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Short-term Intake of Mesquite Beans Affects Ruminal pH but not Intake by Cattle and Goats

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ABSTRACT

Mesquite (*Prosopis glandulosa* Torr.) beans provide ruminants a food source high in sugars and carbohydrates. Although nutritious, mesquite beans may induce acidosis. Two studies were completed in 2019 to assess the effect of mesquite bean consumption on rumen pH and intake. In the first study, 5 non-parous ruminally fistulated cows were fed a basal diet with 0, 20, and 40% of their diet in mesquite beans over a period of 28 days. As the amount of mesquite beans in the diet increased, rumen pH levels decreased. Rumen pH reached levels near 5, but cows apparently did not experience acidosis; all cattle continued to consumed mesquite beans and the basal diet, regardless of the amount of mesquite beans consumed. In the second study, 22 female yearling goats were placed in individual pens. All goats were fed 300, 500, and 700 g of mesquite beans each per day in addition to alfalfa pellets (2.5% BW) to meet maintenance requirements. Eleven goats received water with 2% sodium bicarbonate to attenuate acidosis while 11 goats received water without additional sodium bicarbonate. Goats that received sodium bicarbonate consumed less mesquite beans indicating that goats did not experience acidosis at the levels fed in this study.

KEY WORDS: acidosis, rumen, intake, aversions

INTRODUCTION

When available, mesquite (*Prosopis glandulosa* Torr.) beans are readily consumed by livestock and wildlife during the summer months in West Texas (Ansley et al. 2017). As a food source for ruminants, mesquite beans (pods) contain both simple sugars and complex carbohydrates that are easily digested in the rumen resulting in the rapid release of volatile fatty acids (VFAs) (Becker and Grosjean 1980). The rapid release of the VFAs, propionate and lactate, can lead to rumen acidosis especially when ruminants consume a diet consisting primarily of roughages (Giger-Reverdin 2017). As rumen pH declines rumen microbial populations may be altered, resulting in additional digestive disorders (Sanders et al. 1980). Others have illustrated that acidosis results in aversive postingestive feedback and the formation of conditioned food aversions to high energy food sources that cause acidosis (Phy and Provenza 1998).

Once aversive postingestive feedback is experienced, animals avoid those foods and flavors that were associated with feedback in the past (Provenza 1995). This neurological mechanism allows animals, including grazing animals, to recognize harmful foods and avoid foods that cause malaise and interfere with metabolism. When nutritious alternative foods are limited, animals may be forced to consume foods that have resulted in aversive feedback in the past. Plant-induced toxicosis is often the result of grazing animals unable to meet nutritional requirements unless poisonous (aversive) plants are included in the diet (Provenza 1995).

While acidosis is typically not considered plant-induced toxicosis, lower rumen pH interferes with normal metabolism and results in livestock death in the most extreme cases. Given the high sugar content of mesquite beans, reports of mesquite bean toxicosis may be the result of over-consumption of mesquite beans and subsequent acidosis when nutritious alternative forages are limited.

Additionally, the consumption of mesquite pods could have an additional dietary consequence. Mesquite beans have been found in the tract of beef cattle for as long as nine months after the last possible day of consumption (Sanders et al. 1980). While the pod, sugars, and carbohydrates surrounding mesquite seeds are digestible, the seeds are not and could potentially cause some blockages within the gastrointestinal tract of the livestock. The rapid digestion of glucose

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and the reduced digestion of the cellulose could also alter rumen microbial populations and the ability to digest any remaining fiber in the diet.

Reported symptoms of mesquite bean toxicosis include twitching of the lips, head tremors, excessive salivation, emaciation and more serious symptoms such as muscle atrophy, anemia, decreased blood glucose levels and amino acid imbalances (Cook et al. 2008). Tabosa et al. (2006) noted that goats with long-term consumption of mesquite bean pods started to develop mandibular tremors, mainly during the act of mastication. In addition to the mandibular tremors and difficulty swallowing, other neurological effects occurred as the result of amino acid imbalances, causing an apparent neuropeptide deficiency and further causing paralysis of the trigeminal nerve.

