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Supplements Containing Escape Protein Improve Redberry Juniper Intake by Goats

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Abstract

Redberry juniper (*Juniperus pinchotii* Sudw.) is a common invasive plant species in west-central Texas. Goats will consume redberry juniper, but intake is limited by monoterpenoids found in the plant. Previous research has shown that goats will increase juniper intake through 1) conditioning and 2) protein supplementation. This study compared intake of juniper when goats received different protein supplements either with or without protein sources that are high in amino acids that escape digestion in the rumen. Recently weaned Boer-cross goats ($n = 47$) were randomly placed into five treatments. Treatments 1, 2, 3, and 4 received a protein supplement and juniper for 1 h daily for 14 d, along with a basal diet of alfalfa pellets (2% body weight). Treatment 5 received only a basal diet of alfalfa pellets and juniper. All supplements were formulated to be isonitrogenous (37% crude protein [CP]). Treatment 1 contained cottonseed meal (high CP escape value), treatment 2 contained cottonseed meal and distiller's dried grain (higher CP escape value), treatment 3 contained soybean meal (low CP escape value), and treatment 4 contained soybean meal and distiller's dried grain (moderate CP escape value). Refusals of juniper, supplements, and alfalfa were weighed daily to determine intake. Supplementation with 1) cottonseed meal, 2) soybean meal, or 3) soybean meal and distillers dried grain did not influence ($P > 0.05$) juniper intake. Conversely, goats supplemented with cottonseed meal and distiller's dried grain ate more ($P < 0.05$) juniper than goats receiving only alfalfa, possibly because of increased escape of glucogenic amino acids. We contend that supplementation with feeds high in protein escape values should increase juniper intake on rangelands.

Resumen

Juniperus pinchotii Sudw. es una especie vegetal invasora común en centro-oeste de Texas. Las cabras consumen *J. pinchotii*, pero su ingesta está limitada por mono-terpenoides encontrados en esta planta. Investigaciones previas han demostrado que las cabras aumentan el consumo de *J. pinchotii* a través de 1) condicionamiento y 2) suplementación proteica. En este ensayo se comparó la ingesta de *J. pinchotii* de cabras que recibieron distintos suplementos proteicos con o sin fuentes de proteína con alto contenido de aminoácidos que escapan la digestión en el rumen. Cabras cruza Boer recientemente destetadas ($n = 47$) fueron asignadas al azar a 5 tratamientos. Los tratamientos 1, 2, 3, y 4 recibieron un suplemento proteico y *J. pinchotii* durante una hora diaria a lo largo de 14 días, junto con una dieta basal de pellets de alfalfa (2% peso corporal). El tratamiento 5 recibió solamente una dieta basal de pellets de alfalfa y *J. pinchotii*. Todos los suplementos fueron formulados para ser iso-nitrogenados (37% PB). El Tratamiento 1 incluyó expeller de algodón (alto nivel de proteína pasante); el Tratamiento 2 incluyó expeller de algodón y granos de destilería de maíz desecados (contenido superior de proteína pasante); el Tratamiento 3 incluyó expeller de soja (bajo nivel de proteína pasante), y el Tratamiento 4 incluyó expeller de soja y granos de destilería de maíz desecados (moderado nivel de proteína pasante). Los restos de *J. pinchotii*, suplementos y alfalfa se pesaron diariamente para cuantificar la ingesta. La suplementación con 1) expeller de algodón, 2) expeller de soja, o 3) expeller de soja y granos de destilería de maíz desecados no influyeron ($P > 0.05$) sobre la ingesta de *J. pinchotii*. Sin embargo, las cabras suplementadas con expeller de algodón y granos de destilería de maíz desecados consumieron más ($P < 0.05$) *J. pinchotii* que las cabras que recibieron alfalfa solamente, posiblemente debido al aumento de aminoácidos glucogénicos pasantes. Sostenemos que la suplementación con alimentos con alto contenido de proteína pasante debería incrementar la ingesta de *J. pinchotii* en condiciones de pastizal natural.

