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Activated charcoal and experience affect intake of juniper by goats

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Abstract

Goats consume juniper, but toxic terpenoids within the plant limit intake. Our objective was to determine if dosing goats with the adsorptive compound activated charcoal would increase juniper consumption. Twenty Boer-cross goats were placed in individual pens; at 0800 hours, 10 were dosed with 1 g kg^{-1} body weight (BW) of activated charcoal in an aqueous solution, and 10 were not dosed. Dosing occurred daily for 10 days. Goats were offered redberry juniper (*Juniperus pinchotii* Sudw.) in Trial 1, ashe juniper (*Juniperus ashei* Buch.) in Trial 2, and a choice between redberry and ashe juniper in Trial 3. For each trial, juniper was offered to all goats for 2 hours after dosing with activated charcoal. In Trial 1, goats dosed with activated charcoal consumed more ($P < 0.05$) redberry juniper during the first 5 days of exposure. In Trial 2, activated charcoal did not affect ashe juniper intake. In Trial 3, dosing with activated charcoal did not affect juniper intake. All goats preferred ashe to redberry juniper. Juniper intake increased across days of exposure for Trials 1 and 2, apparently because goats adapted to the terpenoids in juniper through repeated exposure. It appears that activated charcoal will only increase redberry juniper intake during initial exposures.

Key Words: *Juniperus, J. ashei, J. pinchotii, Capra,* experience, preference, toxicosis, feedback, aversions, browsing

Resumen

Los caprinos consumen el “Juniper”, pero los terpenoides tóxicos que contiene la planta limitan su consumo. Nuestro objetivo fue determinar si la administración a los caprinos del compuesto adsortivo carbón activado incrementaría el consumo de “Juniper”. 20 cabras de cruza Boer se colocaron en corrales individuales a las 0800 horas, a 10 se les administro1 g kg^{-1} de peso vivo (PV) de carbón activado en solución acuosa y las 10 restantes no recibieron carbón activado. La administración del carbón activado fue diaria durante 10 días. En el experimento 1 a las cabras se les ofrecio “Redberry juniper” (*Juniper pinchotti* Sudw.), en el experimento 2 se les ofrecio “Ashe juniper” (*Juniperus ashei* Buch.) y en un tercer experimento se les ofrecio a libre elección “Redberry juniper” y “Ashe juniper”. En cada experimento el “Juniper” se les ofrecio a todas las cabras 2 horas después de administrarles el carbón activado. En el experimento 1, durante los primeros 5 días, las cabras que recibieron carbón activado consumieron más ($P < 0.05$) “Redberry juniper”. En el experimento 2, el carbón activado no afecto el consumo de “Ashe juniper”. En el experimento 3, la administración de carbón activado no afectó el consumo de “Juniper”. Todas las cabras perfirieron “Ashe juniper” que “Redberry juniper”. En los experimentos 1 y 2 el consumo de “Juniper” aumentó a través de los días de exposición, aparentemente porque las cabras se adaptaron a los terpenoides del “Juniper” por la exposición repetida a la que estuvieron sometidas. Parece que el carbón activado solo incrementará el consumo de “Redberry juniper” durante el inicio de exposición a él.

Redberry (*Juniperus pinchotii* Sudw.) and ashe (*Juniperus ashei* Buch.) juniper are increasing over most of central and western Texas (Smeins et al. 1997). In the Rolling Plains region of Texas, redberry juniper is common while ashe juniper or a mixture of redberry and ashe juniper occur throughout the Edwards Plateau of Texas (Ansley et al. 1995, Smeins and Fuhlendorf 1997, Ueckert 1997). Control alternatives are available, but most are expensive and may adversely impact other desirable shrubs (Reinecke et al. 1997, Johnson et al. 1999). Recent efforts have focused on training goats to consume juniper (Launchbaugh et al. 1997, Pritz et al. 1997) or selecting replacements for the flock from goats that readily consume juniper (Jones et al. unpubl. data).