For this study, different levels of mesquite beans were fed to determine (1) the level of mesquite bean consumption on a short-term basis that is sufficient to induce acidosis in cattle and goats, and (2) if short-term consumption of mesquite beans results in aversive postingestive feedback and the formation of a conditioned food aversion.

MATERIALS AND METHODS

Two experiments were conducted to assess the effect of short-term consumption of mesquite beans to cattle and goats. Throughout each feeding study, cattle (Experiment 1) and goats (Experiment 2) were housed in individual pens. Cattle were fed a basal ration (Table 1) while goats were fed alfalfa pellets (2.5% BW) to meet maintenance requirements (National Research Council 2007; National Academy of Sciences, Engineering, and Medicine 2016). Each individual was offered fresh water (*ad libitum*). Cattle were fed a basal ration at 9 kg per individual · day^{-1} while goats were fed alfalfa pellets at 2.5% BW to meet maintenance requirements. In addition, the cattle also received sorghum hay (*ad libitum*). Cattle were housed in 6.1 m × 24.4 m individual pens while goats were housed in 1 m × 1.5 m individual pens. All research protocols were approved by Angelo State University Institutional Animal Care and Use Committee (IACUC).

Table 1. Ingredients and nutrient content of basal ration* fed to cattle during the first study.

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

* Sudangrass hay was available *ad libitum*.

The first study (cattle study) consisted of five ruminally fistulated non-parous Angus cows (five-year old, weighing approximately 453 kg) at the Angelo State University Management, Instruction and Research (MIR) Center (Lat: 310 34’ 8.99” N, Long: 1000 32’ 26.399’ W). Sample size for the first study was limited because there were only five ruminally fistulated cows available. Cows were placed into a modified Latin square study design, where each of the cows received basal diet (Table 1) with no mesquite bean pods for seven days. Thereafter, cows were fed a diet consisting of 20% mesquite bean pods for seven days, followed by a seven-day adjustment period. For the last seven days, cows received a diet of 40% mesquite bean pods. Intake was monitored daily. Rumen pH was measured at 12 hours on days 0, 7, and 14 of each feeding trial. Four rumen pH measurements were taken from each cow at each sampling interval and averaged together to estimate rumen pH.

The second study (goat study) consisted of 22 weaned Boer-cross female goats housed at the Angelo State University MIR Center. Goats were approximately 6 months old and weighed 26 kg. Following a five-day period to adjust to their pens and alfalfa pellets, goats were fed three different levels of mesquite beans (300, 500, and 700 g). The remainder of the diet consisted of alfalfa pellets, fed at 2.5% BW to meet maintenance requirements. All goats received 300 g of mesquite beans on day 6 through 10. On days 11 through 15, 500 g of mesquite beans were fed, followed by feeding 700 g of mesquite beans on day 16 through 20.

Goats were randomly assigned to each treatment and were fed treatment diets for 5 days. Of the 22 individual goats used, 11 of the individuals had their water treated with sodium bicarbonate at a 2% aqueous solution (*ad libitum*), while the other 10 individuals were given untreated water (*ad libitum*). In other studies, the same protocol was used to alleviate acidosis for over ingestion of grain (Phy and Provenza 1998). Each individual goat's diet was weighed daily before feeding and the refusals were weighed following the feeding period to monitor intake. Mesquite beans were available to the goats for one hour before the refusals were removed and weighed. Following the mesquite beans, the goats were fed alfalfa pellets at 2.5% BW to meet maintenance requirements (National Research Council, 2007).

Rumen pH data for the cattle study was analyzed as a Latin square design using an analysis of variance with the amount of mesquite beans fed as the main effect and day of feeding as the repeated measure. Data for the goat study was analyzed as a repeated measures analysis of variance with level of mesquite pods in the diet as the main effect, individual animals nested within treatments serving as replications and day of collection as the repeated measure. Means were separated using Tukey's Protected LSD with $P \leq 0.05$ and data was analyzed with the statistical package JMP (SAS Institute 2007).

