WILL SUPER JUNIPER-EATING SIRES PRODUCE SUPER JUNIPER-EATING OFFSPRING?

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ABSTRACT

When preconditioned in pens, goats develop a preference for juniper on pasture. The objective of this study was to see if sires selectively bred for high juniper consumption produce offspring that consume more juniper than offspring from sires chosen for production characteristics. Five sires chosen for high juniper consumption and five sires chosen for production characteristics were bred to 7 does each (n= 70). Kids were weaned at 90 days of age and placed in individual pens for feeding trials. Consumption of juniper was measured and compared among sire groups. Body condition scores and weights were taken and compared among sire groups after goats were on feed for 30 days following each feeding trial. There were no differences in juniper consumption, body condition scores, and weights among treatments. Goats increased juniper consumption daily in individual pens.

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INTRODUCTION

Redberry (*Juniperus pinchotii* Sudw.) and ashe (*Juniperus asheii* Buch.) juniper are invasive woody species found throughout west central Texas (Ansley et al. 1995; Smeins et al. 1997; Owens et al. 2010). Both redberry and ashe juniper are evergreens that were historically found on rocky outcrops and north-facing slopes where both were protected from fires (Ellis and Schuster 1968). During the past 100 years, juniper has encroached onto grasslands reducing the amount of available forage for grazing animals (Dye et al. 1995; Ueckert et al. 2001). Juniper dominates rangelands throughout western and central Texas because it is avoided while other forbs, shrubs, and grasses are consumed (Archer 1994).

Monoterpenoids, a form of terpenes contained in *Juniperus* sp., cause aversive postingestive feedback and the formation of conditioned food aversions (Riddle et al. 1996; Pritz et al. 1997). Goats consume juniper, but intake is limited because monoterpenoids kill rumen bacteria when intake exceeds 30% of the diet (Straka et al. 2003). It appears that goats are able to acclimate to the monoterpenoids in the juniper if exposed to the plant slowly over several days (Bisson et al. 2001). Two studies have confirmed this observation by feeding juniper to goats in individual pens for 10-14 days (Ellis et al. 2005; Dunson et al. 2007). In addition, goats will continue to consume juniper on pasture at levels up to 30% when preconditioned for 14 days at weaning (Dietz et al. 2010). When preconditioned goats were placed on pastures for 1 year, browse lines became

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apparent on mature junipers and several immature junipers were defoliated (Dietz et al. 2010).

Genetic selection has led to the development different breeds for production characteristics (milk, meat, and fiber), behavior, color, size, and resistance to disease, pests, or environmental extremes (Lasley 1987). Selection and breeding of animals with specific diet characteristics could be used to develop livestock for vegetation management such as weed control or improved forage utilization (Snowder et al. 2001). Undoubtedly, genes play an important role in physiological mechanisms affecting food preference and detoxification of chemicals (Walker 1995). Recent research conducted by the Texas AgriLife Research Station has selected both sires and dams for their ability to consume juniper. Over the past several generations, these efforts have increased juniper intake in the lineage of goats selected for the willingness to consume juniper (Campbell et al. 2007, Waldron et al. 2009). The objective of this study was to determine if sires selected for their willingness to consume juniper will produce offspring that consume more juniper than others selected for production characteristics.

OBJECTIVES

To determine if sires selected for juniper consumption will produce offspring that consume more juniper.

LITERATURE REVIEW

CURRENT PROBLEM OF JUNIPER CONTROL

Redberry and ashe juniper cover continue to increase throughout the southwestern states including Texas, Oklahoma, New Mexico, Arizona, and the country of Mexico (Ansley et al. 1995). Juniper encroachment in grasslands usually progresses toward a stable woody state of mature trees that requires a significant disturbance to shift succession in another direction (Ansley et al. 2006). Redberry juniper is a common invasive brush species that reduces rangeland productivity over vast hectares in the Rolling Plains and Edwards Plateau regions of Texas (Dye et al. 1995). In ecosystems with juniper encroachment, ecological processes (i.e., infiltration) are typically impaired as intercanopy plant structure degrades during woodland expansion (Petersen et al. 2009). The interest in removal of juniper has increased because of the public's concern over the impact of woody plant encroachment on the hydrologic cycle effecting overall water yield (Thurow and Hester, 1997; Bednarz et al. 2000).

