Feeding Shinoak to Meat Goats Improves Four-wing Saltbush and Total Intake

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ABSTRACT

Herbivores consume a variety of foods that contain toxins in order to increase food intake, but typically avoid over ingestion of any single toxic food. Four-wing saltbush (*Atriplex canescens*) and shinoak (*Quercus havardii*) are two shrubs common to the southwestern United States that are consumed by ruminants, but intake is limited to avoid toxicity. Four-wing saltbush contains saponins while shinoak contains tannins. Saponins and tannins may chelate in the digestive tract of ruminants which would reduce the toxicity of both. We compared intake of four-wing saltbush and shinoak singly and together to determine if feeding both shrubs increased overall intake or intake of either shrub. In addition, alfalfa hay (saponin-containing plant) was fed with shinoak to determine if intake of shinoak would increase when alfalfa was fed. The study used 39 freshly weaned Boer-cross goats. Each was individually penned and then randomly assigned to 1 of 5 treatments. Eight were fed four-wing saltbush, eight were fed shinoak, eight were fed both, eight were fed shinoak and alfalfa, and seven were fed a basal ration for two weeks. Goats preferred shinoak to four-wing saltbush when each was fed alone. When both were offered simultaneously, goats ate more four-wing saltbush than when it was fed alone. Total intake was also increased when both shrubs were fed and when alfalfa was fed with shinoak. Feeding four-wing saltbush or alfalfa did not affect shinoak intake. Serum levels indicative of toxicosis were similar among treatments. Tannins and saponins may chelate in the digestive tract of ruminants when they are consumed simultaneously thereby increasing overall intake and decreasing the likelihood of experiencing toxicity.

KEY WORDS: intake, chelation, rangelands, food aversions, toxins

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INTRODUCTION

Herbivores may consume a variety of foods that contain different toxins to increase nutrient intake and to avoid toxicosis (Freeland and Janzen 1974, Westoby 1978, Provenza 1995). A varied diet should enhance an animal's ability to meet its nutritional needs when foraging on plants with secondary compounds provided the toxins have different physiologic effects, are detoxified by independent metabolic pathways, and do not interact with each other to become more toxic (Freeland and Janzen 1974, Burritt and Provenza 2000). While ruminants typically avoid over ingestion of toxic plants, complete avoidance of toxic plants in arid regions may result in nutritional deficiencies.

Tannins and saponins are among the more common classes of phytochemicals used as defenses by plants (Cheeke 1998). While both toxins can limit intake in animals, each affects the animal differently. Tannins can bind up nutrients that are consumed making them unavailable for digestion, which affects enzymatic and microbial activity mainly in the rumen and intestine. The reduction in substrate, microbial and enzymatic activity reduces levels of volatile fatty acids in the rumen (Makkar et al., 1995). Reduced volatile fatty acid levels lower food quality and palatability. Saponins are triterpenoid glycosides that can cause aversive postingestive feedback, anorexia, gastroenteritis, diarrhea, and kidney failure in ruminants (Cheeke 1998). They may also have the effect of being powerful surfactants and hemolytic agents (Scheline 1991). Herbivores may be able to overcome the toxic effects of tannins and saponins by simultaneously consuming both because tannins and saponins may chelate in the intestinal tract thereby reducing the aversive effect of both compounds (Freeland et al., 1985).

Four-wing saltbush (*Atriplex canescens*) and shinoak (*Quercus havardii*) are common throughout the southwestern United States. Four-wing saltbush contains saponins while shinoak contains tannins. A study was designed to determine the complementary and physiologic effects of tannins and saponins as they relate to intake, weight gain, and serum level when they are fed singly and together. Both of these plants have a relatively high nutritive value, even though they both contain toxins. Given their widespread distribution throughout the southwestern United States, they have potential importance as forage for browsing ruminants. It is difficult though to determine how these two toxins may react with each other because little information is available on diet selection when both shrubs are available. The purpose of this study was to quantify differences in intake related to the ingestion of tannins and saponins fed singly compared to being fed in conjunction with each other. We hypothesized that feeding tannin- and saponin-containing plants simultaneously would increase intake of both.

