast to total protein on detoxification capacity remains unclear. In our results, as percentage DP in the supplement increased, juniper intake increased. This remains an interesting area for future investigation. It is possible that the effect on microbial fermentation and/or higher levels of microbial protein reaching the abomasum provides a better source of amino acids for incorporation into oxidative enzymes required for increased detoxification capacity. The literature regarding protein supplementation and mixed function oxidase activities (Anderson et al. 1982; Guengerich 1995) describes results from studies done with monogastric animals, and does not take into account the effect of fore-stomach fermentation on the availability of protein substrates.

### Table 4. Mean ± standard error of percentage juniper in the diet of free-ranging goats as affected by category of juniper intake, breed, and soybean meal supplementation.

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean ± SE</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>29.1 ± 2.2</td>
<td>P = 0.0031</td>
</tr>
<tr>
<td>Low</td>
<td>22.4 ± 2.0</td>
<td></td>
</tr>
<tr>
<td>Breed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angora</td>
<td>27.1 ± 2.0</td>
<td></td>
</tr>
<tr>
<td>Boer × Spanish</td>
<td>24.5 ± 2.1</td>
<td>P = 0.2370</td>
</tr>
<tr>
<td>Supplementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement</td>
<td>28.1 ± 2.1</td>
<td>P = 0.0345</td>
</tr>
<tr>
<td>None</td>
<td>23.5 ± 2.1</td>
<td></td>
</tr>
</tbody>
</table>

Energy
All the supplemental diets in Experiment 1 were isonitrogenous, yet juniper intake was less with corn, a high-starch supplement, than for alfalfa and cottonseed, which both contain a relatively high concentration of protein (P = 0.004). In fact there was no difference in juniper intake between the control and corn (P = 0.944). When the supplements were evaluated for digestible energy content (DE), the lack of a response to the protein in the corn supplement can be explained (Table 4). There was an inverse relationship between DE content and juniper intake. The high starch content of the corn supplement, combined with the fact that it comprised close to 100% of the goats’ diets, might have created conditions favoring amylolytic bacteria to predominate in the rumen. Bacterial fermentation of high starch diets reduces ruminal pH, which halts cellulose
Breed and Individual Animal Differences

The variability in juniper intake among animals (SE = 2.53) plays a greater role in patterns of juniper intake in a population than does the variability between breeds (SE = 1.27). Breed differences that have been reported in the literature support the hypothesis that breed differences might remove the selective pressures for animals to develop physiological mechanisms necessary to consume unpalatable plants. In this study, however, breed differences were not apparent.

Variability in juniper intake among individual animals constituted the greatest source of variation in both experiments in this study. Previous research showed substantial differences in intake among animals within breed (Pritz et al. 1997; Riddle et al. 1999; Bisson et al. 2001). Differences in pharmacological sensitivity to monoterpenes could account for idiosyncrasies within populations of goats. Inheritance accounts for a large part of the differences between individuals in the response to an administered drug (Rowland and Tozer 1989). Utilizing intranspecific differences to breed strains that can exhibit fast or slow metabolism for a particular compound (Vesell 1968) has long been suggested as a means to increase capacity of mammals to degrade specific chemicals (Freeland and Janzen 1974). The identification of a bimodal frequency distribution of juniper consumption, where there were significant differences in juniper intake equal to almost one third of total intake identified in the second study, indicates promise for developing a successful breeding program for juniper consumption.

MANAGEMENT IMPLICATIONS

Numerous studies implicate protein as an important factor in increasing detoxification capacity and subsequently increasing consumption of a chemically defended plant. Providing protein at a rate of 1.5 g · kg BW⁻¹ in a high-protein, low-starch supplement can increase juniper intake of goats in a pen environment and on pasture. The nutrient quality of the supplement can affect the availability of molecular substrates for incorporation into metabolic detoxification pathways. Although corn is often fed to goats on range, this practice is detrimental to grazing goats as a low-cost brush management tool. A supplement with lower DE would promote greater juniper intake when juniper management through herbivory is the primary objective.

Three critical elements in managing juniper with goats include 1) reducing the stature of the juniper to within reach of the goats, 2) browsing with a high ratio of goats to juniper, and 3) reducing seedling recruitment by harvesting juniper in the cotyledon stage. The first two elements could involve the integration of other brush management treatments (i.e., mechanical, prescribed fire, etc.). However, regardless of the treatment or combination of treatments used to manage juniper, improving the efficacy of goat use of juniper is an important part of the overall juniper management plan. Increased juniper intake by goats, whether by selection of high-consuming animals or by protein supplementation, reduces use on other more desirable forage species and creates a targeted grazing pressure on the undesirable species. Furthermore, the economic response to supplementation with respect to animal performance is already well established. Huston et al. (1971) concluded that if goats are worth keeping, they are worth supplementing to the level required to maintain health and vigor. The current study was designed to utilize and evaluate typical winter supplementation practices used by ranchers to provide adequate nutritional quality to goats on rangeland during periods of forage dormancy.
LITERATURE CITED


HUSTON, J. E., M. SHELTON, AND W. C. ELLIS. 1971. Nutritional requirements of the Angora goat. College Station, TX: Texas Agricultural Experiment Station Publication B-1105. 16 p.