Several methods including the use of herbicides (spraying), prescribed burning, and mechanical removal (grubbing, chaining, root plowing) are utilized to aid in the management of juniper species (Steuter and Wright 1983, Ueckert et al. 1994). Because of high costs, mechanical removal and herbicides are not economically feasible (Johnson et al. 1999). Prescribed burning is effective in controlling ashe juniper, but redberry juniper readily resprouts after topkill. Given that both species are often found on the same sites, fire is not an effective method for overall juniper control (Bryant et al. 1983, Steuter and Britton 1983).

TOXINS IN JUNIPER

Many plants have evolved physical and chemical defense mechanisms to avoid herbivory (Barry and Blaney, 1987; Provenza et al. 1992). *Juniperus* sp. contain monterpenoids that reduce the likelihood of mammalian herbivory by causing aversive postingestive feedback (Riddle et al. 1996; Pritz et al. 1997). Redberry juniper contains 16 identified monoterpeniods while ashe juniper contains 18 (Owens et al. 1998; Campbell and Taylor 2007; Dietz et al. 2010). Differences in composition and concentration of monoterpenoids account for variations in preference between the two species and probably seasonal and site variations. Generally speaking, goats consume more ashe than redberry juniper when given a choice between the two species (Pritz et al. 1997). Of the monoterpenoids found in juniper, only alpha pinene, sabinene/beta-pinene, myrcene, limonene, and terpeniol are negatively correlated with intake (Riddle et al. 1996). Since identification of the aversive properties of some monoterpeniods in juniper, several studies have illustrated that preconditioning goats improves juniper consumption apparently because goats undergo physiological adaptation that improves detoxification of monoterpeniods in juniper (Bisson et al. 2001, Ellis et al. 2005, Dunson et al. 2007, Dietz et al. 2010).

EFFECTS OF GENETICS ON DIETARY SELECTION

Genetics has long been used to manipulate almost every part of animals we see today. Studies on sire influence on dietary selection have had positive outcomes in the past. Snowder et al. (2001) conducted a 2 year study where they estimated the heritability of the percentages of mountain big sagebrush (*Artemisia tridentata* Nutt.) consumed in diets of sheep where the heritability of consumption was $H^2 = 0.28$. Warren et al. (1983) reported heritability of diet selection on various forage species by Spanish goats averaged $H^2 = 0.30$ for non-preferred species. Two studies done with limited numbers of observations have shown a significant sire effect for the botanical composition of diets of free-grazing goats (Warren et al. 1983) and cattle (Winder et al. 1995).

MATERIALS AND METHODS

This study was conducted at the Angelo State University's Management, Instruction, and Research (MIR) Center. During October, five sires genetically chosen for high juniper consumption, while 5 unrelated sires selected for other production characteristics were acquired. Each of the 10 sires was placed in an individual research pen (3 X 9 m) with a breeding group of 7 randomly selected does selected for production characteristics. Breeding occurred in December of 2009. Prior to breeding, does received two injection of lutelyse to synchronize estrus. Each individual breeding group of one sire and seven does was fed a ration of Ram 20 (Table 1) to meet their maintenance requirements. Does were maintained on a wheat pasture throughout gestation.

When kidding occurred in the spring (March-April), kids were ear tagged immediately after birth according to sire. Kids and does were housed on haygrazer fields prior to weaning. All kids were weaned at 90 days. After weaning, kids from each sire group were assigned to 3 separate feeding trials and placed in individual pens. The facilities at the MIR Center will house 43 kids at one time in individual pens. For Trial 1, the 43 largest kids were randomly assigned to individual pens. For the second trial, 43 of the remaining kids were randomly assigned to individual pens. For the last trial, the remaining 17 kids were randomly assigned to individual pens.

Once a feeding trial began, the kids were allowed a seven-day adjustment period to adjust to the basal diet and environment change. Each kid was fed a basal diet of alfalfa pellets at 2.5% body weight for maintenance requirements as well as the treatment diet

Table 1. Ingredients and nutrient contents of RAM 20 ration.