Key Words: ashe, cottonseed meal, distiller's grains, glucogenic, soybean meal

INTRODUCTION

Redberry (*Juniperus pinchotii* Sudw.) and ashe (*Juniperus asheii* Buch.) juniper are chemically defended woody species that have invaded millions of hectares of Texas rangelands (Ansley et al. 1995; Smeins et al. 1997). Several studies have shown that goats will consume juniper, particularly after feeding juniper at weaning (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007). Unfortunately, intake of juniper is at times limited because monoterpenoids found in the plant cause aversive postingestive feedback (Riddle et al. 1996; Pritz et al. 1997). Indeed, most poisonous plants reduce the likelihood of herbivory through aversive postingestive feedback and formation of conditioned food aversions (Provenza et al. 1992;

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Provenza 1995). However, ruminants may be able to reduce the likelihood of experiencing aversive feedback if toxins are metabolically altered through digestion and metabolism processes.

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 monoterpeniod oils are conjugated with endogenous cofactors, such as glucuronic acid and excreted in urine (Bidlack et al. 1986; Scheline 1991).

Protein sources that escape rumen metabolism and are high in glucogenic amino acids should increase the likelihood of detoxification because they may provide the substrate (i.e., glucuronic acid) for conjugation. Preliminary research has illustrated that protein supplementation improved 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 supplementation of cows improved tolerance of broom snakeweed toxicosis (*Gutierrezia sarothrae* [Pursh] Britt and Rusby) because of increased liver capacity to conjugate and eliminate xenobiotics (Strickland et al. 1998). Supplementation with soybean meal has also improved detoxification of some other poisonous plants (Calhoun et al. 1989; Villalba et al. 2002a, 2002b).

Distiller's dried grain (DDG) has a high rumen escape value (National Research Council [NRC] 2007), while soybean meal (SBM) is readily degradable in the rumen. CSM is a common source of protein for winter supplementation of livestock in the southwestern United States, and it also provides a source of escape proteins (NRC 2007). We hypothesized that protein sources high in escape protein (CSM, DDG) would improve juniper consumption over protein sources that are highly degradable in the rumen.

MATERIALS AND METHODS

In this experiment, 47 recently weaned, castrated Boer-cross goats (23.6 ± 1.5 kg) were randomly placed into five treatments ($n = 9$–10 goats/treatment). Fifty goats were purchased for this study, but three goats died before the feeding of juniper because of poor body condition and high loads of intestinal parasites, leaving nine goats in three treatments. Goats were separated into individual pens (1×1.5 m) and allotted 7 d for pen adjustment at Angelo State University's Management, Instruction, and Research Center (lat 31°38′N, long 100°05′W). Excrement was removed weekly from pens. Alfalfa pellets (2% body weight [BW]) were fed daily to meet the animals' intake requirements for maintenance, and supplements were fed according to treatment to meet growth requirements (NRC 2007). Alfalfa pellets were chosen as the basal diet because of commercial availability and because feeding a grain-based ration could confound results from supplemental treatment diets (described below). Other studies have used alfalfa pellets as the basal diet when feeding juniper apparently without affecting juniper intake (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007; Dietz et al. 2010). Goats also received ad libitum freshwater and a calcium and phosphorous mineral with trace elements. Goats were supplemented each day before feeding juniper according to treatment group (Table 1). Treatment 1 received a supplement with CSM as the protein source, treatment 2 received a supplement with CSM and DDG as the protein source, treatment 3 received a supplement with SBM as the protein source, and treatment 4 received SBM and DDG supplement as the protein source. Treatment 5 received no protein supplementation: alfalfa pellets only. All supplements were isonitrogenous (37% crude protein [CP]), and the ingredients in the supplement were the same except for the source of protein. Digestible energy levels differed depending on the source of protein (Table 1). The amount of alfalfa fed to treatment 5 was increased so that all goats received the same amount of protein daily.

Table 1. Ingredients and nutritional value (%) of protein supplements.[1]

	Supplement (treatment)			
Ingredients	1	2	3	4
Cottonseed meal	88.7	77.5	—	—
Soybean meal	—	—	78.7	63.1
Distiller's dried grain	—	16.2	—	26.7
Molasses, cane	3.4	3.4	3.4	3.4
Rice bran	7.5	2.5	17.5	6.5
Trace mineral	0.02	0.02	0.02	0.02
Vitamins A, D, E	0.3	0.3	0.3	0.3
Total digestible nutrients	70.2	72.3	73.8	76.6
Protein	37.3	36	39.6	37.3
Digestible energy ($mcal \cdot kg^{-1}$)	5.68	5.54	8.15	7.43

[1]All percentages based on 909.1 kg.

