MATERNAL INFLUENCE ON JUNIPER CONSUMPTION IN BOER-CROSS GOATS

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CONSUMPTION IN BOER-CROSS GOATS

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ABSTRACT

The objectives of this study were to determine if maternal influences increased redberry juniper (*Junipers pinchottii* Sudw.) consumption by goats. Twenty-one Boer nannies were bred to determine the effects of maternal influences from different stages of exposure. Experiment 1, examined the exposure in the uterus in the third trimester, Experiment 2 examined the effect of exposure through lactation. Experiment 3, examined the mothers influence as a social role model and the last treatment group was the control. At weaning, all kids were fed juniper in individual pens at the Angelo State University Management Instruction and Research Center, San Angelo, TX. Kids were fed juniper 30 min each day for 24 days and refusals were weighed back daily to monitor intake. Following the juniper feeding, kids were fed a basal diet of alfalfa pellets (2.5% BW) to meet body maintenance requirements. All kids increased intake over the 24 days of exposure. Kids that foraged with mom on juniper-dominated rangelands initially ate more juniper.

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Introduction

Redberry (*juniperus pinchotii* Sudw.) juniper is one of the most problematic plant species for landowners in west central Texas. Redberry juniper was originally limited to the rocky outcrops and steep canyons; however, a decrease in the frequency of wildfires, overgrazing, and drought has caused an increase in hectares infested with juniper (Ansley et al 1995). There are several control methods for redberry juniper, including the use of herbicides (spraying), prescribed fire, and mechanical removal, which can be achieved by using grubbing, root plowing and chaining (Steuter and Wright 1983). Redberry juniper possesses the ability to re-sprout which makes follow-up maintenance necessary (Johnson et. al 1999). With the increasing costs of labor, fuel, and herbicides many landowners are being forced to find alternative methods of control. Fire can be an effective control, however; because of the loss of production associated with pre and post burn grazing deferment, and the potential risk involved, many landowners are unwilling to use fire.

An alternative method is biological control using goats; studies show that goats can decrease encroachment by browsing seedlings and immature plants (Taylor 1992). Prior to goats consuming a large amount of juniper on pasture, it has been necessary to condition an acceptance of the plant, by feeding juniper to goats in individual pens at weaning (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007). Once goats are conditioned to consume juniper, a goats' diet can consists of up to 40% juniper of total bites taken on pasture (Dietz et al. 2006)

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Without conditioning an acceptance of the plant, the monoterpenoids levels in juniper limits consumption through aversive postingestive feedback and the formation of conditioned food aversion (Riddle et al. 1996; Pritz et al. 1997). After conditioning goats apparently possess the physiological ability for adaptation to the monoterpenoids thereby reducing aversive feedback (George et al. 2010).

Unfortunately, feeding facilities and labor are needed to condition goats to consume juniper. Research shows that when lambs are exposed to a novel food with their mother as compared to exposed alone they will consume more of the food later in life (Thorhallsdottir et al. 1990). This gives the possibility that the offspring of conditioned nannies, may consume more juniper if they browse in a juniper-infested pasture with their mom prior to weaning.

Some foods and flavors are noticeable in the mothers' milk, therefore, exposing the offspring to the flavor of a novel food while nursing. Nolte and Provenza (1991) found that lambs would consume more of a food if they had been exposed to the same flavor through their mothers' milk while they were nursing. This gives the possibility that you may be able to condition goats to consume juniper by feeding the nannies juniper while lactating.

During the third trimester of pregnancy, the fetus develops the sense of taste and smell; it has also been shown that compounds like garlic can cross the placental barrier (Nolte et. al 1992). This may cause the fetus to form a preference for that compound, while it is still in the uterus. If the flavor of juniper crosses the placental barrier the kid may form a preference for juniper while still in the uterus.

Objectives

The objectives of this study were to examine the roles that maternal influence could have on juniper consumption. Specifically, this study:

1. Determined if kids that forage on juniper with their mother would consume more juniper post-weaning.
2. Determined if kids would consume more juniper after experiencing the flavor through the mother's milk.
3. Determined if exposure to juniper during the third trimester of pregnancy would cause increased consumption of juniper post weaning.

