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Research Note

Differences in Food Ingestion and Digestion Among Sheep Classified as High or Low Sagebrush Consumers

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Abstract

Animals vary substantially in amount of three-tip sagebrush (*Artemisia tripartita* [Rydb.] *tripartita*) or other chemically defended plants they will voluntarily consume. This individual variation results from differences in dietary experience and inherited digestive characteristics. We conducted a series of experiments to examine behavioral and digestive traits of sheep identified as high or low consumers of sagebrush. In a pen-acceptance trial, high sagebrush consumers ate the same amount of sagebrush as low consumers when they had unrestricted access to a basal ration of alfalfa pellets ($P = 0.77$). However, when animals were restricted to 75% of their recommended energy requirement, sheep identified as high consumers ate more sagebrush than low consumers ($P = 0.05$). In a digestion trial, sagebrush reduced the dry matter digestibility when it was added to a hay-based diet. In vivo digestibility of a diet containing 10% fresh sagebrush and 90% alfalfa/grass hay was higher for high sagebrush consumers than low consumers ($P = 0.02$). The parameters measured in this trial suggest sheep that willingly consume high amounts of sagebrush, digest diets containing sagebrush more efficiently than low consumers.

Resumen

El consumo voluntario de "Sagebrush" (*Artemisia tripartita* [Rydb.] *tripartita*) y otras plantas con defensas químicas varía substancialmente entre los animales. Esta variación individual resulta de diferencias en la experiencia de forrajeo del animal y las características digestivas heredadas. Condujimos una serie de experimentos para examinar las características digestivas y de comportamiento de ovinos identificados con consumo alto y bajo de "Sagebrush." En un ensayo en corral, los animales con alto consumo comieron la misma cantidad de "Sagebrush" que los animales de bajo consumo, esto cuando tuvieron acceso irrestricto a una ración basal de alfalfa paletizada ($P = 0.77$). Sin embargo, cuando el consumo de energía de los animales se restringió al 75% de sus requerimientos, los ovinos identificados como altos consumidores comieron más "Sagebrush" que los bajos consumidores ($P = 0.05$). En un experimento de digestión se detectó que cuando el "Sagebrush" fue adicionado a una dieta a base de heno redujo la digestibilidad de la materia saca. La digestibilidad In vivo de una dieta conteniendo 10% de "Sagebrush" en verde y 90% de heno de alfalfa/zacate fue mayor en los ovinos de alto consumo que en los de consumo bajo ($P = 0.02$). Los parámetros medidos en este experimento sugieren que los ovinos que consumen voluntariamente altas cantidades de "Sagebrush" digieren más eficientemente las dietas que contienen "Sagebrush" que los ovinos de bajo consumo.

Key Words: chemically defended plants, diet selection, digestion balance, grazing behavior, prescribed grazing

INTRODUCTION

Rangeland managers have long tried to improve the grazing value of brush-infested rangelands, including pinyon–juniper woodlands (Aro 1971; Rippel et al. 1983), mesquite woodlands (Herbel et al. 1958), and sagebrush steppe (Johnson 1969) through chemical and mechanical brush control. A more contemporary management approach is to select and manage animals with the ability to harvest and digest the existing forage supply efficiently (Launchbaugh et al. 2001). We know animals vary in preference and intake of specific range plants (Provenza et al. 2003). This individual variation is based on experience (Provenza et al. 2003) and inheritance (Snowder et al. 2001) and could be exploited to create herds and flocks of animals with specific dietary attributes to reach grazing management goals.

Two experiments were conducted to examine ingestive and digestive traits affecting consumption of three-tip sagebrush (*Artemisia tripartita* [Rydb.] *tripartita*) by domestic sheep. Our objectives were to examine behavioral and metabolic differences in sheep identified as either high or low consumers of sagebrush in 1) a pen feeding trial examining voluntary intake or acceptance of sagebrush, and 2) a metabolism trial to determine differences in dry matter (DM) digestion and energy and nitrogen retained from sagebrush consumption.