All goats were naive to supplements prior to the initiation of the study; thus, a 7-d pretrial was used to familiarize goats with pens and the supplements. Goats were placed in individual pens (1×1.5 m) and offered supplements for 1 h daily for 7 d. Amount of supplement for each goat was based on providing 1.9 $g \cdot kg^{-1}$ BW to meet CP maintenance requirements. In addition, 2.9 $g \cdot kg^{-1}$ BW of additional protein was fed each day to surpass daily protein requirements for growth (NRC 2007). The amount of each supplement fed was based on requirements for maintenance and growth minus the number of grams of protein provided by alfalfa pellets (17% CP). Supplements were offered from 0800 to 0900 hours daily. Alfalfa was offered from 0900 to 1700 hours each day.

After the pretrial, animals received one of four supplemented protein treatments and juniper for 14 d during testing. Protein supplementation was offered from 0800 to 0900 hours to goats in each treatment. Redberry juniper leaves were offered to all animals from 0900 to 1000 hours. Prior to initiation of the study (June 2007), redberry juniper was harvested from randomly selected trees at the Texas AgriLife Research Center, Sonora, Texas (lat 30°58′N, long 100°65′W). Leaves were stripped from the stems before feeding, composited, and stored at 4°C (Utsumi et al. 2006). Initially, 50 g of juniper were offered to each goat. If an individual goat consumed all the juniper offered, the amount fed was increased daily until

Table 2. Average intake of alfalfa, supplements, and protein for treatments receiving different protein supplements during the 7-d pretrial.[1]

Supplement	Intake		
	Alfalfa ($g \cdot kg^{-1}$ BW)	Supplement ($g \cdot kg^{-1}$ BW)	Protein ($g \cdot kg^{-1}$ BW)
Cottonseed meal (CSM)	17.6 ± 0.8 a	3.3 ± 0.4	0.2 ± 0.02
CSM/distiller's dried grain (DDG)	20.3 ± 0.8 a	3.3 ± 0.4	0.2 ± 0.02
Soybean meal (SBM)	18.2 ± 0.8 a	2.6 ± 0.4	0.2 ± 0.02
SBM/DDG	18.8 ± 0.8 a	2.9 ± 0.4	0.2 ± 0.02
Alfalfa	24.0±0.8 b	—	0.2 ± 0.02

[1]All supplements were isonitrogenious (37%). Means within columns with different letters differ ($P < 0.05$). BW indicates body weight.

Table 3. Average intake of alfalfa, supplements, protein, and juniper for treatments receiving different protein supplements.[1]

Supplement	Intake			
	Alfalfa ($g \cdot kg^{-1}$ BW)	Supplement ($g \cdot kg^{-1}$ BW)	Protein ($g \cdot kg^{-1}$ BW)	Juniper ($g \cdot kg^{-1}$ BW)
Cottonseed meal (CSM)	17.8 ± 1.3	3.6 ± 0.4	0.2 ± 0.02	1.5 ± 0.5
CSM/distiller's dried grain (DDG)	20.5 ± 1.3	3.3 ± 0.4	0.2 ± 0.02	2.6 ± 0.5
Soybean meal (SBM)	18.1 ± 1.3	3.3 ± 0.4	0.2 ± 0.02	1.5 ± 0.5
SBM/DDG	19.7 ± 1.3	3.3 ± 0.4	0.2 ± 0.02	1.4 ± 0.5
Alfalfa	22.9 ± 1.3	—	0.2 ± 0.02	0.9 ± 0.5

[1]All supplements were isonitrogenious (37%). BW indicates body weight.

refusals were noted. Goats then received alfalfa pellets (2% BW) from 1200 to 1700 hours to meet maintenance requirements. Intake of supplements, juniper, and alfalfa were recorded daily for the 14 d of the study.

True in vitro digestibility, digestible CP, and bypass protein potential of the supplements were determined using six cannulated goats, located at the Texas AgriLife Research and Extension Center, San Angelo, Texas. Goats were fed alfalfa pellets (2% of BW) at 0800 hours for 12 days. Four hours after feeding, approximately 500 mL of rumen fluid per goat was collected on days 0, 3, and 7 (three replications) through one layer of cheesecloth into a prewarmed thermos. Approximately 200 g of material left on the cheesecloth were crumbled and also added to each thermos. Thermoses were sealed and shaken (Labline, Melrose Park, IL) for 3 min to dislodge some particle-associated bacteria.