MATERIALS AND METHODS

This study was conducted during the summer and fall of 2003 at Angelo State University's Management, Instruction, and Research (MIR) Center, San Angelo, TX (31E N; 100E W). Intake along with serum metabolite levels were monitored throughout. Research objectives for this study were addressed by placing goats in individual pens and feeding tannin- and saponin-containing plants. In addition to receiving shrubs, all goats received a basal diet (2% BW) to meet maintenance requirements (NRC 1981) (Table 1). Fresh water was provided *ad libitum* to all goats during testing in individual pens.

Table 1. Ingredients and nutrient content of ration fed to goats to meet maintenance requirements.

Ingredient	**Percent in the Diet**
Alfalfa	17
Corn Grain	45
Cottonseed meal	10
Soybean hulls	22.5
Cane molasses	3
Premix	2.5
Nutrient	
Crude protein	14.4
Crude fiber	13.7
Digestible energy	2.8 Mcal/kg
TDN	62.7

Shinoak leaves were collected on the Coleman Ranch in Colorado City, TX in July 2003 and then transported to the Angelo State University's MIR Center where they were air-dried and stored until feeding. Four-wing saltbush leaves were collected on established plots located on the Angelo State University MIR Center. Both four-wing saltbush and shinoak leaves were stored separately throughout both trials in similar environmental conditions.

A pretrial was conducted to quantify levels of *ad libitum* intake of four-wing saltbush and shinoak. Levels were established by individually penning 14 castrated male Boer-cross goats (0=45 kg). Seven were fed four-wing saltbush and seven were fed shinoak. All goats received a basal diet (2% BW) to meet maintenance requirements (Table 1).

Once *ad libitum* intake levels were established, 39 different freshly weaned mixed sexed (average weight 45 kg) Boer-cross goats were placed in individual pens after weaning. Eight were fed shinoak, eight fed four-wing saltbush, eight fed both, eight were fed shinoak and alfalfa, and seven were fed only the basal ration for 14 days. Each food item (shinoak, four-wing saltbush, alfalfa) were fed for 1 hr daily for 14 days. Initially, 50 g of each was fed to each goat. If goats consumed all that was offered, the amount fed was increased daily to the point of refusal. Intake was monitored daily.

Serum metabolite levels were monitored every 72 hrs to assess liver and tissue damage from toxicosis. Blood samples were collected via jugular venipuncture, centrifuged, frozen, and transported to the Texas A&M University Medical Diagnostic Lab for analysis. Changes in serum metabolite levels are often indicative of toxicosis (Cornelius 1989, Calhoun et al., 1981). Serum metabolites measured included serum aspartate transaminase (AST), gamma glutamyltransferase (GGT), blood urea nitrogen (BUN), and creatinine (CREAT). Increases in serum metabolite levels, particularly GGT and AST levels, are indicative of liver damage while increases in creatinine are indicative of kidney damage. In addition, any weight changes were determined at the end of the trial.

Differences between treatments for intake, serum metabolite levels, and weight change were assessed using repeated measures analysis of variance with individual goats as replications nested within treatments and day of observation as the repeated measure (Hicks 1993). Differences among means were determined using the LSD test when P<0.05 (Gomez and Gomez 1984). The statistical package JMP was used for all analyses (SAS 2007).

RESULTS

Goats readily consumed shinoak and four-wing saltbush when each was fed alone; however, intake differed between the two species. Goats consumed more shinoak than four-wing saltbush (91.0 g vs 60.0 g SEM=5.3) on a daily basis. The diet by day interaction also differed (Fig. 1). Intake was similar for days 1 through 6; however, on day 7, goats consumed more of the shinoak daily every day thereafter. Four-wing saltbush intake varied between treatments. Goats that were offered four-wing saltbush and shinoak consumed more four-wing saltbush than goats that were offered four-wing saltbush alone (Table 2). Intake for goats also varied by treatment and day (Fig. 2). Intake of both diets varied daily; however, goats ate more four-wing saltbush on most days when they were also fed both shinoak.

Shinoak intake was similar for goats receiving shinoak alone, shinoak and four-wing saltbush, or shinoak and alfalfa (Table 2). However, the treatment by day interaction differed (Fig. 3). Goats typically consumed more shinoak when it was fed with four-wing saltbush than when it was fed alone or with alfalfa.