Intake of a particular plant species depends on the herbivore’s ingestive and digestive abilities and familiarity with the forage (Provenza 1995, 1996). When herbivores encounter and consume chemically defended plants for the first time, 2 responses typically occur. Most toxins cause aversive postingestive feedback and the formation of conditioned taste aversions (Provenza et al. 1992). Thus, herbivores usually avoid toxic plants after the initial consumption. If alternative forage is limited, herbivores may continue to consume the toxic plant but limit intake below toxic levels (Launchbaugh et al. 1993). Both responses limit the effectiveness of using livestock herbivory to control chemically defended plants such as redberry and ashe juniper.

Both redberry and ashe juniper contain terpenoids, but composition of specific terpenes in the essential fraction differs among the 2 species (Riddle et al. 1996). Terpenoids in redberry juniper cause more digestive distress than those in ashe juniper, and goats prefer ashe to redberry juniper (Straka 1993).

Activated charcoal attenuates toxicosis from several toxic forages; activated charcoal reduced aflatoxicosis in chickens

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(Ademoyero and Dalvi 1983, Dalvi and Ademoyero 1984, Dalvi and McGowan 1984), toxicosis from tannins in 2 shrubs from Zanzibar (Cooney and Struhsaker 1997, Struhsaker et al. 1997), and toxicosis from the sesquiterpene lactone in bitterweed (*Hymenoxys odorata* DC) (Poage et al. 2000). Given the effectiveness of activated charcoal with several other toxins, we hypothesized that dosing with activated charcoal would improve acceptance and increase intake of both redberry and ashe juniper.

Methods

Animals and Feeding

Three trials were conducted at the Texas Agricultural Experiment Station, Sonora, Tex (Lat. 31°N, Long 100°W). Twenty freshly-weaned male and female Boercross goats, weighing about 25 kg (range 15 to 29 kg), were placed in individual pens for the duration of the study. Goats were reared on juniper-free rangelands and were naive to juniper before initiation of the study. Each goat was fed 1.5% of their body weight (BW) of alfalfa pellets (15% CP, 2.22 Mcal kg^{-1} DE) daily to meet maintenance requirements (NRC 1981). All goats had ad libitum access to fresh water and a calcium/phosphorus mineral with trace elements. Alfalfa was fed from 1000 hours to 1700 hours each day. At 1700 hours, alfalfa residuals were weighed to estimate intake. Goats only received water and access to mineral supplement overnight.

Trial 1

Trial 1 assessed the effect of dosing with activated charcoal on consumption of redberry juniper. The duration of the trial was 10 days. Twenty goats were randomly assigned to 1 of 2 treatments with an equal number of males and females in each treatment. Each morning (0800 hours), 10 goats were dosed (by gavage) with 1 g kg^{-1} BW of activated charcoal mixed in solution with 500 ml of distilled water at room temperature. This dosage agrees with the recommended dose for alleviating toxicosis (Buck and Bratich 1986) and the level shown to attenuate toxicosis with the toxic plant bitterweed (Poage et al. 2000). The 10 remaining goats were not dosed. In other studies, dosing with water alone did not affect intake (Provenza et al. 1994, Poage et al. 2000).

Immediately after dosing, all goats were offered 200 g of redberry juniper for 2 hours. If an individual consumed all 200 g, an additional 100 g was fed. Juniper was collected near the research facilities 1 hour before feeding. Branches were clipped from mature trees, and leaves were stripped from the stems before feeding. Refusals were collected and weighed to determine intake. Four additional samples were placed out of reach of goats in similar feeding troughs to account for moisture change.