Literature review

Juniper ecology

The number of hectares infested with redberry juniper throughout the years has increased substantially. In an area in northwest Texas, a 61% increase in juniper was noted in a 34-year period (Ansely et al 1995). Once juniper invades a site, forage production and plant diversity decline (Dye et al.1995; Archer 1995). There is also an increased interest regarding the impact juniper invasion has on watersheds. The encroachment of juniper on the watersheds for lakes and streams in Texas has the potential to reduce the quantity, quality and evapotranspiration of water (Thurow and Hester 1997; Moore et al 2012).

Redberry and Ashe (*Juniperus asheii* Buch.) juniper are increasing throughout most of central and western Texas (Smeins et al. 1997). On the Edwards Plateau region of Texas a mixture of redberry and ashe juniper occur, on the Rolling Plains region of Texas, redberry juniper is the dominate juniper species (Ansley et al. 1995, Smeins et al. 1997). Redberry juniper posses the ability to respout after fire or top removal (Johnson et. al 1999), while ashe can be killed. Ashe juniper is more palatable then redberry juniper and it appears that goats can distinguish between the two based on volatile oil content (Riddle et al. 1996).

Experiences early in life

Early dietary experience is an important determinant of later dietary habits in ruminants (Distel and Provenza, 1991; Walker et al., 1992 Provenza 1996; Olson et al. 1996). Research suggests that neurological, Physiological, and morphological processes are susceptible to change in the immature animal and can be altered so that they can better forage in the environment in which they are reared including the consumption of toxic plants (Provenza 1996). Goats consume more of the toxic shrub blackbrush (*Coleogyne ramosissima Torr*.) after exposure to the plant at weaning. Similarly, sheep consume more of the toxic forb leafy spruge (*Euphorbia esula L.*) after exposure to the plant early in life (Olson et al. 1996; Kronberg and Walker 1999). Apparently, exposure at weaning allows goats to adapt to the juniper as well (Bisson et al. Ellis et al. Dunson et al.).

The dam has an important role in what her offspring selects in their diet. When lambs are exposed to a novel food with their mother they consume more of the food then when exposed with a dry ewe (Thorhallsdottir et al 1990). Mirza and Provenza (1990) found that the mother had greater influence on the acceptance of a novel food at 6 weeks of age more than at 12 weeks of age. It has also been found that a sensitive period for learning about new foods may be around the same time as the weaning period (Provenza and Balph 1988). This may lead to easy acceptance of novel foods at weaning.

Some of the compounds that the mother consumes may be detected through the taste of milk. Nolte and Provenza (1991) found that lambs that were exposed to onion-flavored milk developed a stronger preference for onion-flavored food and the same for lambs that were exposed to garlic-flavored milk.

Similarly, many compounds in plants cross the placenta from the mother to fetus (Nolte et al. 1992). The fetus has the ability to taste these flavors through the blood when it circulates through the tongue (Bradley and Beidler 1970). In a study conducted with garlic using sheep the taste of garlic was detected in the fetal environment for at least 100 min after it was given to the ewe (Nolte et al. 1992). This would expose the fetus to the taste for that amount of time and may cause the fetus to form a preference for the taste of juniper.

Weaning is an important time in the development of feeding preferences because of the loss of maternal influences (Hinch et al 1987, Howery et al. 1997, 1998). Likewise, experiences early in life have a larger impact on dietary preferences then experiences later in life (Provenza et al 1992, Provenza 1996). As ruminants age, food neophobia limits the number of items within the diet; ruminants are reluctant to consume novel foods as they age (Squibb et al. 1990). Thus exposure to juniper at weaning may be critical to continued use of the plant throughout life while foraging on pasture (Dietz et al. 2010).

Alternatives Methods to Improve Juniper Consumption

There is some evidence that genetic selection may improve selection of juniper as well (Campbell and Taylor 2007, Waldron et al. 2009). However, selection for juniper consumption may result in selection of other structure or growth characteristics that are not desirable (Tidwell et al. unpublished data).

Protein Supplementation improves juniper consumption by goats. Cottonseed meal (CSM) and alfalfa supplementation increased Redberry juniper intake by 40% compared to goats fed a corn supplementation and 30% for goats receiving no supplementation (Campbell et al. 2007). Protein sources high in amino acids that escape rumen degradation appear to increase juniper consumption over protein sources that are readily degradable in the rumen (George et al. 2011).