Total intake varied between treatments (Table 2) and across days of feeding (Fig 4). Total intake was higher for goats that were offered shinoak with four-wing saltbush or shinoak with alfalfa compared to feeding either shrub alone. Total intake was lower for the control group (basal ration only) when compared to inclusion of a shrub or alfalfa in the diet.

Serum metabolite levels of gamma glutamytransferase (GGT), serum aspartate transaminase (AST), and creatinine were similar among treatments (Table 3). The treatment by day interaction was not significant for any of the serum metabolites measured. Weight change was similar among treatments (Table 4).

Table 2. Average intake of four-wing saltbush, shinoak, and total intake for treatments fed food items singly or in combination

Treatment	Four-wing	Shinoak	Total
Four-wing	24.8[b]	--	524.8[b]
Shinoak	--	38.6	538.6[b]
Four-wing +Shinoak	36.6[a]	44	580.6[a]
Alfalfa + Shinoak	--	36.6	582.7[a]
Control	--	--	500[c]

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

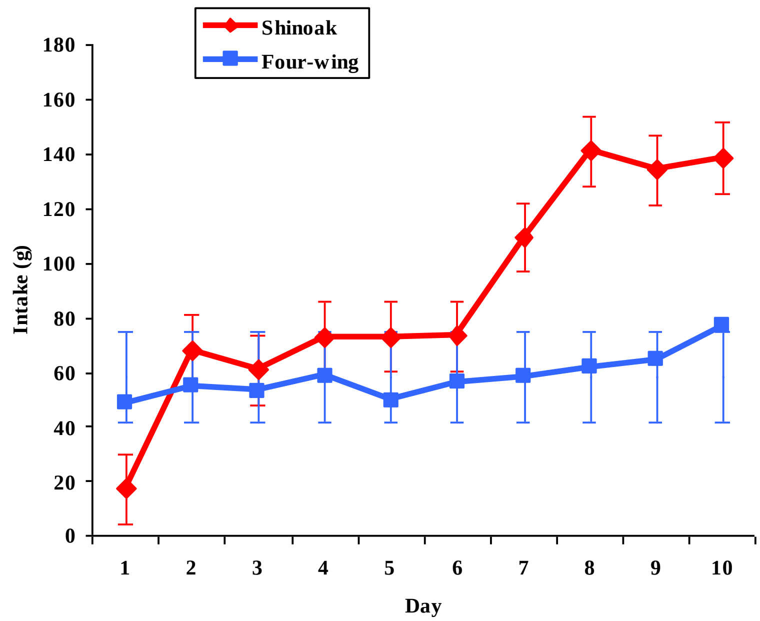

Figure 1. Intake of shinoak and four-wing saltbush when each was fed separately during the pre-trial.

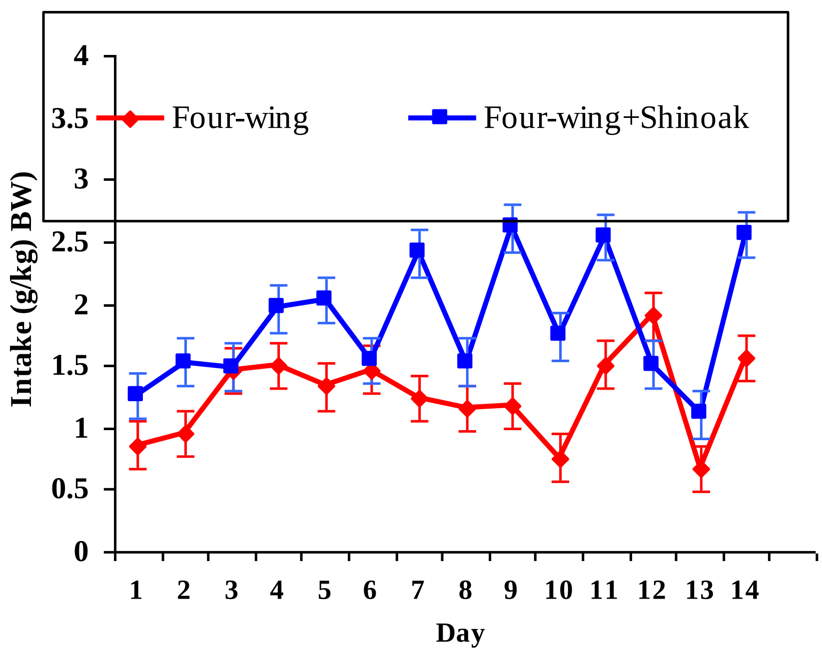

Figure 2. Intake of four-wing saltbush when it was fed singly versus when it was fed with shinoak