MATERIALS AND METHODS

Animal Selection

Sagebrush consumption in 597 Rambouillet ewes was characterized at the USDA Agricultural Research Service Sheep Experiment Station near Dubois, ID (lat 44°14′N, long

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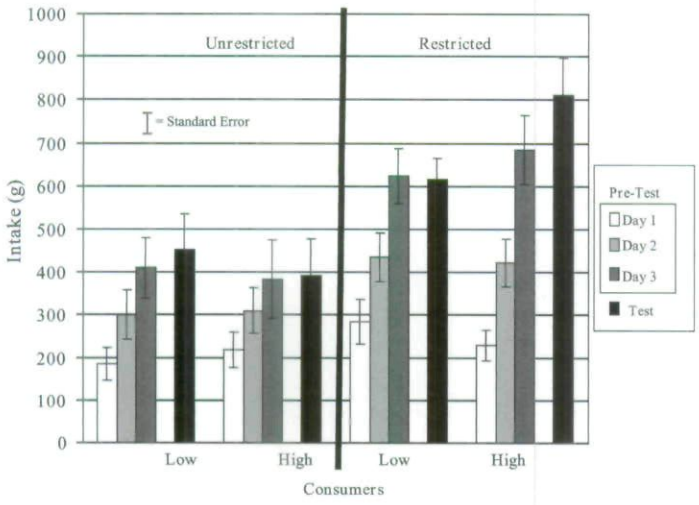

Figure 1. Three-tip sagebrush intake during 3 days of adaptation (pretest) and a 1-day acceptance test by sheep ($n = 10$) identified as high and low consumers of sagebrush with unrestricted (*ad libitum* access for 21 hours) and restricted (75% of daily digestible energy requirements) access to an alfalfa pellet basal diet. Vertical bars represent ± 1 SE.

112°11′W). This was accomplished by near-infrared reflectance spectroscopy (NIRS; Walker et al. 2002) of sheep feces collected by rectal palpation in September and October of 1996 and 1997 resulting in 4 collection periods, while ewes grazed a three-tip sagebrush dominated pasture. Ewes consistently in either the quartile of greatest or least sagebrush consumption were classified as high or low sagebrush consumers, respectively. Ten high and 10 low sagebrush consumers between 2 and 6 years of age were selected. Sheep were not pregnant or lactating during this research and averaged 70.2 kg (± 3.2 SE) with no difference between high or low sagebrush consumers ($P = 0.64$).

Experiment 1: Voluntary Sagebrush Intake

Voluntary consumption of sagebrush was examined with 10 high sagebrush consumers and 10 low consumers fed restricted or unrestricted amounts of a basal ration. Diet treatments were split across 2 periods (6–12 June and 26 June–2 July 1998) such that half of each consumer group (high or low) received each diet in each period. Animals were housed in individual outdoor pens, with free access to salt and water. Ewes assigned the restricted ration were offered alfalfa (*Medicago sativa* L.) pellets at 75% of their daily digestible energy requirements, and sheep on the unrestricted basal ration were offered ad libitum access to alfalfa pellets for 21 hours each day (Fraker 1999).

Sheep received the assigned basal ration for 3 days followed by a 3-day conditioning period and a 1-day acceptance trial when sheep were offered fresh sagebrush branches for 2 hours (0800–1000 hours). Sagebrush branches were collected daily and clamped to a wire with branches pointing upward, simulating the natural growth form of sagebrush. Branches were weighed before and after offering to determine intake.

This experiment was conducted in a 2-period balanced crossover design (Gill 1978) with one unavoidable limitation that sagebrush consumer group could not be randomly applied. Sagebrush intake by high and low consumer groups was compared for the restricted and unrestricted basal ration treatments. We also compared intake during the 3-day conditioning period with day as a repeated measure (Gill 1978).

Experiment 2: Digestion and Metabolism of Sagebrush

Three of the highest and 3 of the lowest consumers of sagebrush from experiment 1 were selected to determine the effect of consumer group on sagebrush digestibility. Two trials were conducted: the first examined digestion of alfalfa/grass hay and the second examined a diet of 10% fresh sagebrush current year's leaves and stems and 90% alfalfa/grass hay.

Sagebrush branches were collected daily, in the morning, and stored in a walk-in cooler (4°C) to limit volatilization of essential oils. Both diets were fed at 1.65% of body weight on a dry matter basis offered in 2 portions, at 0700 and 1900 hours. To ensure all sagebrush was consumed during the second trial, sagebrush was offered separately 30 minutes before the hay and amount of hay offered was adjusted to accomplish a 10% sagebrush and 90% hay diet. All diets were completely consumed within 30 minutes. Each trial period was initiated with a 7-day adaptation phase in which sheep were housed in individual pens for 4 days and then moved to metabolism crates equipped for fecal and urine collections for 3 days.