Rumen fluid was combined, mixed, and continually flushed with CO_2, and 400 mL were filtered through two layers of cheesecloth. The remaining rumen material in the cheesecloth was rinsed once with approximately 200 mL of a McDougal buffer solution (1.064 g of urea per liter of solution). The rumen fluid–buffer mixture was transferred to an incubation jar containing 1 400 mL of McDougal buffer, purged with CO_2 for 1 min, and sealed. This procedure was repeated for the other three jars. A separate incubation jar for each supplement was used to ensure that one type of supplement did not influence another. Each protein supplement was ground to pass a 1-mm screen (Wiley Mill), and 0.35 g of each supplement was placed into a fiber bag (F57; Ankom Technology Corp., Fairport, NY) that was then heat sealed. Bags of supplement were incubated for 0 h, 24 h, or 48 h. Bags were introduced in reverse order, removed all at once, and placed into an ice water bath for 5 min to arrest microbial fermentation.

Bags (24 h and 48 h) were placed into a washing machine and subjected to five rinse cycles (low water level) with 1-min agitation (delicate setting) and a 2-min spin per rinse (Coblentz et al. 1997). After washing, bags were subjected to a neutral detergent solution (no Na sulfite; four bags per supplement per hour), dried (60°C) for 48 h, and weighed to determine true in vitro dry matter digestibility. Bags and contents were then analyzed for CP by a modified Kjeldahl procedure (Tecator Kjeltec 2400; Association of Official Analytical Chemistry 2001). Crude protein from residue remaining after the neutral detergent fiber (NDF) procedure is the neutral detergent insoluble nitrogen, which is also considered to be the rumen undegradable CP content since NDF solution rinses away particle-associated bacteria (Mass et al. 1999). To determine nondigestible CP content, three bags per supplement were digested and washed with the other bags during the first digestibility run, subjected to an acid detergent solution, dried, weighed, and analyzed for CP. Acid detergent fiber and NDF procedures were performed using methods of Van Soest et al. (1991) modified for an Ankom^{2000} Fiber Analyzer (Ankom).

The study design was a completely randomized design with a model that included treatment, day, and their interaction. Differences between treatment means (protein supplement) were assessed using repeated-measure analysis of variance. Individual goats were nested within treatments and served as replications. Treatment means were analyzed as a fixed effect, individual animals as a random effect, and days of feeding as the repeated measure. Linear planed orthogonal contrasts were also used to assess treatment effects. Means were separated using least significant differences when $P \leq 0.05$. Means and standard errors were calculated for undegradable intake protein (UIP), in vitro dry matter digestibility (IVDMD), and digestible CP. Data were analyzed using the JMP statistical package (SAS Institute Inc. 2007).

RESULTS

Protein intake was similar ($P > 0.05$) among treatments and across days during the 7-day pretrial. Alfalfa intake differed ($P < 0.05$) during the pretrial (Table 2). Goats in the control treatment were offered more alfalfa each day and thus consumed more alfalfa than goats that received a protein supplement in addition to alfalfa. Goats typically consumed all the alfalfa and protein supplement offered each day. Digestible energy estimates differed among supplements (SBM > SBM/DDG > CSM > CSM/DDG; Table 1).

When means were compared across all treatments, juniper, alfalfa, supplement, and protein intake were similar ($P > 0.05$) among treatments (Table 3). Juniper intake did vary across days of feeding for all treatments (Fig. 1). Initially, goats were

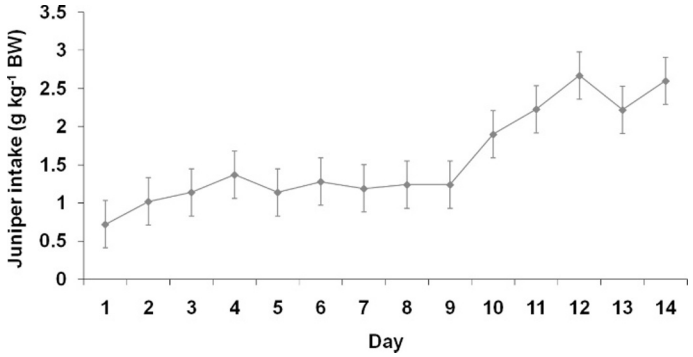

Figure 1. Juniper intake ($g \cdot kg^{-1}$ body weight [BW]) averaged across treatments for the 14 d of feeding different protein supplements.