Blood samples were collected by jugular venipuncture on the day before initiation of Trial 1, midway through the trial, and the day after the trial to measure serum metabolite levels. Serum metabolite levels can provide additional evidence of toxicosis or that liver damage has occurred from toxicosis (Radostits et al. 1994). For instance, elevated aminotransferase (AST) is indicative of soft tissue damage from toxicosis, while elevated levels of blood urea nitrogen (BUN), gamma glutamyltransferase (GGT), and creatinine are indicative of liver dysfunction from tissue damage (Cornelius 1989, Kramer 1989, Cheeke 1998). Nevertheless, changes in serum metabolite levels do not provide conclusive evidence that toxicosis has occurred. Serum metabolite levels vary among healthy individuals, and levels can be affected by disease or tissue damage unrelated to toxicosis (Cornelius 1989, Kramer 1989). A decrease in intake may be a more accurate measure of toxicity when dealing with plants that contain compounds that cause aversive postingestive feedback (Calhoun et al. 1981, Pfister et al. 1992).

Blood samples were centrifuged, serum harvested, frozen, and transported to the Texas Medical Diagnostic Laboratory, College Station, Tex. for analysis. Samples were analyzed for BUN, creatinine, AST, and GGT levels as indications of toxicosis and liver damage.

Trial 2

Trial 2 began 2 weeks after the completion of Trial 1 and lasted for 10 days. Trial 2 assessed the effect of dosing with activated charcoal on consumption of ashe juniper. The same protocol used in Trial 1 was used in Trial 2. The same goats were used in Trial 2 but were re-assigned to treatments. A systematic method of allocation was used to minimize the effect of previous experiences with juniper. Goats were assigned to treatments so that the dosed (control) treatment consisted of 5 goats dosed with activated charcoal in Trial 1 and 5 that were not dosed.

Trial 3

Trial 3 began 2 weeks after the completion of Trial 2 and lasted for 10 days. Goats were randomly re-assigned to treatments (dosing with activated charcoal or not dosed) and offered a choice of redberry and ashe juniper. We fed 200 g of each type of juniper for 2 hours to each individual goat. If an individual consumed all of either type of juniper, 100 g were added. Serum metabolite levels were not measured during Trial 3, because simultaneous feeding both types of juniper would confound metabolite levels.

Statistical analysis

Intake data from Trials 1 and 2 were analyzed using repeated measures analysis of variance with day of feeding as the repeated measure (Hicks 1993). Dosing with or without charcoal served as the

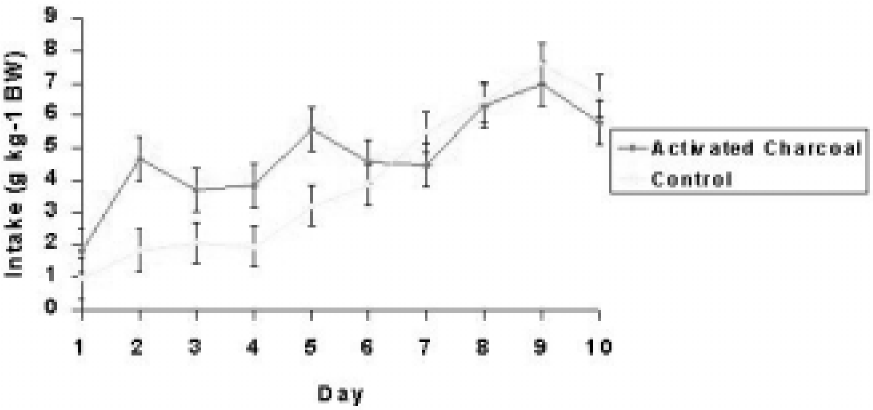

Fig. 1. Intake (g kg^{-1} BW) of redberry juniper by goats that were dosed with either activated charcoal in aqueous solution or not dosed (control) in Trial 1.

Table 1. Serum metabolite levels when goats were fed redberry (Trial 1) or ashe juniper (Trial 2) immediately after dosing with activated charcoal (1 g kg^{-1} BW). Serum was collected before, during, and after each trial. Levels before each trial were used as a covariate to account for initial variations among goats. Values presented are averaged across samples taken during and after each study.