Materials and Methods

Thirty-six Boer-cross nannies were exposed to Boer billies for 76 days for breeding at the Angelo State University Management, Instruction and Research (MIR) Center. Nannies were pregnancy checked using ultrasonographic (Classic Medical, Palm Scan PSM-3.5-S) imagery to determine approximate kidding dates. When the approximant kidding dates were determined, the nannies were split into 4 treatment groups, according to kidding dates. Nannies selected for Treatment 1 were fed juniper during the third trimester of pregnancy. Nannies selected for Treatment 2 were fed juniper while lactating. Nannies selected for Treatment 3 were housed on juniper-dominated rangelands from gestation through weaning, while nannies selected for Treatment 4 were not be fed juniper (i.e., control).

The redberry juniper that was fed to the nannies in Treatment 1 and 2 was collected at the Texas Agrilife Experiment Station in Sonora, Texas (31° N; 100°W) Leaves were stripped from the trees, composited, and stored at 4°C until feeding (Utsumi et al. 2006). All nannies were housed at the MIR Center.

Nannies in the middle of the third trimester of pregnancy (Treatment 1) were placed in individual pens and fed juniper for 21 days. The nannies were given 7 days for adjustment in the individual pens (1 m X 1.5 m) where they were fed 1 pound of RAM 20 per day throughout the feeding trial to meet maintenance requirements (Table 1.). Intake of RAM 20 was measured daily throughout the feeding trial. After the 7-day adjustment period each nanny was offered 50 g of juniper daily for 21 days. Juniper was fed at 0800 each day for 30 minutes. If a nanny consumed all 50 g, the amount of

Table 1. Ingredients and nutrient content 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

juniper was increased daily until refusals were noted. Prior to kidding, the nannies were placed in a pen in a single group and fed RAM 20 until kidding. Once kidding occurred, individual kids were weighed and individually eartagged.

Nannies selected for Treatment 2 were housed in a single group and fed RAM 20 until kidding. Once kidding occurred, each kid was weighed at birth and individually ear-tagged. Each nanny was penned daily to be fed juniper for 30 minutes per day for 21 days. Kids were separated from their dams while feeding juniper to minimize the kid's exposure to the plant. Intake of juniper was monitored daily using the same feeding protocol as described above. After feeding, the nannies were released into a larger pen with their kids and RAM 20 was fed to meet maintenance and lactation requirements.

Nannies selected for Treatment 3 were transported to Texas Agrilife Experiment Station in Sonora, Texas after kidding. Kids were born at the MIR Center. Each kid was weighed, individually eartagged, and returned to their dam. Once the kids appeared in good health, nannies and kids were transported to the Texas Agrilife Experiment Station, Sonora, TX and placed in a 16.2 ha juniper-dominated pasture (20.3 % canopy cover) (Dietz 2010). Dietary selection was monitored bimonthly until weaning using the bite count method as described by Dietz et al. (2010). At weaning, nannies and kids were transported back to the MIR Center.

The control group that was housed at the MIR center and fed a balanced diet of RAM 20 throughout gestation and lactation. Once the kids were born, birth weight was recorded and each kid was individually ear-tagged.

After weaning kids from all treatments were placed in individual pens (1 m X 1.5 m) and fed juniper for 24 days. Juniper was offered daily for 30 minutes with intake recorded. Initially, all kids received 50 g of juniper. The amount offered was increased daily until refusals were noted.

Intake of juniper and RAM 20 by nannies in Treatments 1 and 2 were compared among treatments using repeated measures analysis of variance with individual nannies nested within treatments serving as replications and day of collection as the repeated measure. For nannies and kids exposed to juniper on pasture, bite count data was compared among classes of forages (juniper, other shrubs, herbaceous forage) by calculating means and standard errors. Intake of juniper and alfalfa pellets by kids was analyzed using the same model utilized to compare differences in intake of juniper and Ram 20 by nannies. For the kid data intake data was also compared among periods (day 1-7, day 8-14, day 15-21). Birth weights were compared among treatments using analysis of variance with treatment group and the main effect. Means were separated using Tukey's least significant difference when $P<0.05$. Data was analyzed using the statistical package JMP (SAS 2007).

Results

Of 36 nannies exposed to billies, 24 nannies became pregnant and were divided into 4 treatments for this study. Seven nannies lost their kids due to kidding problems and extreme weather conditions during kidding. Therefore, 24 of the 36 nannies weaned 31 kids resulting in a 129% kidding percentage.