The adaptation phase was followed by a 5-day collection period within a 6-day trial period. Apparent in vivo dry matter digestibility was determined from forage intake and fecal output measurements (Harris 1970). Samples of alfalfa/grass hay and sagebrush were collected daily and a single composite was used for chemical analysis. Fecal and urine output were collected on days 2–6 with 20% aliquots from each sample used to create a composite sample.

Alfalfa/grass hay, sagebrush, and fecal samples were dried and ground to 1 mm, and urine samples were frozen and freeze dried (Fraker 1999). Gross energy (GE) was determined by adiabatic bomb calorimetry (Parr Instrument Company, Moline, IL). Nitrogen content was determined using the peroxide digestion procedure (Hach Co., Loveland, CO; Watkins et al. 1987), and converted to crude protein (CP). Neutral detergent fiber (NDF) content was determined by ANKOM filter apparatus Model F100 (ANKOM Technology Corp; Fairport, NY; Komarek et al. 1994). In situ degradability was determined by fermenting samples in the rumen of a fistulated beef cow (Harris 1970).

Digestibility parameters were compared for consumer groups across periods. The statistical design was a repeated measures analysis of variance with the examination split across 2 periods (Gill 1978).

RESULTS

Experiment 1: Voluntary Sagebrush Intake

Sagebrush consumption increased over the conditioning period for all animals (Fig. 1). There was a significant interaction ($P = 0.04$) between basal diet (restricted or unrestricted) and day (1, 2, or 3). Regardless of consumer group, sheep increased sagebrush consumption faster when their intake of the basal ration was restricted than when they had unrestricted access to

Table 1. Crude protein (CP), neutral detergent fiber (NDF), gross energy (GE), and in situ degradability calculated as a percent of dry matter for diets of mixed hay (50:50 grass/alfalfa), 100% three-tip sagebrush (current year's leaves and stems), and 10% sagebrush 90% mixed hay diets.

Nutritional parameter	Hay	100% sagebrush[1]	Calculated hay and sagebrush
CP[2] (%)	10.2 ± 0.1	8.4 ± 0.1	10.0 ± 0.1
NDF[2] (%)	60.4 ± < 0.1	49.5 ± 0.6	59.3 ± 0.1
GE[2] (cal/g)	4283.4 ± 35.3	5240.0 ± 40.7	4347.6 ± 36.1
In situ degradability (%)	45.1 ± 0.8	56.6 ± 3.2	46.6 ± 1.1

[1]100% sagebrush was for comparison only and was not offered to ewes.
[2]Forage quality was calculated for a diet containing grass/alfalfa hay with 10% sagebrush based on laboratory analysis of grass/alfalfa hay and sagebrush, in 90:10 proportions, respectively.

the basal diet. During the conditioning period no differences in sagebrush consumption were observed between consumer groups (Fig. 1; $P = 0.70$). Sheep ate more sagebrush on the test-day when the basal diet was offered in restricted amounts than when sheep had unrestricted access to the basal diet (Fig. 1; $P < 0.01$). Sheep identified as high sagebrush consumers ate the same amount of sagebrush as low consumers when they had unrestricted access to the basal ration ($P = 0.77$). However, when the amount of basal ration was restricted, sheep identified as high sagebrush consumers ate more sagebrush than low consumers ($P = 0.05$).

Experiment 2: Digestion and Metabolism of Sagebrush

The crude protein, NDF, gross energy levels, and in situ degradability of the diets are shown in Table 1. In vivo DM digestibility of an alfalfa/grass hay diet was similar for sheep identified as high or low sagebrush consumers (Table 2; $P = 0.41$). Overall, DM digestibility of the daily ration was reduced when 10% sagebrush was added ($P = 0.02$). The apparent in vivo DM digestibility of the sagebrush ration was higher for sheep identified as high sagebrush consumers than for low sagebrush consumers (Table 2; $P = 0.02$).

Both consumer groups retained a similar amount of gross energy from the basal diet (Table 2; $P = 0.71$) and the 10% sagebrush diet (Table 2; $P = 0.36$). All sheep were in a negative nitrogen balance and were apparently losing nitrogen from body reserves, regardless of diet or sagebrush consumer group, and the same level of nitrogen retention was observed on the grass/alfalfa hay and sagebrush-containing diet (Table 2; $P = 0.72$ and $P = 0.10$, respectively).