Ingredients/Nutrients	As fed (%)
Alfalfa Pellets	10.0
Cotton Seed Meal	12.5
Soybean hulls	31.5
Cane Molasses	3.5
Premix	2.5
Sorghum Grain (milo)	40.0
DE	2.6 Mcal/kg
TDN	59.0
Crude Protein	14.5
Crude Fiber	14.2

(NRC 2007). The basal diet and fresh redberry juniper was fed for 14 days. Initially, 50 g of juniper was fed daily for 30 minutes daily. Once an individual goat consumed all of the juniper offered on 2 consecutive days, the amount offered was increased by 25 grams until refusals were noted. Juniper and alfalfa consumption was measured by weighing the amount offered then weighing back and subtracting the refusals. Intake of both alfalfa and juniper were recorded daily. Intake of juniper by kids from the two different sets of sires was compared to determine if kids from the sires genetically chosen for juniper consumption consumed more juniper than the kids form the sires chosen for production characteristics.

The kids waiting to enter the feeding trial were housed separately and fed the Ram 20 (Table 1). A week before they entered the feeding trial they were fed alfalfa pellets *ad libitum* to acclimate them to the basal diet used in each trial.

When the pen feeding trials were over, kids were put on feed for 30 days then weighed and given conformation structure scores (1-5), 1=perfect structure and conformation and 5=poor structure and conformation. After this study 83 kids were placed on pastures for 12 months at the Texas Agrilife Research Center, Sonora, TX to quantify juniper intake on pasture.

Alfalfa pellet and juniper intake (g kg BW^{-1}) were compared among treatments (A&M vs. other), sires, and feeding trials of the study was analyzed using repeated measures analysis of variance. Individual goats were the experimental unit. Day of observation served as the repeated measure. Means were separated using Tukey's LSD test when $P\leq0.05$.

Offspring intake of juniper was also compared among individual sires using the same statistical model. Data was analyzed using the statistical package JMP (SAS 2007).

RESULTS

Fifty kids were reared out of the 35 nannies bred to sires selected for juniper consumption (A&M sires) (Table 2). Fifty three kids were reared out of the 35 nannies that were bred to sires selected for other production characteristics (other sires).

Juniper intake differed ($P<0.05$) among trials (Table 3). Kids in the second trial consumed more juniper than kids in the first or third trials. Alfalfa intake was similar ($P>0.05$) across the three trials (Table 3).

Juniper intake was similar between treatments (Table 4). Likewise, there were no differences among sire groups (Table 5). The hypothesis, sire selection for juniper consumption would increase intake of juniper by their offspring, was rejected; kids from the genetically chosen sires (i.e. A&M sires) did not consume more juniper than kids from sires chosen for production characteristics. Alfalfa intake was also similar among treatments but differed across sire groups (Table 4). Kids out of sires 4799 and K2 consumed more alfalfa than kids out of sire K1. There were no differences among the other sires.

Goats were reluctant to consume the juniper on the first day of feeding but soon began consuming juniper by days two and three. Juniper consumption by goats in both treatments steadily increased throughout the trials from .35 ± .33 $g \cdot kg^{-1}$ BW on the first day to 6.33 ± .33 $g \cdot kg^{-1}$ BW on the last day by kids from the genetically chosen sires and .32 ± .33 $g \cdot kg^{-1}$ BW on the first day to 5.69 ± .33 $g \cdot kg^{-1}$ BW on the last day by the kids from the sires chosen for production characteristics. The day effect in the model differed for juniper consumption but the treatment X day interaction was similar (Fig. 1).

Table 2. Total number of offspring fed juniper from individual sires.

Sire	# of Kids
A&M	
4332	6
4433	11
4571	10
4602	10
4799	13
Total	50
Other	
305	13
716	11
K1	8
K2	9
VICK'S	12
Total	53
Grand Total	103

Table 3. Average intake (g kg BW^{-1}) of redberry juniper and alfalfa pellets across the the trial of this study.

Feed	Trial		
	1	2	3
Juniper	2.5^{b}±.09	4.1^{a} ±.09	2.8^{b}±.17
Alfalfa	23.4±.46	24.5 ± .46	24.6±.73

[a-b]Means within rows with different superscripts differ (P<0.05).