Of the 31 kids, 25 were exposed to juniper through a form of maternal influence. Six kids were exposed to juniper in the uterus during the third trimester of pregnancy (3^{rd}), nine kids were exposed to juniper through the nannies milk by lactation (Lac), eight kids were exposed to juniper through social facilitation (SF) and six kids served as a control for this study (Con). The sample size for each treatment differed due to the parturition problems at kidding and some of the yearling nannies had difficulty carrying the fetus for the full pregnancy.

Eight nannies were fed juniper in the third trimester in individual pens where intake was monitored daily. Intake increased ($P < 0.05$) daily for all nannies (Fig 1). Intake on day one was (.33$\pm$ .40 $g \bullet kg^{-1}$ BW) and on day 21 was at (2.2$\pm$ .39 $g \bullet kg^{-1}$ BW). These nannies weaned six kids, which consumed (.11 $\pm$ .45 $g \bullet kg^{-1}$ BW) on day 1 to (3.0$\pm$ .45 $g \bullet kg^{-1}$ BW) on day 24.

Eight nannies were fed juniper during lactation for 21 days. All nannies increased intake across the 21 days of feeding (Fig 2). Intake on day 1 was (.34$\pm$ .16 $g \bullet kg^{-1}$ BW) and on day 21 was (1.4$\pm$ .16 $g \bullet kg^{-1}$ BW). Nine kids were weaned from these nannies with the kids consuming (0.17$\pm$.37 $g \bullet kg^{-1}$ BW) on day 1 and on day 24 was (3.5$\pm$ .37 $g \bullet kg^{-1}$ BW).

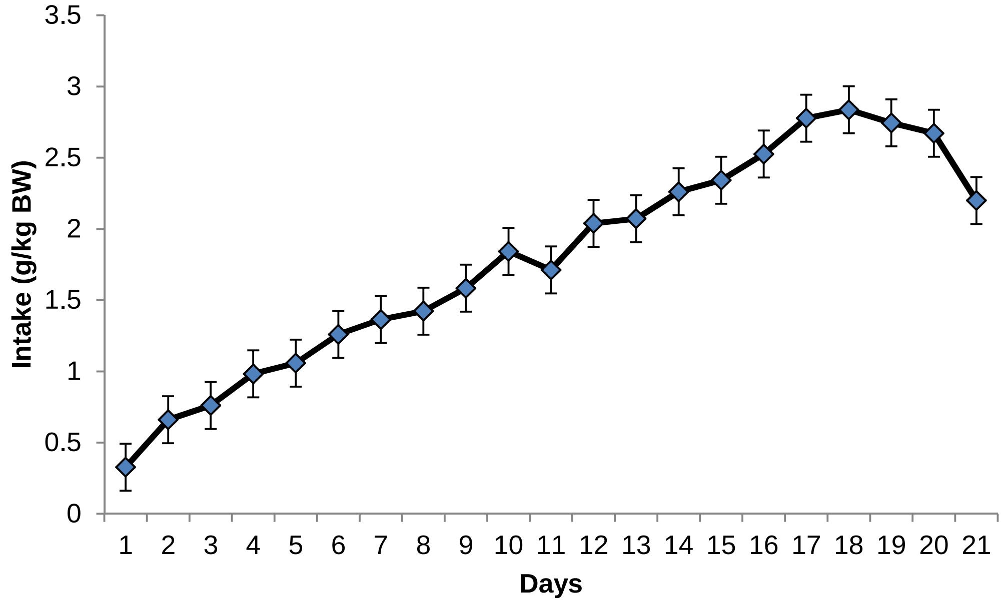

Figure 1. Intake (g•kg^{-1} BW) of redberry juniper fed to nannies in the third trimester. Goats were fed juniper for ½ hour daily for 21 days and intake was monitored daily. Goats were also fed basal diet of Ram 20 (2% BW) to meet maintenance requirements.