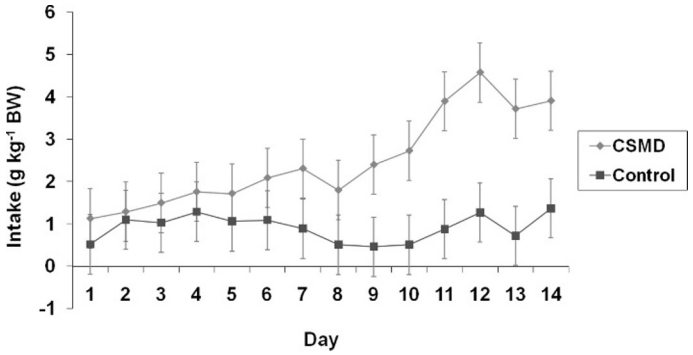

Figure 3. Juniper intake ($g \cdot kg^{-1}$ body weight [BW]) for the 14 d of feeding of the cottonseed meal/distiller's (CSMD) grain supplement versus alfalfa alone.

reluctant to consume juniper (0.72 ± 0.31 $g \cdot kg^{-1}$ BW); however, by day 12, intake had increased to 2.67 ± 0.31 $g \cdot kg^{-1}$ BW. The treatment × day interaction was not significant. Treatment means for juniper intake varied from 0.88 ± 0.55 $g \cdot kg^{-1}$ BW for the treatment receiving no supplementation to 2.63 ± 0.55 $g \cdot kg^{-1}$ BW for the treatment receiving a protein supplement containing both CSM and DDG as a protein source.

When average juniper intake for each treatment was compared to the control, one difference was evident. Goats receiving supplements containing CSM/DDG consumed more ($P < 0.05$) juniper than goats receiving alfalfa alone (Fig. 2). This was particularly evident when comparing juniper intake across the 14 d of feeding (Fig. 3). Average juniper intake for the other treatments (CSM, SBM, and SBM/DDG) did not differ from average juniper intake for the control.

The CSM/DDG supplement resulted in more escape protein (UIP) than the other three supplemental rations (Table 4). The UIP value for alfalfa was also high, suggesting a high escape value, but overall digestibility (IVDMD) was lower for alfalfa compared to the supplemental protein rations.

DISCUSSION

Results of this study illustrate that goats receiving a protein supplement consisting of CSM and DDG ate more redberry juniper than goats receiving alfalfa alone. Before this study, little was known about how the source of protein would affect intake of redberry juniper by goats. Campbell et al. (2007) reported that supplementation with protein sources (CSM, SBM, or alfalfa) increased juniper intake, while energy supplementation (corn) did not. The SBM supplement and SBM/DDG supplements used in this study contained more energy (8.15 and 7.43 $mg \cdot kg^{-1}$, respectively) than the CSM and CSM/DDG supplements (5.68 and 5.54 $mg \cdot kg^{-1}$, respectively). Apparently, additional energy intake had no affect on juniper consumption in our study and supports the observations of Campbell et al. (2007).

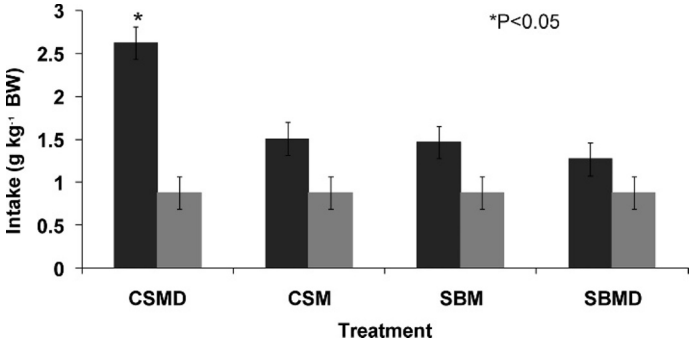

Figure 2. Comparison of juniper intake ($g \cdot kg^{-1}$ body weight [BW]) when each treatment was compared to the control diet (alfalfa alone). CSMD indicates cottonseed meal/distiller's grain; CSM, cottonseed meal; SBM, soybean meal; and SBMD, soybean meal/distiller's grain.