Table 4. Average intake (g kg BW^{-1}) of redberry juniper and alfalfa pellets for kids out of sires selected for juniper consumption (A&M) or sires selected for other production characteristics.

Feed	**Treatment**	
	A&M	**Other**
Juniper	3.5 ± .26	3.0 ± .25
Alfalfa	24.0 ± .48	23.8 ± .48

Table 5. Average intake (g kg BW^{-1}) of redberry juniper and alfalfa pellets for kids out of each sire selected for juniper consumption (A&M) or sires selected for other production characteristics.

Sires	Feed	
	Juniper	Alfalfa
A&M		
4332	3.3 ± .73	24.3^{ab} ± .57
4433	3.5 ± .49	23.7^{ab} ± .62
4571	3.0 ± .57	23.4^{ab} ± .72
4602	4.2 ±.52	24.1^{ab} ± .65
4799	3.6 ± .47	24.7^{a} ± .59
Other		
305	2.6 ± .45	24.5^{ab} ± .57
716	2.7 ± .49	24.3^{ab} ± .62
K1	3.0 ± .58	20.7^{b} ± .73
K2	3.7 ± .55	25.6^{a} ± .69
VICK'S	3.2 ± .51	23.9^{ab} ± .65

[a-b]Means within columns with different superscripts differ ($P<0.05$).

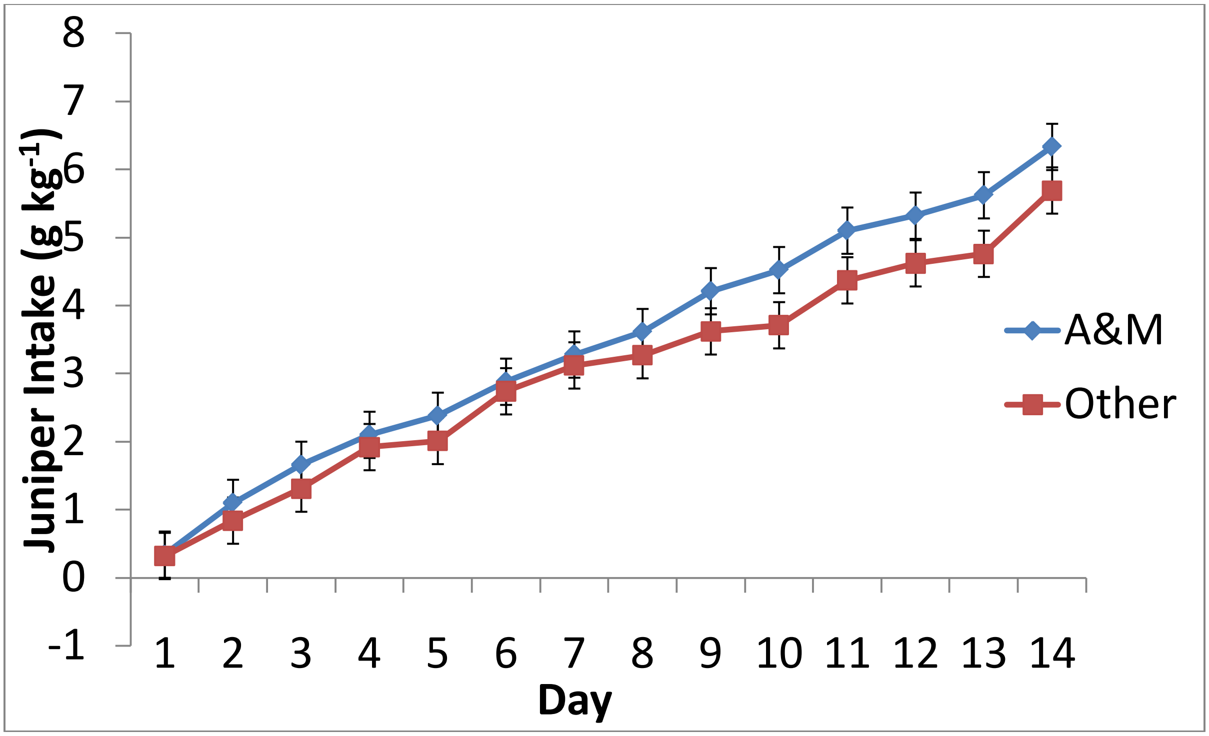

Fig. 1. Average daily juniper intake (g kg BW^{-1}) for kids out of sires either selected for juniper consumption or for sires selected for other production characteristics.