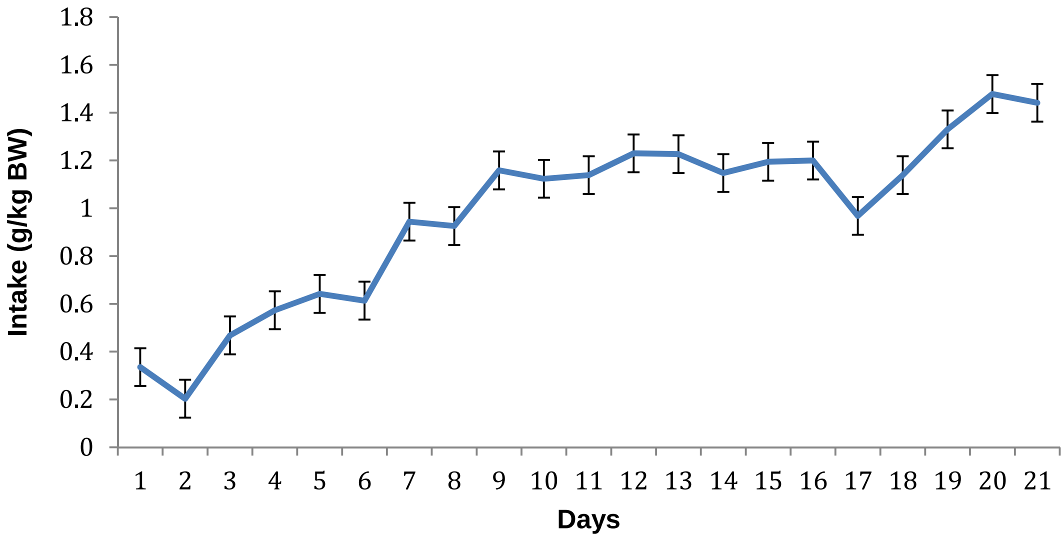

Figure 2. Intake ($g \bullet kg^{-1}$ BW) of redberry juniper fed to nannies that were lactating. Nannies were separated from kids once a day and fed redberry juniper individually or 21 days and intake was monitored daily. Goats were also fed basal diet of Ram 20 (2% BW) to meet maintenance requirements.

Four nannies were exposed to juniper through grazing on juniper-infested rangeland. The four nannies selected 38.1 percent of their diet in juniper, 50.0 percent in herbaceous (grass and forbs) and 11.2 percent of diet in other shrubs (Table 2). These nannies raised eight kids that consumed (.92$\pm$ .39 g•kg^{-1} BW) on day 1 and (4.3$\pm$ 0.3 g•kg^{-1} BW) on day 24.

Birth weights were analyzed between treatments with the mean birth weight of each treatment being compared to other treatments. The mean birth weights per treatment were (3rd 2.83, Lac 3.31, SF 3.25 and Con 2.81 kg). Feeding juniper to nannies while pregnant did not appear to have any effect of birth weights (Figure 3).

When offspring were weaned, they were placed in individual pens and fed juniper, juniper intake was similar between treatments (Table 3). Likewise, all treatments increased in juniper intake throughout the feeding trial (Figure 4). The hypothesis that one type of maternal influence would increase juniper consumption was rejected.

The treatment X day interaction did not differ. However, there was a treatment X period interaction, with the SF treatment consuming more ($P<0.05$) juniper than the other treatments during period 1 of the feeding trial (Table 4).

Table 2. Preference of nannies in SF treatment for herbaceous vegetation, juniper or other shrubs (percent of total bites) for nannies grazing with kids on juniper dominated rangeland.

Forage type	% of Diet	SEM
Herbaceous	50.0	0.14
Juniper	38.1	0.11
Other Shrubs	11.2	0.05