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. Results from our study suggest 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. 2006). Ideally, our study should have included a negative control that received a basal diet that did not include alfalfa. Alfalfa may have increased juniper intake over other roughage diets as reported by Campbell et al. (2007). Clearly, however, results of this study illustrated that supplementation with CSM and DDG increased intake of juniper over goats receiving alfalfa alone.

Many toxins are absorbed, biotransformed, and metabolized by mammals to form organic acids that must be buffered and excreted from the body (Foley et al. 1995). If a food is toxic, no amount of exposure is likely to increase intake beyond toxic satiation (Distel and Provenza 1991). Illius and Jessop (1995) hypothesized that animals limit consumption of toxins when nutritional stress reduces their tolerance to allelochemicals. During times of early starvation, the body can undergo depletion of glycogen stores and increased gluconeogenesis from degraded amino acids and fatty acids utilized for energy. This response to starvation can result in a loss of the MFO reactions and conjugation enzymes that reduce an animal's ability to handle plant toxins (Bidlack 1982). Detoxification also requires additional expenditures of amino acids and glucose to conjugate with toxins and maintain an animal's acid-base balance (Illius and Jessop 1995). Levels of cytochrome P-450 and reductase are reduced in animals fed protein-deficient diets (Owens and Zinn 1988).

Table 4. True in vitro dry matter digestibility (tIVDMD), potential undegradable intake protein (UIP), and acid detergent insoluble crude protein (ACDICP).

	Treatment				
Item[1]	Alfalfa	Cottonseed meal (CSM)	CSM/distiller's dried grain (DDG)	Soybean meal (SBM)	SBM/DDG
24-h					
tIVDMD	61.44	80.60	79.22	90.38	87.52
UIP, % initial dry matter (DM)	4.45	2.76	3.65	1.44	2.22
dCP, % initial DM	16.35	36.68	35.95	39.16	37.54
ADICP, % initial DM	2.57	3.69	6.58	1.87	2.57
ADICP, % initial crude protein (CP)	12.36	9.29	16.61	4.61	6.36
48-h					
tIVDMD	69.07	83.72	84.60	94.20	92.20
UIP, % initial DM	3.33	2.48	2.87	0.67	1.43
dCP, % initial DM	17.47	37.22	36.73	39.93	38.98
ADICP, % initial DM	2.18	3.89	4.09	1.66	3.07
ADICP, % initial CP	10.48	9.79	10.33	4.09	7.59

[1]24-h and 48-h = digested for 24 or 48 h, washed, and rinsed with neutral detergent solution.

In addition to supplying building blocks for protein, amino acids also supply a major portion of the glucose needed by ruminant animals. Alanine, aspartate, glutamate, and glutamine are the primary amino acids used as a source of carbon for glucose, alanine being the most glucogenic, accounting for 40–60% of the glucose formed from amino acids (Fahey and Berger 1988). Thus, feeding excess amino acids or protein sources high in escape protein may provide a source of amino acids that can be used for synthesis of glucose in the liver, which may play a role in the conjugation of toxins to be secreted from the body (Illius and Jessop 1995).

Proteins that escape microbial degradation in the rumen are particularly important for growth, development, gluconeogenesis, and possibly toxin excretion when the amino acid profiles of the escape proteins differ from microbial proteins (Maiga et al. 1996). Both CSM and DDG provide a source of amino acids to the small intestine that differ from the amino acids available from microbial protein (Storm and Orskov 1983; O'Mara et al. 1997; Table 5). CSM provides more arginine and glutamine to the small intestine, while DDG provides more glutamine and proline to the small intestine. DDGs also provide more leucine, but leucine is ketogenic, while arginine, glutamine, and proline are glucogenic and may provide a substrate for toxin excretion in the liver (Orskov 1992). Arguably, the increase in intake of juniper only when both CSM and DDG were included in the protein supplement may have been the result of the increased availability of arginine, glutamine, and proline reaching the small intestine and apparently transported to the liver. However, this hypothesis was not tested in this study. Nevertheless, the ingredients (other than the source of protein) and nutrient content were the same among the rations used in this study with the exception of digestible energy (higher in the SBM-based supplements). Future research should examine the response to providing specific amino acids to the small intestine and their effect on juniper consumption.