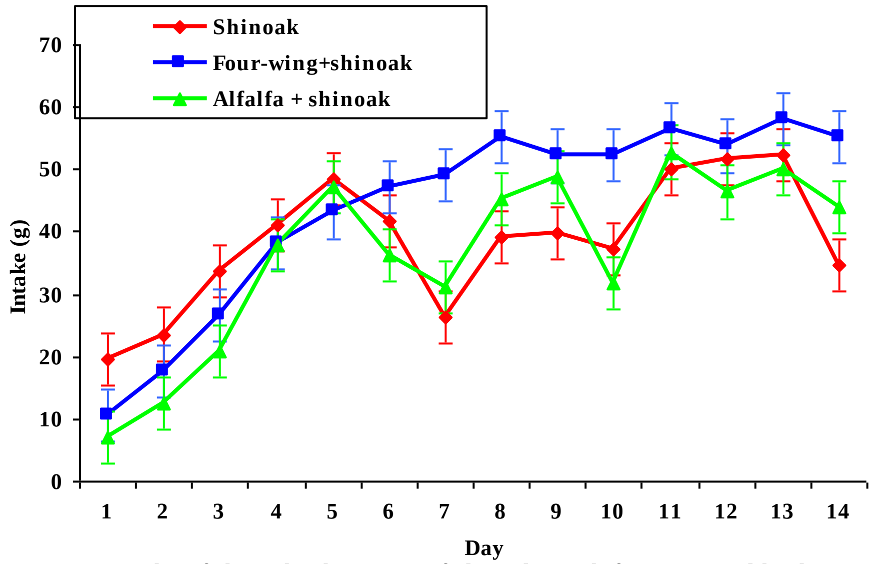

Figure 3. Intake of shinoak when it was fed singly, with four-wing saltbush, or with alfalfa hay

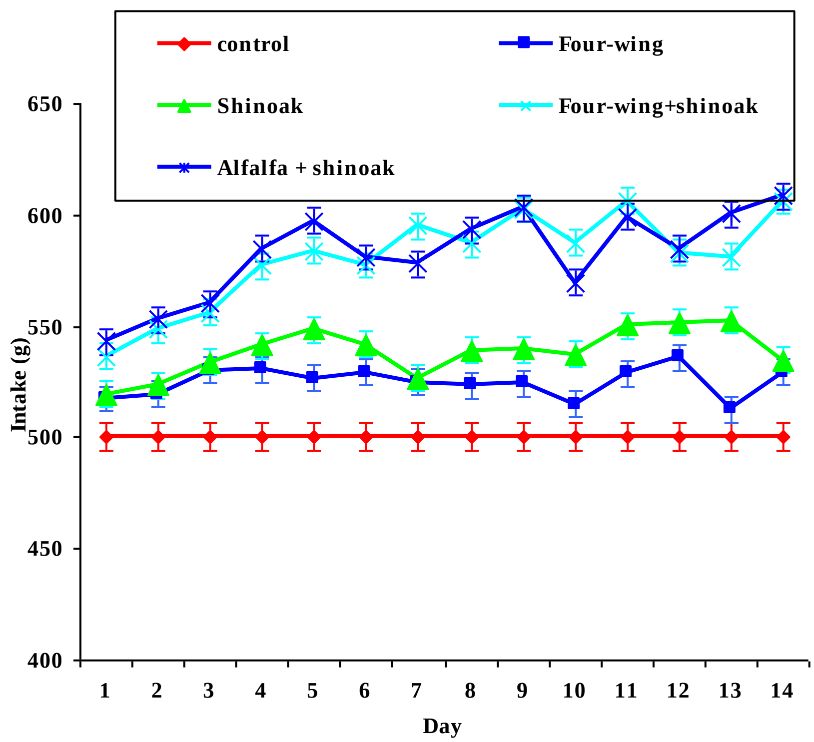

Figure 4. Total intake between treatments on a daily basis. Each treatment was fed a basal diet (2% BW) and either four-wing saltbush, shinoak, both, shinoak with alfalfa hay or neither shrub