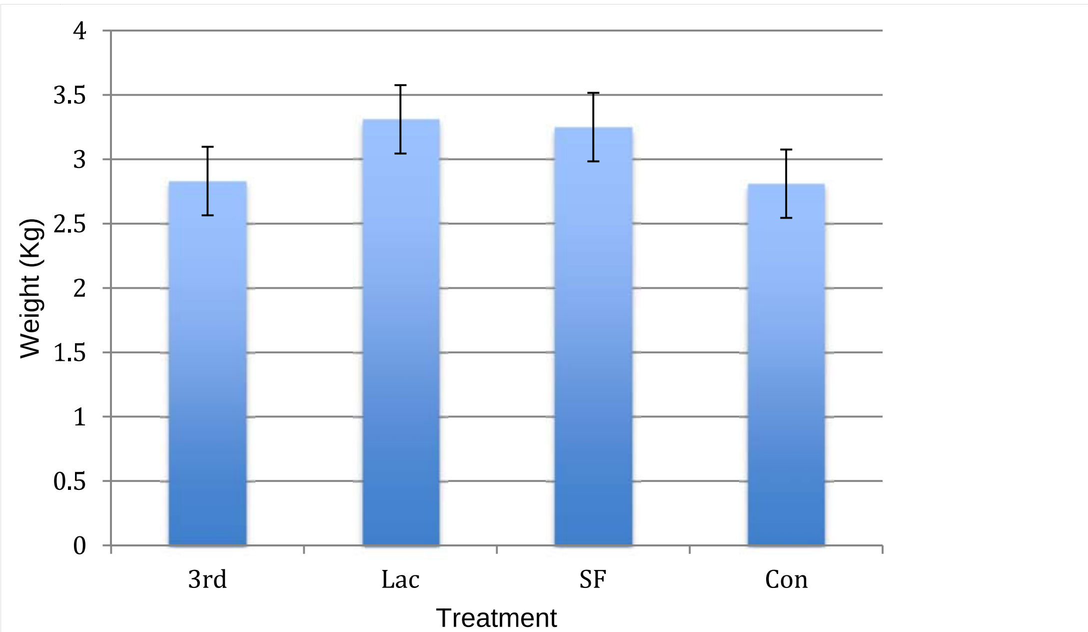

Figure 3. Average birth weights of kids by treatment.

Table 3. Consumption of juniper by treatment for day 1-24 when kids were weaned and placed in individual pens for 24 days.

Treatment	Mean	SEM
SF	2.9^{a}	0.3
Con	2.0^{ab}	0.3
Lac	1.7^{ab}	0.3
3rd	1.7^{b}	0.3

$^{a-b}$ Means within columns with different superscripts differ ($P<0.05$)

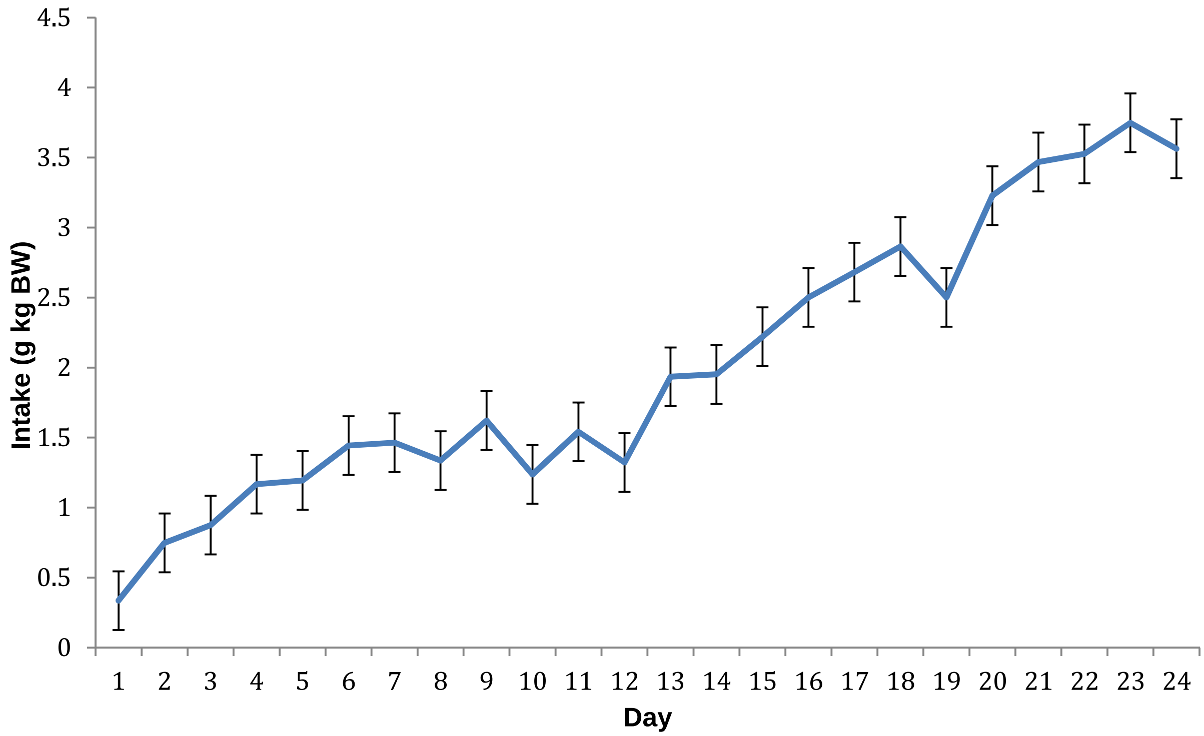

Figure 4. Intake (g•kg^{-1} BW) of redberry juniper of all treatments pooled together during final feeding trial. Goats were offered juniper daily for ½ hour where intake was monitored daily. Goats were also fed basal diet of alfalfa (2.5% BW) to meet maintenance requirements.