Alfalfa consumption varied across days of feeding ($P<0.05$) while the treatment X day interaction for alfalfa intake was similar (Fig. 2). Alfalfa intake increased from day eight to nine then stayed consistent through day seventeen with the introduction and consumption of juniper starting on day seven. Alfalfa intake went from 22.69 ± .66 $g{\cdot}kg^{-1}$ BW on day 8 to 24.71 ± .66 $g{\cdot}kg^{-1}$ BW on day 17 by kids from the genetically chosen sires, and from 23.90 ± .78 $g{\cdot}kg^{-1}$ BW on day 8 to 24.50 ± .65 $g{\cdot}kg^{-1}$ BW on day 17 by kids from the sires chosen for production characteristics.

Body condition scores were similar among treatments (Table 6). Final weights taken 30 days after completion of each feeding trial were also similar among treatments (Table 6).

Data from the second experiment (pasture study) were not available for this thesis. Data will be combined with the data from this thesis project and submitted for publication in the scientific journal *Rangeland Ecology and Management*.

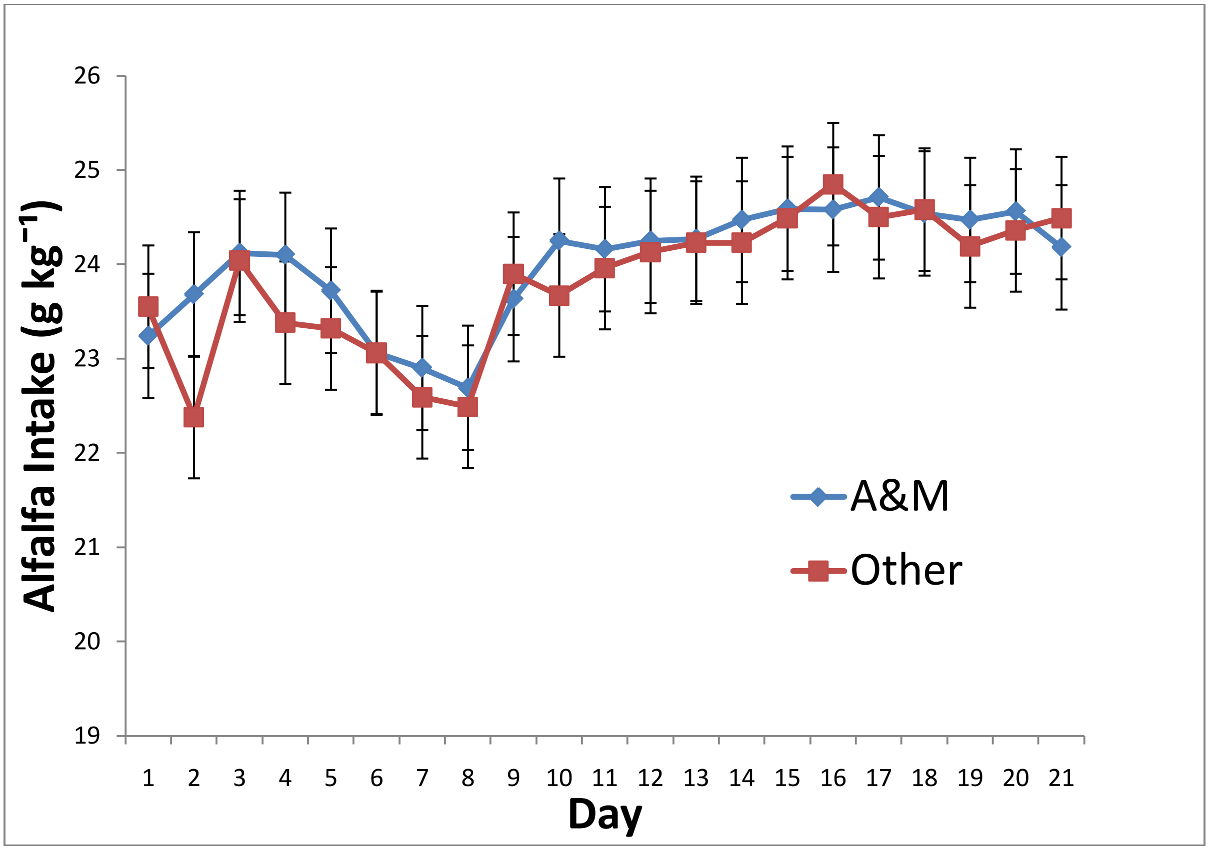

Fig. 2. Average daily alfalfa intake (g kg BW^{-1}) for kids out of sires either selected for juniper consumption or for sires selected for other production characteristics.

Table 6. Body condition scores (1-5) and final weights (kg) for goats taken 30 days after the completion of each trial. Two observers independently assigned a score to each goat, where 1=perfect structure and conformation and 5=poor structure and conformation.

Production Characteristic	**Treatment**	
	A&M	**Other**
Body Condition	2.9±2.9	2.7±2.7
Final Weight (kg)	22.7±0.4	22.4±0.4

DISCUSSION

Results from this study support the observation that goats will increase intake of redberry juniper at weaning when offered the plant in individual pens for 14 days (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007). Kids from both sire groups increased intake across the 14 days of feeding in each trial. Once released on pasture, conditioned goats will continue to consume juniper throughout the year, with juniper accounting for 30% of their diet (Dietz et al. 2010). If sire selection had influenced juniper consumption, kids from the A&M sires should have either (1) began consuming juniper faster, or (2) consumed more juniper than kids from sires selected for other production characteristics. Both groups increased consumption of juniper over days of feeding at the same rate and consumed similar amounts of juniper. When sires are bred to a group of randomly selected doe, sire selection appears to have little impact on juniper consumption of offspring.