DISCUSSION

Differences in the propensity of sheep to ingest sagebrush may be most apparent in seasons and situations when the supply or quality of alternative forages is limited. Our research also indicates that sheep identified as high sagebrush consumers gain greater digestive benefit from sagebrush than those classified as low consumers. The reason for increased digestion of diets containing sagebrush for sheep identified as high consumers is unclear, though it is likely related to characteristics of digestive morphology or enzyme systems that may have been inherited (Snowder et al. 2001) or developed through dietary experience (Launchbaugh et al. 2001).

The observed greater consumption of sagebrush when alterative forage was limited is consistent with findings of Burritt et al. (2000) in which sheep ate more sagebrush when maintained on an alfalfa pellet basal ration that was 33% compared to 80% of voluntary intake. Villalba and colleagues (2004) also found lambs without prior experience to chemically defended feed consumed more when access to nutritious alternatives was limited. However, other studies report that sheep consumed more big sagebrush (*Artemisia tridentata* Nutt.) when they received an energy or protein supplement (Banner et al. 2000; Villalba et al. 2002). Thus, it appears that sheep can be either coerced (by restricting the basal ration) or enticed (by offering a supplement) into eating sagebrush and possibly other chemically defended plants.

Our chemical analyses agree with published studies that big sagebrush is a potentially nutritious forage with in situ degradability of 57% and moderate crude protein value of about 8%. These forage quality estimates agree with studies including Welch and Pederson (1981), who reported that big sagebrush collected in winter had an average in vitro digestibility of 53% (using mule deer rumen inoculum). Striby et al. (1987) reported in vitro digestibility varying from 45% to 52% (with sheep rumen inoculum) for mountain big sagebrush (*Artemisia tridentata* Nutt. *vaseyana* [Rydb.] Beetle) collected in winter. However, when three-tip sagebrush was added to the ration, dry matter digestibility decreased (Table 2). This is consistent with the findings of Ngugi and colleagues (1995),

Table 2. Intake, digestibility, and energy and nitrogen retention (means ± standard errors) of alfalfa/grass hay diets and a hay diet plus 10% fresh sagebrush leaves and current year's stems. Data were based on in vivo digestion trials with sheep identified as high ($n = 3$) and low consumers ($n = 3$) of three-tip sagebrush.[1]

Treatments	Intake (g/kg BW)	Apparent in vivo digestibility (%)	Retained energy[2] (kcal/kg BW)	Retained nitrogen[2] (g/kg BW)
Grass/alfalfa hay				
High[3]	16.50 a ± 0.01	60.74 a ± 0.23	36.11 a ± 0.74	−0.25 a ± 0.14
Low	16.50 a ± 0.01	59.53 ab ± 0.97	37.01 ab ± 0.76	−0.19 a ± 0.01
10% sagebrush				
High	18.65 b ± 0.01	58.65 b ± 0.71	37.18 ab ± 1.18	−0.17 a ± 0.05
Low	18.59 b ± 0.01	55.09 c ± 0.50	38.42 b ± 0.29	−0.06 a ± 0.01

[1]Values in the same column followed by different letters are significantly different ($P = 0.05$).
[2]Based on dried sagebrush samples, even though fresh sagebrush was fed in the digestion trial. Reported on kg of body weight (BW) basis.
[3]Sheep classified as high or low sagebrush consumers.

who reported reduced dry matter digestibility when as little as 10% mountain big sagebrush was added to the ration.

MANAGEMENT IMPLICATIONS

Our research suggests that selecting animals that possess desired dietary preferences may be a tool to achieve grazing management objectives. Observed differences of sagebrush cover in pastures grazed by animals selected for their dietary sagebrush preference has not been clearly demonstrated (Seefeldt 2005), but consistent use of sagebrush by sheep can reduce sagebrush abundance (Bork et al. 1998). Thus, selection and breeding of animals based on dietary preference for use in targeted grazing remains a potentially powerful management tool. However, the conditions under which individual variation is observed may be set by the availability of alternative forages, therefore requiring careful selection of season and stocking rate for grazing.