Table 3.Serum metabolite levels for treatments fed different combinations of a basal diet with four-wing saltbush, shinoak, and alfalfa. Samples were collected on days 0, 4, 8, 12 and 16 of the study. Serum levels on day 0 were used as a covariate to account for variation among individual goats

	Serum Metabolite Levels		
Treatment	**Creatinine**	**AST**	**GGT**
Four-wing	0.76∀0.05	46.9∀3.1	51.7∀1.8
Shinoak	0.74∀0.05	49.1∀2.8	47.0∀1.6
Four-wing + Shinoak	0.74∀0.05	51.8∀2.9	48.0∀1.7
Alfalfa + Shinoak	0.78∀0.05	49.0∀2.9	47.0∀1.7
Control	0.80∀0.05	48.4∀3.1	51.8∀1.8
Normal range	0.4-1.2	32-152	<319

Table 4. Weight change for treatments fed different combinations of a basal diet with four-wing saltbush, shinoak, and alfalfa. Weights were recorded at the beginning and end of the study

	Weight (kg)		
Treatment	**Initial**	**Ending**	**SEM**
Four-wing	44.8	43.2	3.5
Shinoak	39.5	37.6	3.5
Four-wing + Shinoak	44.9	43.2	3.5
Alfalfa + Shinoak	45.8	43.9	3.5
Control	46.6	44.1	3.8

DISCUSSION

Shinoak was apparently less aversive than four-wing saltbush during this study. Four-wing saltbush is sometimes planted as forage for livestock and wildlife in central and western Texas. It is also found growing on native southwestern rangelands and is considered a nutritious, preferred browse plant (Marquart et al., 1992). Conversely, shinoak is considered a problematic species, out-competing other browse plants and herbaceous forage on many southwestern rangelands. Data from this study illustrates that shinoak may be preferred over four-wing saltbush.

When feeding both shrubs, intake increased for four-wing saltbush but not for shinoak. However, shinoak intake remained high throughout the study for goats fed shinoak singly, with four-wing saltbush, or with alfalfa. Shinoak was collected during July (approximately 45 days after bud break). Tannin levels are high in new growth during bud break in the spring and decrease thereafter (Villena and Pfister 1990). Shinoak, because of decreased tannin levels, may not have been aversive to goats in this study. Nevertheless, tannins do not disappear during summer months. It is reasonable to assume that shinoak contained some level of tannins during this study (Villena and Pfister 1990).

The increase in four-wing saltbush intake confirms the hypothesis that the saponins in four-wing saltbush and tannins in shinoak may have chelated in the small intestine of goats. Conversely, the lack of difference in shinoak intake does not support the hypothesis. The hypothesis of this study was that feeding both four-wing saltbush and shinoak would increase intake of each because of chelation of toxins. Given the different patterns of intake when comparing the two shrubs, we cannot confirm nor reject the hypothesis. However, other studies do offer some support for chelation of tannins and saponins. Saponins in small grains (e.g., wheat) often cause bloat in cattle grazing in the High Plains region of Texas. Recent research suggests that inclusion of therapeutic levels of condensed tannins in the diet reduce the number of bloat incidences from saponin ingestion (Bill Pinchak, pers. comm.).

When goats were offered alfalfa (saponin-containing plant), shinoak intake did not improve. The hypothesis of this study was that inclusion of alfalfa in the diet would increase intake of shinoak was not confirmed. If tannin levels would have been higher in shinoak, results may have been different in both trials. Future studies should feed shinoak leaves collected soon after budbreak.

Serum metabolite levels were similar among treatments and remained within the range for healthy goats (Table 3). Weight change was also similar among treatments (Table 4). It does not appear that goats experienced any physiological damage from consumption of four-wing saltbush or shinoak (Cheeke 1998, Vermeire and Wester 2001).