The sires in the A&M treatment in this study came from a flock that had been selectively bred for six years; both sires and dams had been selected for their willingness to consume juniper. The other five sires obtained made up the other group of sires chosen for production characteristics. The does used in this study were either (1) purchased from a commercial breeder with no knowledge of their willingness to consume juniper, or (2) originated from a flock of goats that consumed an average amount of juniper; dams were classified as neither consuming high nor low amounts of juniper. The results of this study showed no influence on juniper consumption of offspring from sires selected for their willingness to consume juniper. Ellis et al. (2005) reported that heritability of redberry juniper was low for half-siblings. Waldron et al (2009) reported a heritability index of 0.13 for juniper consumption after selection of both dams and sires for juniper consumption. Indeed, the authors argued that improvements in juniper consumption by genetic selection would be slow. Conversely, Snowder et al. (2001) reported that mountain big sagebrush consumption heritability was moderately high (H^2 = .28) while Warren et al. (1983) reported the heritability of nonpreferred species of vegetation was H^2 = .30. Both mountain sagebrush and redberry juniper are considered nonpreferred shrubs because both contain similar toxins (monoterpenoids). It is unclear why genetic selection improves consumption of some nonpreferred species with similar toxins. Apparently, the metabolism of the toxic compounds in redberry juniper are not influenced by genetic selection in the same manner. Conversely, results of this study and others (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007; Dietz et al. 2010) show that goats can apparently circumvent juniper toxicosis when exposed to the plant slowly over 14 days of feeding at weaning. When combined with the observation that juniper is indeed toxic and can result in a conditioned food aversion to the plant (Riddle et al. 1996; Pritz et al. 1997), especially when intake exceeds 30% of the diet (Straka et al. 2003), the observations of this study and others suggest that goats are able to adapt to the monoterpenoids in juniper. Apparently, rumen function or microbial population shifts are not responsible of this adaptation (Dunson et al. 2007). Thus, others have argued that low levels of juniper consumption may result in enzymatic changes in the liver, which improve goats' ability to consume juniper (Foley et al. 1995; Dunson et al. 2007; Dietz et al. 2010)

When goats consume low to moderate levels of juniper, monoterpenoids in the plant are liberated after ingestion and absorbed through the rumen wall and small intestine. These partially metabolized compounds are then transported to the liver via the portal systems for detoxification. Apparently, these compounds are then oxidized by cytochrome P-450 enzymes (Bidlack 1982; Foley et al. 1995). Thereafter, altered monoterpenoid oils are conjugated with endogenous cofactors, such as glucuronic acid and excreted in urine (Bidlack et al. 1986; Scheline 1991). Thus, feeding protein sources that escape microbial digestion and contain glucogenetic amino acids that reach the liver apparently provide the substrate for monoterpenoid detoxification and excretion.