We expected juniper intake to increase linearly as the amount of escape protein increased in the supplements (alfalfa < SBM < SBM/DDG < CSM < CSM/DDG). However, the only differences noted were that goats supplemented with CSM/DDG ate more juniper (2.63 $g \cdot kg^{-1}$ BW) than goats receiving alfalfa alone (0.88 $g \cdot kg^{-1}$ BW). Juniper intake for the other treatments ranged from 1.51 $g \cdot kg^{-1}$ BW for goats supplemented with CSM to 1.27 $g \cdot kg^{-1}$ BW for goats supplemented with SBM/DDG. Reasons for a lack of a response as the amount of escape protein increased remain unclear.

Soybean meal is readily degradable in the rumen and potentially could improve rumen detoxification of the monoterpenoids in juniper. In this study, neither of the SBM-based

Table 5. Profiles of amino acids reaching the small intestine from microbial protein, alfalfa, soybean meal, cottonseed meal, and distiller's dried grain.[1]

	Protein source				
Amino acid	Microbial[2]	Alfalfa[3]	Soybean meal[4]	Cottonseed meal[4]	Distiller's dried grain[4]
Arginine	5.2	5.9	6.1	10.2	2.7
Histidine	2.1	1.9	2.5	2.8	2.3
Isoleucine	5.7	4.4	5.2	3.9	4.0
Leucine	7.6	8.6	8.6	7.3	14.1
Lysine	8.5	6.0	5.3	4.2	1.1
Methionine	2.4	2.4	1.8	2.1	2.4
Cysteine	1.2	1.8	1.6	1.5	1.6
Phenylalanine	4.9	6.2	5.4	6.1	5.5
Tyrosine	4.4	3.1	4.3	3.5	4.6
Threonine	5.4	5.3	4.5	3.8	3.4
Valine	6.0	5.1	5.8	5.4	5.1
Alanine	7.1	6.4	5.0	4.7	8.8
Aspartic acid	11.2	11.9	11.8	10.3	6.4
Glutamine	12.6	13.2	16.9	20.1	21.4
Glycine	5.5	6.7	4.7	4.8	3.2
Proline	3.5	5.3	5.0	4.4	8.6
Serine	4.1	5.7	5.4	4.9	4.8

[1]Values represent amount profile of intestinally digested amino acids following 12 h of ruminal incubation.
[2]Storm and Oskov (1983).
[3]Erasmus et al. (1994).
[4]O'Mara et al. (1997).

supplements affected ($P > 0.05$) juniper intake. Dunson et al. (2007) illustrated that rumen function had no effect on the degradation of several monoterpenoids found in juniper. Thus, based on the results of this study and findings from Dunson et al. (2007), it seems unlikely that providing ruminally degradable sources of protein will improve redberry juniper consumption.

Environmental conditions such as amount of rainfall and daily temperatures can have an effect on monoterpenoid levels found in redberry juniper (Owens et al. 1998), and they tend to be higher in winter and spring (Riddle et al. 1996). However, this is when goats should have a greater impact on juniper species because most preferred browse species are deciduous and dormant. Annual cool-season forbs are important forage for goats during winter and spring, but their availability is highly dependent on receiving cool-season precipitation. Unfortunately, cool-season precipitation does not occur every year. In addition, livestock may require additional protein during the winter to meet maintenance requirements. Therefore, supplementation with CSM and DDG seems warranted, especially during winter months.

Goats in all treatments increased juniper intake daily until day 12, and this pattern of intake has been clearly illustrated in other studies (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2007). In addition, feeding juniper at weaning can increase acceptance of that plant that continues once goats are released on pasture (Dietz et al. 2010). Collectively, we believe that conditioning an acceptance of juniper at weaning along with protein supplementation during the winter with supplements that contain CSM and DDG should increase utilization of juniper by goats.

IMPLICATIONS

Winter protein supplementation is often implemented by landowners throughout the southwestern United States. Supplementation costs continue to rise as feed ingredients (e.g., corn and soybean meal) are used for biofuel production. For livestock enterprises to remain viable, alternative supplements must be identified. DDGs are a readily available by-product of ethanol production. When incorporated in protein supplements with CSM, they seem to provide a source of amino acids that apparently escape rumen digestion and that differ from the amino acids available from microbial proteins. Although speculative at this point, it appears that supplementation with supplements that contain both CSM and DDG may improve juniper consumption on rangelands. Future efforts should compare juniper intake on pastures with and without supplementation with CSM and DDG. In addition, the specific impact on juniper consumption of amino acids reaching the small intestine should be addressed.

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