Table 4. Consumption of juniper by treatment for period 1 day 1-7 when kids were weaned and placed in individual pens.

Treatment	Mean	SEM
SF	1.6[a]	0.1
Con	0.9[b]	0.1
Lac	0.8[b]	0.1
3rd	0.7[b]	0.1

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

Goats were reluctant to consume juniper on day 1 but began increasing juniper intake each day after that. Juniper consumption from all treatments increased throughout the feeding trial, with the SF consuming more in the first period of the trial. Juniper consumption for the kids exposed in the third trimester increased throughout the trial; started at (.11 $\pm$ .45 g•kg^{-1} BW) on day 1 to (3.03$\pm$ .45 g•kg^{-1} BW) on day 24. The juniper consumption for the kids exposed through lactation at day 1 was (0.17$\pm$.37 g•kg^{-1} BW) and on day 24 was (3.53$\pm$ .37 g•kg^{-1} BW). The SF treatment at day 1 was (.92$\pm$ .39 g•kg^{-1} BW) and (4.32$\pm$ 0.39 g•kg^{-1} BW) on day 24. The control treatment consumed (.12$\pm$ 0.45 g•kg^{-1} BW) of juniper on day 1 and (3.35$\pm$ 0.45 g•kg^{-1} BW) on day 24. Juniper consumption from all treatments steadily increased throughout the trial from an average of (.33$\pm$ 0.21 g•kg^{-1} BW) on the first day to (3.56$\pm$ .21 g•kg^{-1}) on the last day of feeding. The hypothesis that exposure to juniper at weaning would increase consumption of juniper regardless of maternal influence was confirmed.

The alfalfa consumption (Figure 4) varied from days 1 to 15 with a decrease at day 9 to (10.14$\pm$ 0.24 g•kg^{-1} BW). From day 16 to day 24 the alfalfa consumption stayed consistent at (11.33$\pm$ 0.24 g•kg^{-1} BW) regardless of juniper intake.

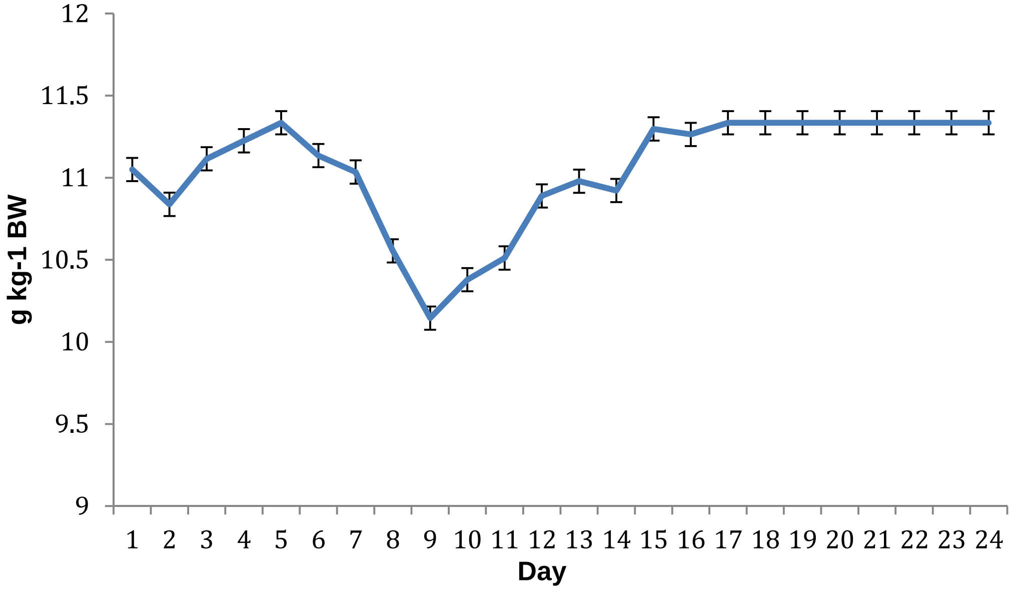

Figure 5. Intake (g•kg^{-1} BW) of alfalfa by kids across all treatments during final feeding trial. Goats were fed alfalfa individually where intake was monitored daily.