RESULTS

Prior to feeding mesquite beans, cows had a mean ruminal pH of 6.02 ± 0.06. Rumen pH declined as the percentage of mesquite beans fed increased from 0 to 20% of the cattle's diet, and again as the amount of mesquite beans increased to 40% of the diet (Fig 1). At 20% of the diet, ruminal pH decreased to 5.7 ± 0.05. Once the percentage of mesquite beans in the diet was increased to 40% of the diet, rumen pH declined to 5.37 ± 0.05. The hypothesis that mesquite beans would lower rumen pH was accepted.

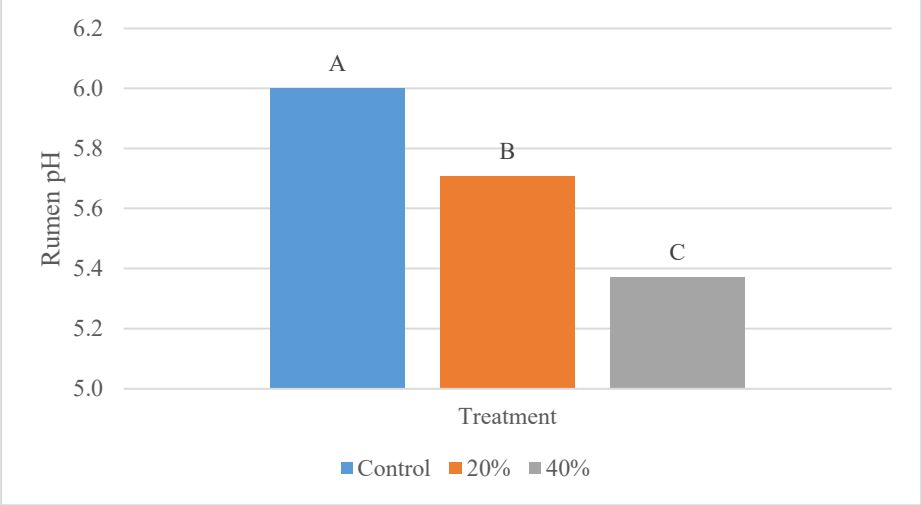

Figure 1. Mean pH taken 12 hours after feeding mesquite beans. Cattle received a diet consisting of either 0 (control), 20%, or 40% mesquite beans. Bars with different superscripts, differ (P < 0.05).

Rumen pH tended to decline the first day after feeding diet consisting of 20% or 40% mesquite beans (Figs. 2 and 3). Thereafter, rumen pH remained relatively constant throughout each feeding trial (20 and 40% of the diet). Even though rumen pH declined, cattle did not apparently experience acidosis given that cattle continued to consume all of the mesquite beans offered and all of their basal diet each day. The hypothesis that over-consumption of mesquite bean would result in aversive postingestive feedback and avoidance of mesquite beans was not accepted based on the data from this study.