LITERATURE CITED

Aro, R. S. 1971. Evaluation on pinyon–juniper conversion to grassland. *Journal of Range Management* 24:188–197.

Banner, R., J. Rogosic, E. A. Burritt, and F. D. Provenza. 2000. Supplemental barley and charcoal increase intake of sagebrush by lambs. *Journal of Range Management* 53:415–420.

Bork, E. W., N. E. West, and J. W. Walker. 1998. Cover components on long-term seasonal sheep grazing treatments in three-tip sagebrush steppe. *Journal of Range Management* 51:293–300.

Burritt, E. A., R. E. Banner, and F. D. Provenza. 2000. Sagebrush ingestion by lambs: effects of experience and macronutrients. *Journal of Range Management* 53:91–96.

Fraker, M. J. 1999. Examination of digestive and behavioral mechanisms to explain individual variation in sagebrush consumption by sheep [thesis]. Moscow, ID: University of Idaho. 76 p.

Gill, J. L. 1978. Repeated measures and split-plot designs. *In:* Design and analysis of experiments in animal and medical sciences. Ames, IA: Iowa State University Press. p 169–259.

Harris, L. E. 1970. Nutritional research techniques for domestic and wild animals. Volume 1. Logan, UT: Utah State University. 240 p.

Herbel, C. H., F. Ares, and J. Bridges. 1958. Hand grubbing mesquite in semidesert grassland. *Journal of Range Management* 11:267–270.

Johnson, W. M. 1969. Life expectancy of sagebrush control in central Wyoming. *Journal of Range Management* 22:177–182.

Komarek, A. R., J. B. Robertson, and P. J. Van Soest. 1994. A comparison of methods for determining ADF using the filter bag technique versus conventional filtration. *Journal of Dairy Science* 77(Suppl 1):114.

Launchbaugh, K. L., F. D. Provenza, and J. A. Pfister. 2001. Herbivore response to anti-quality factors in forages. *Journal of Range Management* 54:431–440.

Ngugi, R. K., F. C. Hinds, and J. Powell. 1995. Mountain big sagebrush browse decreases dry matter intake, digestibility, and nutritive quality of sheep diets. *Journal of Range Management* 48:487–492.

Provenza, F. D., J. J. Villalba, L. E. Dziba, S. B. Atwood, and R. E. Banner. 2003. Linking herbivore experience, varied diets, and plant biochemical diversity. *Small Ruminant Research* 49:257–274.

Rippel, P., R. D. Pieper, and G. A. Lymbery. 1983. Vegetational evaluation of pinyon–juniper cabling in south-central New Mexico. *Journal of Range Management* 36:13–15.

Seefeldt, S. S. 2005. Consequences of selecting rambouillet ewes for mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) dietary preference. *Rangeland Ecology and Management* 58:380–384.

Snowder, G. D., J. W. Walker, K. L. Launchbaugh, and L. D. VanVleck. 2001. Genetic and phenotypic parameters for dietary selection of mountain big sagebrush in rambouillet sheep. *Journal of Animal Science* 79:486–492.

Striby, K. D., C. L. Wambolt, R. G. Kelsey, and K. M. Havstad. 1987. Crude terpenoid influence on in vitro digestibility of sagebrush. *Journal of Range Management* 40:244–248.

Villalba, J. J., F. D. Provenza, and R. E. Banner. 2002. Influence of macronutrients and activated charcoal on intake of sagebrush by sheep and goats. *Journal of Animal Science* 80:2099–2109.

Villalba, J. J., F .D. Provenza, and H. GouDong. 2004. Experience influences diet mixing by herbivores: implications for plant biochemical diversity. *Oikos* 107:100–109.

Walker, J. W., S. D. McCoy, K. L. Launchbaugh, M. J. Fraker, and J. Powell. 2002. Comparison of methods for calibrating fecal NIRS equations for botanical composition of diets. *Journal of Range Management* 55:374–382.

Watkins, K. L., T. L. Veum, and G. F. Krause. 1987. Total nitrogen determination of various sample types: a comparison of the Hach, Kjeltec, & Kjeldal methods. *Journal of the Association of Official Analytical Chemists* 70:410–412.

Welch, B. L., and J. C. Pederson. 1981. In vitro digestibility among accessions of big sagebrush by wild mule deer and its relationship to monoterpenoid content. *Journal of Range Management* 34:497–500.