Discussion

Results from this study support the hypothesis that goats will increase intake of juniper when being fed in individual pens at weaning (Bisson et al. 2001; Ellis et al. 2005; Dunson et. al 2007). Kids from all treatment groups increased intake throughout the 24 day feeding trial. Dietz et al. (2010) showed that goats would continue to consume juniper once released on pasture, consuming 30% of their diet in juniper. This study complements the conclusions of other studies that feeding juniper at weaning will increase intake and subsequent consumption on pasture. Others continue to argue that genetic selection for juniper consumption will increase consumption on pasture (Waldron et al. 2009, Campbell and Taylor 2007). However, genetic selection for juniper consumption may require selection for a single trait (i.e. intake of juniper) over several generations ignoring other production characteristics that many producers may desire for a marketable product. Feeding juniper at weaning should allow producers to continue selection for production characteristics while improving juniper consumption on pasture.

If maternal influence had an effect on diet selection, kids from one of the treatment groups (SF, Lac, and 3rd) should have either (1) consumed juniper at a faster rate, or (2) consumed more juniper than kids from other treatments. All treatment groups increased in consumption at approximately the same rate with the exception being the goats in the SF treatment, which consumed more ($P<0.05$) juniper in the first period of the feeding trial than the other treatments. After the first period of the feeding trial, all treatments increased at the same rate consuming approximately the same amount of juniper.

Kids that were exposed to juniper while foraging with their mother consumed more juniper in the first period of the feeding trial, apparently because they were familiar with juniper while other kids were naïve to the plant. Maternal influence maybe greater on diet preferences then other social models (Thorhallsdottir et al1990). Exposure with the mother at an earlier age has a greater impact on dietary preferences (Mirza and Provenza 1990). Apparently the flavor of juniper does not pass through in utero or via milk. Offspring from the nannies fed juniper during the third trimester and during lactation consumed the same amount of juniper during the first 7 days of exposure as kids naïve to juniper (control). With some foods and flavors, maternal influences strongly influenced diet and habitat selection. For instance, garlic can enter the fetal environment, where the taste can be detected for a period of time after the mother consumed the plant (Nolte et al. 1992), thereafter, lambs consumed more garlic-flavored food.

Nolte and Provenza (1991) found that when lambs were exposed to onion flavored milk they developed a preference for onion flavored food and the same for garlic flavored milk, which developed a preference for garlic flavored food. Likewise Nolte (1992) found that plant compounds, such as garlic, cross the placental barrier and are detected in the amniotic fluid. Apparently, the compounds of redberry juniper do not influence the flavor of the nannies milk or it is possible the toxins (monoterpenoids) prevented the kids from forming a preference to juniper through the flavor of the milk. It appears that redberry juniper does not pass through the uterine wall, therefore; not exposing the fetus in the uterus.

Maternal influence has played a role in diet selection among species such as leafy spurge (*Euphorbia esula* L.) and tansy ragwort (*Senecio jacobaea* L.); and it has influenced habitat selection. Animals that experience a certain habitat early in life have been shown to impact the animal's home range later in life (Howery et al. 1997, 1998). For example replacement heifers preferred the same home ranges and habitat types as their dams and returned to the same locations even in years when forage and water were depleted because of drought conditions.

Learning from mother and other social models increases the rate of acceptance of nutritious food and reduces the likelihood of consuming toxic plants (Provenza 1996). Foraging with nannies that readily accept juniper should facilitate juniper acceptance at weaning. Recently weaned goats should begin consuming juniper at a faster rate than kids naïve to juniper. However, most goats will readily consume juniper after 14 days of exposure irrespective of familiarity with the plant. Exposure with mom may reduce the number of days required for goats to readily accept juniper as a dietary item.

Implications

Producers should select replacement nannies from areas dominated by juniper. Once kids are selected, they should be penned at weaning and fed juniper daily. Because Initial over-ingestion may cause formation of conditioned food aversions and subsequent avoidance of the plant (Dietz et al 2010), producers should slowly increase the amount of juniper available over 14 days of exposure if possible. Available juniper should be limited to <50 g hd$^{<-1}$day^{-1} for the first few days of feeding. Producers should also provide supplemental protein to goats foraging on juniper-dominated rangelands. Protein supplementation especially during the dormant season should further improve juniper consumption (George et al 2011).

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