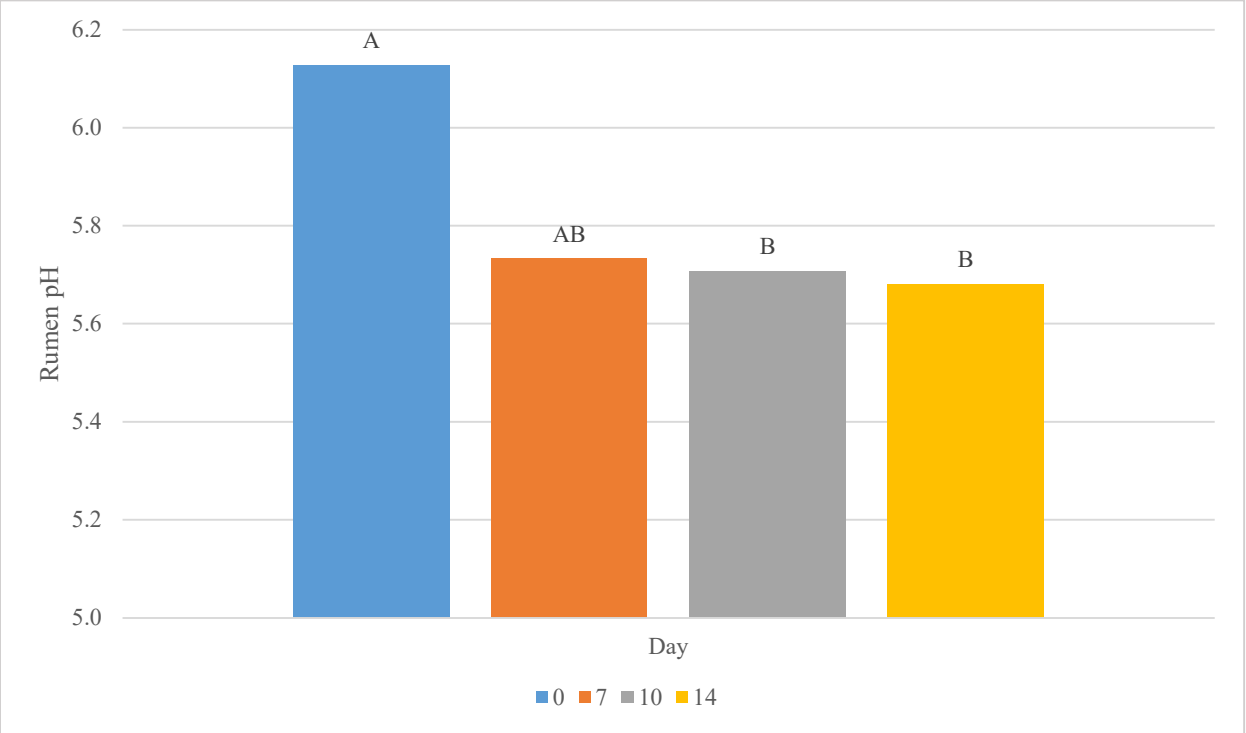

Figure 2. Change in rumen pH when cattle were fed a diet consisting of 20% mesquite beans on days 0-14. Bars with different superscripts, differ (P < 0.05).