	Treatment		
Serum Metabolite	Activated Charcoal	Control	SEM
Feeding redberry juniper			
BUN[1] (mg/dL)	18.1[b]	20.3[a]	0.92
creatinine (mg/dL)	0.81[b]	1.12[a]	0.08
AST[2] (U/L)	48.2[b]	65.9[a]	0.03
GGT[3] (U/L)	18.0	39.0	4.55
Feeding ashe juniper			
BUN (mg/dL)	16.1	17.5	0.95
creatinine (mg/dL)	0.72	0.74	0.12
AST (U/L)	44.9	44.4	3.24
GGT (U/L)	30.1	34.0	2.14

[a,b]Means within rows with different superscripts differ (P < 0.05).
[1]blood urea nitrogen
[2]aminotransferase
[3]gamma glutamyltransferase

whole plot and sex of goat served as a subplot. Serum metabolite levels were analyzed using the same model but with the initial metabolite level as a covariate. For Trial 3, dosing with or without charcoal served as the whole plot and species of juniper as the subplot. We did not analyze for a sex effect in Trial 3 because of the lack of difference in Trials 1 and 2. Means were separated using least significant difference (LSD) when P ≤ 0.05 (Gomez and Gomez 1984). The statistical package JMP was used for all analyses (SAS 1994).

Results

Trial 1

Goats dosed with activated charcoal consumed more redberry juniper on days 1 through 5, while intake was similar among treatments thereafter (Fig. 1; treatment X day interaction, P < 0.05). Alfalfa intake was similar among treatments (196 and 206 g day^{-1}) and across the 10 days of the study.

Dosing with activated charcoal affected serum metabolite concentrations (Table 1). Goats dosed with activated charcoal had lower concentrations of BUN, creatinine, and AST. Concentrations of GGT also tended to be lower for goats dosed with activated charcoal (P = 0.14).

Trial 2

Dosing with activated charcoal did not affect ashe juniper intake throughout the 10-day trial (Fig. 2). Intake increased daily for all goats until day 7. Intake decreased on day 9; intake on day 10 was similar to intake on days 7 and 8. Alfalfa intake was similar among treatments (194 and 194 g day^{-1}) and across the 10 days of the study. Serum metabolite levels were similar among goats dosed with activated charcoal or not dosed (Table 1).

Trial 3

All goats preferred ashe to redberry juniper irrespective of dosing with activated charcoal (Fig. 3). Goats consumed about 20 g kg^{-1} BW of ashe juniper and 3 g kg^{-1} BW of redberry juniper each day. Intake of redberry juniper, ashe juniper, and alfalfa were similar among treatments. The treatment X day interaction was similar for goats offered the 2 species of juniper.

Discussion

Activated charcoal apparently attenuated aversive feedback from redberry juniper during the first few days of feeding; goats dosed with activated charcoal ate more redberry juniper on days 1 through 5 and serum metabolite levels varied among treatments. After day 5, all goats consumed similar amounts of redberry juniper and intake increased daily across treatments until day 6. The effectiveness of activated charcoal depends on the dosage of charcoal and the amount of toxin present in the digestive tract (Edwards and McCredie 1967, Decker et al. 1968, Hayden and Comstock 1975, Levy 1982). The dosage used in this study was based on general recommendations for treating toxicity (Buck and Bratich 1986) and levels effective in reducing plant-induced toxicosis in another study (Poage et al. 2000).

The amount of water used for dosing may have affected intake for goats dosed with activated charcoal. However, other studies have illustrated that dosing with water alone does not affect intake (Provenza et al. 1994, Poage et al. 2000). Evidently, the amount of fill from 500 ml of water in the rumen is not sufficient to induce satiety.

Dosing with 500 ml of water may have diluted terpenoid levels or increased urination and excretion of toxins. If toxin dilution and excretion affected the results of Trial 1 with redberry juniper, a similar response should have been observed in Trial 2 when goats were fed ashe juniper. Ashe juniper also contains terpenoids that have aversive postingestive properties. Intake of ashe juniper was similar across both treatments in Trial 2 regardless of dosing.