There is some indication that protein supplementation may improve juniper intake by providing amino acids to the liver for enhancement of toxin degradation and excretion. Goats supplemented with protein consumed more juniper than goats supplemented with energy or not receiving any supplementation (Campbell et al 2007). Neither protein nor energy supplementation improved consumption of big sagebrush (*Artemisia tridentate* Nutt.) which also contains monoterpenoids (Burritt et al. 2000), while Villalba et al. (2002a, 2002b) argued that protein sources high in ruminally degradable protein sources (SBM) may increase intake of big sagebrush. George et al. (2010) suggested that the amount of protein that escapes rumen digestion may further improve juniper intake. Similar observations have been documented with one-seeded juniper (*Juniperus monosperma* [Engelm.] Sarg) (Utsumi et al. 2009). Apparently, protein supplements that contain amino acids that escape rumen degradation may further improve juniper consumption (George et al. 2010).

By the end of this study, juniper intake accounted for roughly 20% of the diet whereas others (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007) achieved 30%. Monoterpenoid levels of juniper vary monthly and seasonally (Owens et al. 1998; Campbell and Taylor 2007) and probably vary from year to year depending on ambient conditions (Dietz et al. 2010). Monoterpenoid levels of juniper fed in this study could be different with varying weather conditions from one season or year to the next. According to Owens et al. (1998) in west central Texas monoterpenoid levels in juniper were highest in winter and spring. The difference in times of the studies mentioned above and this one could be a factor in the difference in percentages of juniper in the diets. Juniper for this study was collected in the month of August of 2010 monoterpinoid levels were not measured.

Campbell et al. (2007) reported juniper intake was 20% vs 29% for lows verses highs. The “lows” were offspring from dams and sires that consumed very little juniper while the “highs” were offspring from dams and sires that consumed more juniper on average. The percent juniper in diets reported in this study were similar to the lows reported by Campbell et al (2007). Waldron et al. (2009) suggested that juniper percentages in the diet varied greatly even after several generations of selection resulting in a relatively low estimate of heritability (0.13). The mean predicted percentage of juniper in the diet was 30, with a SD of 12, and ranged from –5 to +62% (Waldron et al. 2009). These results were calculated by utilizing fecal NIRS which estimates juniper intake by scanning fecal samples using infra-red light. Thus, intake was not measured directly, but estimated using indirect techniques. On rare occasions goats may consume up to 40% of their diet in juniper (Skiles, unpubl. data).

Nevertheless, it seems unlikely that juniper intake will exceed 30% of the diet given the observation that juniper intake at this level results in microbial death and loss of rumen function (Straka et al. 2003).

IMPLICATIONS

Based on the results of this study and numerous other studies (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007; Dietz et al. 2010) goats will increase juniper consumption when fed juniper in individual pens at weaning. The selection of sires for willingness to consume juniper apparently had no influence on juniper consumption of their offspring. With this, producers can precondition goats at weaning for juniper consumption and use them as a source of biological control of juniper. Instead of selecting sires for willingness to consume juniper, producers can make selections for production characteristics that best suit the goals they have for their operation. In the results of the study of done by (Dietz et al. 2010) female goats will select juniper at levels up to 40% of total bite taken on pasture when preconditioned for 14 days at weaning. Producers normally select replacement does at weaning and separate them from rest of the herd at that time. During this period, they can then precondition the replacement does to consume juniper by feeding juniper stripped from limbs or simply cutting limbs from trees and placing them in pens with the replacement does. Producers will have conditioned their goat flocks for consumption of juniper. Ranchers with the problem of juniper encroachment may further reduce juniper encroachment when biological control with goats accompanies chemical, mechanical, and fire as means of control without seeing a decrease in goat performance (Owens et al. 2010).

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