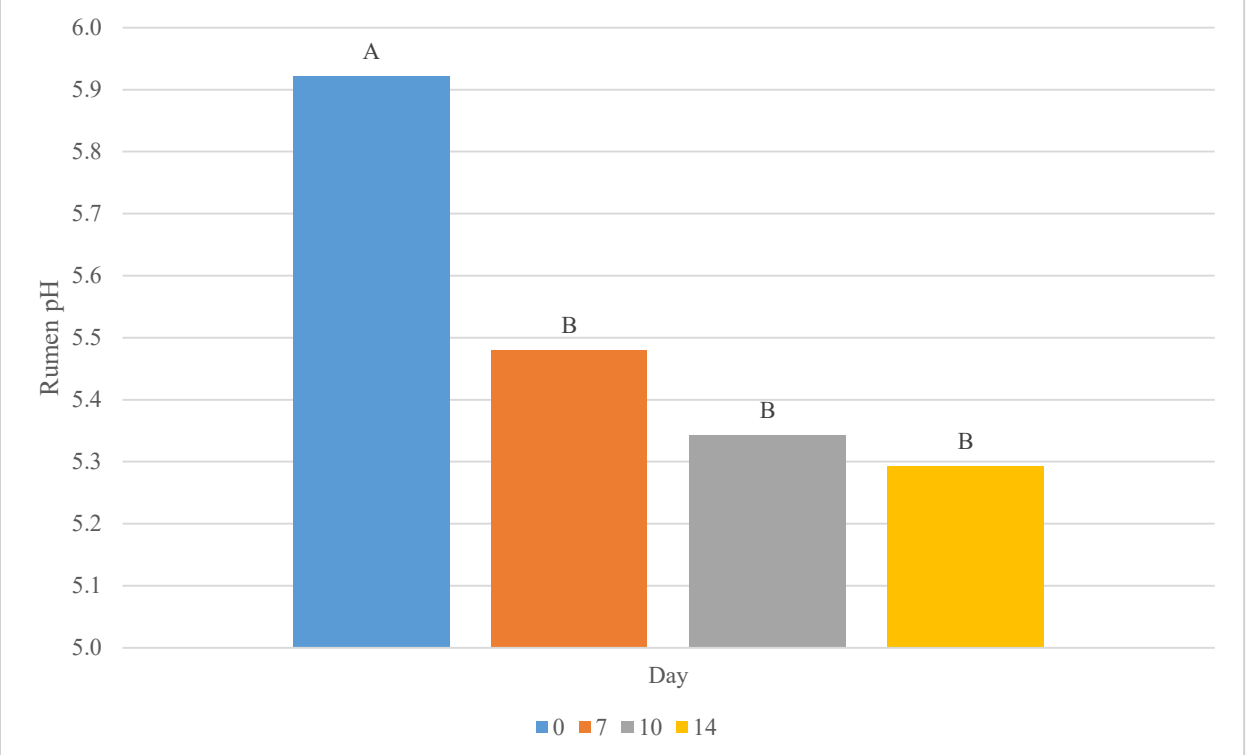

Figure 3. Change in rumen pH when cattle were fed a diet consisting of 40% mesquite beans on days 0-14. Bars with different superscripts, differ (P < 0.05).

Mesquite bean intake by goats varied by treatment (Fig. 4). The treatment by day interaction was also significant ($P < 0.06$; Fig. 5). Goats in the control group typically ate more mesquite beans than goats receiving sodium bicarbonate in their water. Across the 15 days of feeding mesquite beans, goats in the control group ate more mesquite beans than goats receiving sodium bicarbonate except for days 6, 10, and 15 (Fig. 5). Overall, intake increased daily for all goats regardless of treatment. Goats did not appear to be suffering from acidosis or reduce intake because of aversive postingestive feedback. Goats also consumed all of the alfalfa offered each day (data not shown) regardless of treatment or day of feeding. The hypothesis that mesquite beans caused aversive postingestive feedback and an overall reduction in intake was rejected.