Goats consumed four-wing saltbush throughout the trial when it was fed singly and with shinoak despite the fact that it apparently caused aversive post-ingestive feedback. Ruminants typically consume more forage when fed a variety of foods that differ in nutrients and toxins than when a single food if fed (Provenza 1996, Wang and Provenza 1996, Provenza et al., 2003). The maintenance ration used in this study (Table 1) was formulated to meet maintenance requirements for growing goats. Goats could have met their nutritional requirements by avoiding four-wing saltbush or shinoak. Nevertheless, they always ate some four-wing saltbush or shinoak. This study and others (Provenza et al.,1996, Wang and Provenza 1996) have illustrated that ruminants will consume more when a variety of foods varying in nutrients and toxins are available.

Tannin and saponin levels were not measured in this study. Even though absolute levels of each were not known, it can be assumed that four-wing saltbush contained saponins that caused aversive post-ingestive feedback as evident from the lower levels of intake of four-wing saltbush. Palatability is a complex process that integrates the taste, odor, and texture of foods with post-ingestive feedback (Provenza 1995). As intake of toxins that result in aversive post-ingestive feedback increase, palatability decreases. Thus, reduced intake of four-wing saltbush illustrates that it remained aversive, apparently from saponin levels within the plant.

Goats in this study may have relied on other physiological mechanisms to circumvent toxicosis. Many foreign compounds (i.e., toxins) are bio-transformed by chemical reactions to reduce toxicity (Nebbia 2001). Most toxins are absorbed as lipid soluble substances are then metabolized in the body to water soluble metabolites that can then be excreted in the urine (Cheeke 1998). Thus, goats may have been able to detoxify the tannins in shinoak which resulted in higher intake.

Diet quality affects ruminants' ability to detoxify some toxic plants. Energy and nitrogen are required to maintain rumen microbial populations in the rumen and liver function that are involved in the breakdown on toxic substances (Bidlack et al., 1986, Illius and Jessop 1995). Protein supplementation improved redberry juniper (*Juniperus pinchottii*) intake over energy intake, apparently because of improved rumen and liver efficiency (Taylor et al., 1997). Recent research has also illustrated that feeding protein sources high in escape proteins improved consumption of redberry juniper more than supplements with highly soluble protein sources (George et al., 2008). Similarly, supplementation with protein sources high in sulfur-containing amino acids improved the livers ability to detoxify hymenoxon, the toxic substance in bitterweed (*Hymenoxys odorata*) (Ueckert and Calhoun 1988, Calhoun et al., 1989). In some cases, energy supplementation has also improved intake of poisonous shrubs. Intake of big sagebrush (*Artemisia tridentata*) was improved when lambs received supplemental barley (Banner et al. 2000, Burritt et al., 2000).

All treatments received the same nutritious basal diet. Any benefit in terms of supplying nutrients from the basal diet should have been the same given they were all fed the same basal diet and ate the same amount. It is possible that shinoak provided some essential nutrients used to detoxify saponins. Oaks are typically high in condensed tannins which form complexes with proteins reducing their degradation in the rumen (Cheeke 1998). If some amino acids escaped rumen metabolism, they could have been absorbed in the small intestine and improved metabolism of toxins in the liver.

IMPLICATIONS

Ruminants that have the opportunity to utilize a diverse array of forage are better able to meet their nutritional needs on rangelands. By managing for increased levels of plant diversity, producers are able to increase intake and utilize more of the forage that is present on their land. With a varied diet, ruminants will be more likely to meet their nutritional needs much more efficiently. Increased intake will, in turn lead, to an increase in performance. Likewise, supplementation costs should be lower because of greater nutrient intake from a varied diet.

Usually when shrubs are planted or re-established to improve browse quality for livestock and wildlife, a single species, like four-wing saltbush, is planted. Land managers should consider planting a variety of shrubs to improve nutrient quality and limit the likelihood of over-ingestion of toxic plants. Arguably, all foods are toxic. Over-ingestion of any forage can result in internal malaise. Providing a variety of forages will limit the opportunity for plant-induced toxicity in livestock.

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