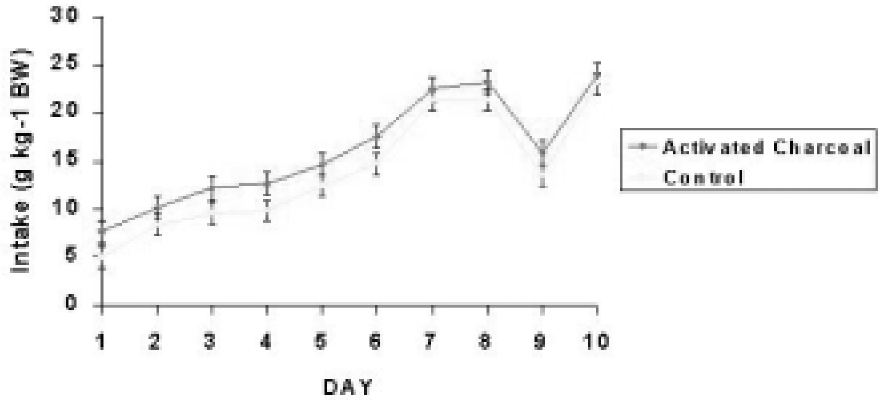

Fig. 2. Intake (g kg^{-1} BW) of ashe juniper by goats that were dosed with either activated charcoal in aqueous solution or not dosed (control) in Trial 2.

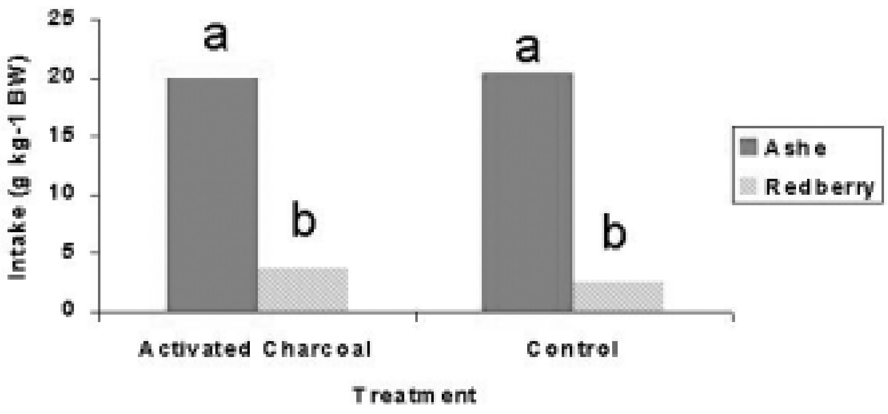

Fig. 3. Intake (g kg^{-1} BW) of ashe and redberry juniper when goats were offered a choice of the 2 species for 2 hours. Goats were dosed with either activated charcoal in aqueous solution or not dosed (control) in Trial 3.

Protein and/or energy supplementation can increase intake of juniper. In another study, feeding a cottonseed meal/alfalfa supplement increased redberry juniper intake by 40% over goats supplemented with corn and 30% over goats fed no supplement (Taylor et al. 1997). Similarly, Banner et al. (2000) showed that supplementing lambs with barley immediately before feeding sagebrush increased sagebrush intake. In this study, goats were fed a nutritious basal ration (i.e., alfalfa pellets) to meet maintenance requirements from 1000 to 1700 hours followed by fasting overnight. Goats did not receive alfalfa again until after feeding juniper for 2 hours. Thus, it seems unlikely that the effect of supplementation observed in other studies would affect the results of this study because of differences in type of supplement and time of feeding.