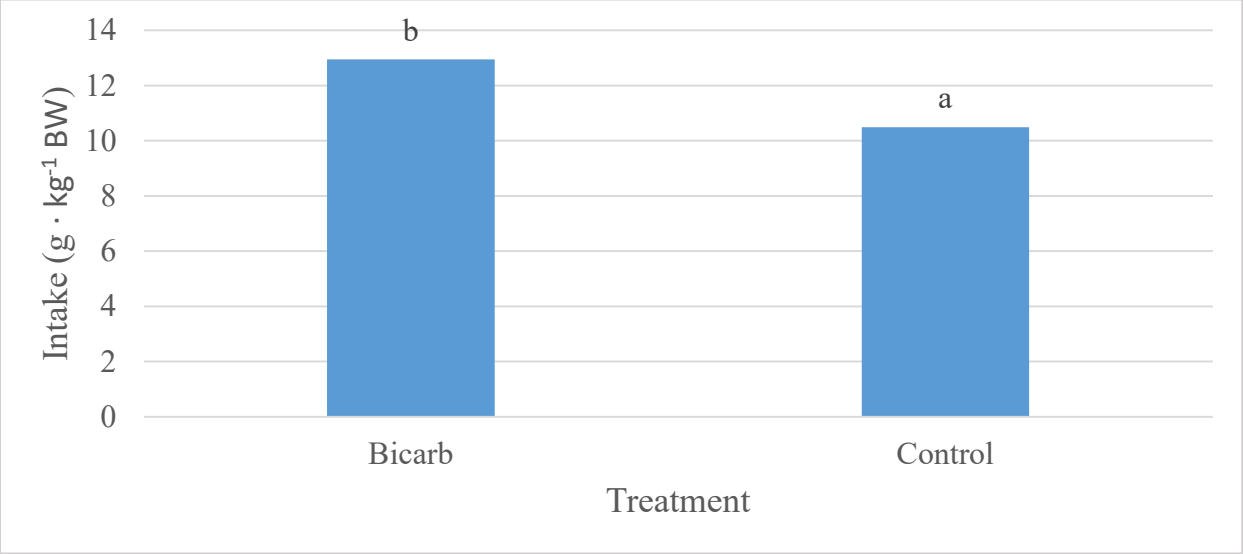

Figure 4. Average intake (g · kg^{-1} BW) of mesquite beans, from days 6 to 20. Treatment received water with 2% Sodium bicarbonate while control received water without Sodium bicarbonate. Bars with different superscripts, differ ($P < 0.05$).

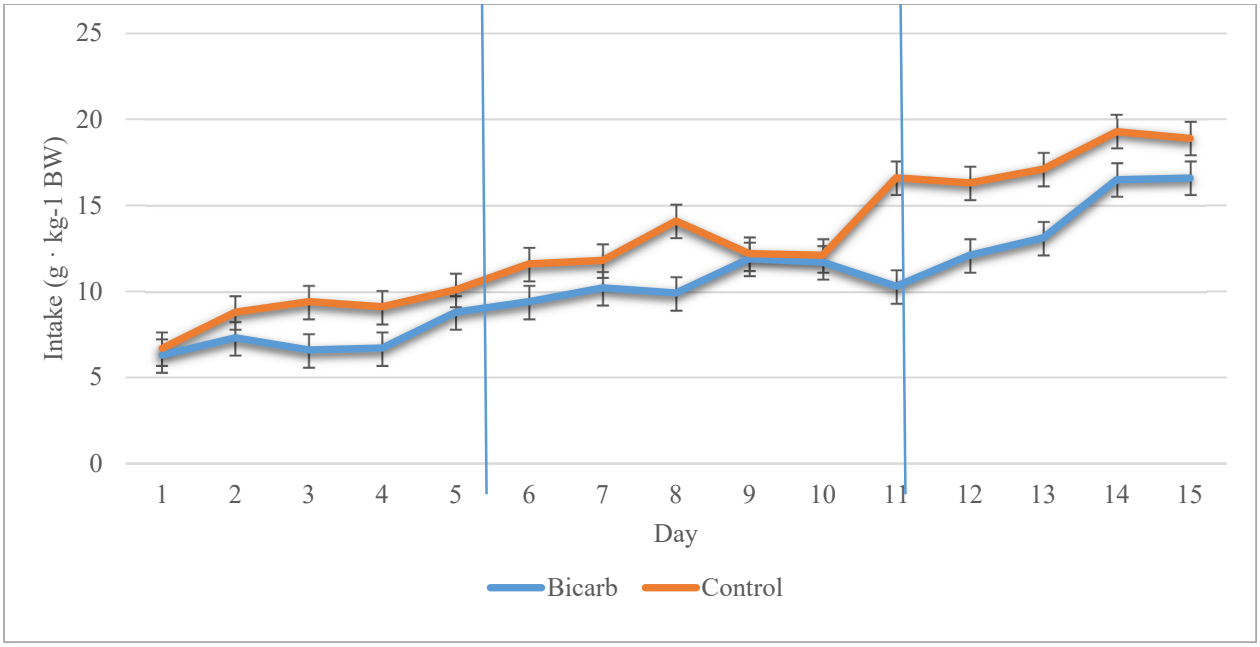

Figure 5. Average intake (g · kg^{-1} BW) of mesquite beans in g, from days 6-20. Treatment included water with Sodium bicarbonate 2% while control received water without Sodium bicarbonate. Vertical lines signify a change in mesquite beans offered (300, 500, and 700 g, respectively).

Goats gained weight from the beginning to the end of the study (day effect $P < 0.05$) (Table 2). The treatment and treatment by day effects for weight gain were similar.