Daily increases in juniper consumption were probably caused by physiological changes that increased the liver's ability to metabolize the terpenoids in juniper (Launchbaugh et al. 1997). Intake increased until goats ate 7.5 g kg^{-1} BW of redberry juniper (Trial 1) and 23 g kg^{-1} BW of ashe juniper (Trial 2), thereafter intake stabilized (Fig. 1 and 2). We contend that goats increased intake of juniper until a toxic threshold was reached. The toxic threshold represents the point at which toxin intake surpasses the liver's ability to oxidize and excrete the terpenoids. When the threshold was reached, goats probably experienced aversive postingestive feedback and decreased intake accordingly.

Dosing with activated charcoal did not affect intake of ashe juniper. This is not surprising considering that goats prefer ashe to redberry juniper because of different toxin compositions (Straka 1993). Goats apparently do not experience aversive postingestive feedback from ashe juniper to the same degree, and feeding activated charcoal did not provide any additional reduction in aversive feedback.

Analysis of serum metabolite levels supports the idea that activated charcoal reduces the toxicity of redberry juniper. As intake of terpenoids increase, AST serum levels increase apparently because of soft tissue damage (Cornelius 1989, Kramer 1989). In this study, AST levels were lower ($P < 0.05$) for goats that were dosed with activated charcoal. Other serum metabolites, which are indicative of toxicosis, were also lower (BUN, creatinine). Exposure to the terpenoids in juniper early in life causes liver damage which reduces subsequent juniper consumption and animal productivity (Pritz et al. 1997). Dosing with activated charcoal during initial exposures to redberry juniper may reduce the toxicological effects of juniper consumption and lead to greater consumption of juniper later in life.

In Trial 3, goats were given a choice of redberry or ashe juniper. Goats preferred ashe juniper regardless of dosing with activated charcoal. Trial 3 was conducted after goats were exposed to both redberry (Trial 1) and ashe (Trial 2) juniper. Previous experiences with both species may have affected intake in Trial 3; goats may have selected ashe over redberry juniper because of the degree of aversive feedback experienced with each species in Trials 1 and 2. Some goats were fed redberry juniper only after dosing with activated charcoal in Trial 1 while others were fed redberry juniper alone. Activated charcoal apparently reduced aversive feedback for goats dosed with activated charcoal in Trial 1, yet all goats preferred ashe to redberry. Thus, previous foraging experiences (avoiding or experiencing aversive feedback) cannot completely account for higher intake of ashe juniper.

Differences in nutrient quality among ashe and redberry juniper could explain differences in preference. In general, junipers contain a crude protein content of 6-9% and digestibility ranging from 57 to 66% (Launchbaugh et al. 1997), but aversive postingestive feedback from terpenoids limit intake below maintenance levels (Riddle et al. 1999). As a result, it seems unlikely that goats would consume one juniper species over another to meet energy and protein needs.

Preference for ashe over redberry juniper also suggests that activated charcoal did not alleviate all potential toxic affects, and goats probably received some aversive postingestive feedback from consuming redberry juniper. Thus, activated charcoal may reduce some of the toxic effects from redberry juniper, but goats may still choose to consume ashe juniper when given a choice of the 2 species.

Implications

Results of this study suggest that dosing goats with 1 g kg^{-1} BW of activated charcoal will improve the acceptance of redberry juniper during initial exposures. However, after initial exposures, activated charcoal appears to have little affect on intake. Thus, continued dosing or feeding activated charcoal to maintain juniper intake is not feasible. This study also offers further evidence that goats prefer ashe to redberry juniper. If goats were used as a biological control method in mixed stands of ashe and redberry juniper, goat browsing would result in a greater decrease in ashe juniper cover. To circumvent this problem, Taylor et al. (1997) suggested prescribed burning followed by goat browsing to control mixed stands of juniper. Prescribed burning can kill ashe juniper trees (Ueckert 1997). Unlike ashe juniper, redberry resprouts from basal buds after topkill. Goat browsing can then be implemented to suppress the resprouts because resprouts have lower terpenoid levels (Straka and Taylor unpubl. data).

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