Table 2. Average weight (kg) of goats at day 1 and day 20 of the study. Day effect was significant but the treatment and treatment by day interactions were similar.

Treatment	Initial (Day 1)	Final (Day 20)	SEM
Sodium bicarbonate	25.1	26.2	1.1
Control	27.4	28.6	1.1
Day Effect	26.2[b]	27.4[a]	0.8

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

CONCLUSION AND DISCUSSION

As the amount of mesquite beans in the diet increased from 0 to 20% and again to 40%, rumen pH of cows declined, accordingly. Acute acidosis occurs when the rumen pH declines to 5 or less for extended periods without recovering to higher levels between feedings (Giger- Reverdin 2017). By the end of the study, rumen pH had declined to levels near 5, sufficient to cause mild acidosis and the formation of a conditioned food aversion. However, cattle continued to consume all of the mesquite beans offered each day, regardless of the amount fed and subsequent drop in rumen pH. Apparently, the sugar content of the mesquite beans was sufficient to reduce rumen pH, but not induce acidosis. Goats can consume mesquite beans for short periods of time (< 2 months) without an apparent toxicosis effect (Kneuper et al. 2006). Conversely, when mesquite beans are consumed for an extended period of time (2-10 months) toxicosis becomes prevalent (Cook et al. 2008).

Cows were fed a complete diet that included sudangrass hay and a concentrate maintenance ration to meet nutritional requirements (Table 1). The maintenance ration contained cottonseed hulls as a source of fiber. Sudangrass hay also provided additional fiber to the cattle diets. Any aversive postingestive consequences may have been alleviated by the amount of fiber in the cattle diets. Most cases of mesquite bean toxicity are reported during dry conditions when the amount of grass (fiber) in the diet is limited by a lack of forage quantity. The results of this study may have differed if less roughage was fed in the diet. On one day of the study, the cows were mistakenly fed hay before rumen pH samples could be collected. When they were collected, all rumen pH levels had risen to above 6. This suggests that the amount of fiber available to cows may have raised pH, allowing cows to avoid prolonged acidosis.

Intake of the basal ration and the percentage of the mesquite beans offered remained constant throughout the study, therefore there is no obvious evidence of toxicosis or rumen compaction of these cattle. If rumen compaction or toxicosis were present intake should have declined.

Preference for or aversion to foods results from postingestive feedback (Provenza 1995). Once aversive postingestive feedback is experienced, animals reduce intake or avoid the food. Conversely, positive feedback results in the formation of preferences for foods associated with nutrient release. The goats used in the study were on pasture with some mesquite beans available before the study and were probably familiar with mesquite beans as a food source. This familiarity with this source of nutrition could have created a preference for or aversion to mesquite beans before the data collection occurred. In other studies, goats would consume all of the mesquite beans offered each day (Kneuper et al. 2006; Cook et al. 2008). Most goats left some beans at each feeding interval after one hour of feeding. Previous experience with mesquite beans may have affected intake in this study.

Cook et al. (2008) showed no toxicosis effect on goats that consume up to 60% of their diet in mesquite beans. By the end of the study, goats were consuming a diet of approximately 50% mesquite beans. If acidosis would have been experienced by goats, those receiving water with sodium bicarbonate should have consumed more mesquite beans by avoiding acidosis and aversive feedback. The level of mesquite beans fed to goats apparently did not result and acidosis and aversive postingestive feedback.

Based on the results of this study and others (Cook et al. 2008), mesquite beans can be consumed on rangelands without inducing acidosis as long as sufficient roughage is available through standing forage. Mesquite beans are nutritious and should improve the overall nutritional status of livestock on rangelands (Becker and Grosjean 1980). Unfortunately, consumption of mesquite beans will result in seed dispersal across the landscape (Kneuper et al. 2006). Up to 80% of the mesquite beans consumed by cattle survived digestion and remained viable when deposited in feces. Conversely, passage through the digestive system of goats reduced the number of viable mesquite seeds (Kneuper et al. 2006).

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