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Importance of grass-legume choices on cattle grazing behavior, performance, and meat characteristics,

Frederick D Provenza

Importance of grass-legume choices on cattle grazing behavior, performance, and meat characteristics[1,2]

B. Maughan,* F. D. Provenza,* R. Tansawat,† C. Maughan,† S. Martini,† R. Ward,† A. Clemensen,* X. Song,† D. Cornforth, and J. J. Villalba*[3]

*Department of Wildland Resources, Utah State University, Logan 84322-5230; and †Department of Nutrition, Dietetics, and Food Sciences, Utah State University, Logan 84322-8700

ABSTRACT: We determined if tall fescue in a mixture with either tannin-containing sainfoin or saponin-containing alfalfa affected cattle foraging behavior, performance, meat quality, and consumer acceptance of meat. Foraging behavior, BW, and pasture biomass before and after grazing were monitored when cattle strip-grazed 3 replications of 2 treatments from May through September 2010 (12 calves/replication) and from June through September 2012 (8 calves/replication). Animals were allowed a choice between tall fescue and sainfoin (SAN) or tall fescue and alfalfa (ALF) growing in strips (fescue, legume, and fescue-legume mixture). Incidence of use (scan samples) of legumes increased from the beginning to the end of the trials ($P < 0.05$), suggesting that cattle learned to mix legumes with tall fescue. Scan samples and assessments of pasture biomass removal revealed greater use of sainfoin than alfalfa when both legumes were abundant in the spring ($P < 0.05$); that pattern reversed toward the end of the growing season ($P < 0.05$) as the abundance of sainfoin declined more than that of alfalfa. Intake of forage per kilogram of gain was greater for SAN than for ALF in 2010 ($P = 0.0003$) and showed a tendency to be greater for SAN than ALF in 2012 ($P = 0.19$). There were no differences in ADG between SAN and ALF in either year (1 kg/d; $P > 0.05$). No incidences of bloat were detected. When cattle (3 calves/treatment in 2010 and 8 calves/treatment in 2012) were slaughtered in September to assess meat quality and consumer acceptance, carcasses were lean (4% to 6% fat content of the longissimus muscle), but compared with ALF, SAN had higher marbling scores, quality grades (Select versus Standard), and back fat thicknesses ($P < 0.05$) in 2012. Steaks from cattle finished on SAN were redder in color than steaks from cattle finished on ALF ($P < 0.05$; 2012). Meat samples from SAN and ALF showed some differences in unsaturated fatty acid profiles and volatiles concentrations ($P < 0.05$), but consumer acceptance did not differ between SAN and ALF ($P > 0.05$). Thus, cattle incorporated a lower-quality grass into their diets even when legumes were available ad libitum during most grazing trials. Choices between tall fescue and legumes differing in the type of secondary compound (tannins vs. saponins) and bloating potential influenced patterns of forage use by cattle and led to differences in meat quality.

Key Words: alfalfa, cattle, diet selection, grazing, sainfoin, tall fescue

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INTRODUCTION

Livestock can better meet needs for nutrition and health when offered a variety of forages on pastures (Provenza et al., 2003; Provenza and Villalba, 2006). A variety of forages with different primary compounds (energy, protein, and minerals) enables animals to meet their needs for nutrients (Westoby, 1978). In addition, a variety of forages enables animals to limit intake of potentially toxic secondary compounds and to create synergies among primary and secondary compounds (Freeland and Janzen, 1974). Indeed, secondary compounds at appropriate con-

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[3]Corresponding author: juan.villalba@usu.edu

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centrations are important for the nutrition and health of livestock (Provenza and Villalba, 2010). For instance, saponins and tannins can inhibit methane and ammonia production in the rumen, which is beneficial for animal production as well as for reducing greenhouse gas emissions (Hu et al., 2005; Waghorn, 2008). Finally, secondary compounds play essential roles in maintaining the health of ecosystems from soil and plants to herbivores and human beings (Rosenthal and Berenbaum, 1992; Engel, 2002; Crozier et al., 2006). Thus, legumes such as sainfoin (tannin containing) and alfalfa (saponin containing) are important components of pastures not only because of their high nutritive value and nitrogen-fixing capabilities but also because of the benefits that their secondary compounds provide.

Sheep and cattle use plants such as tall fescue more efficiently when legumes such as alfalfa and bird's-foot trefoil are present in a mixture (Lyman et al., 2008, 2011, 2012). Nonetheless, little is known about how different legumes (alfalfa or sainfoin) grown with tall fescue affect forage intake and performance of cattle, the chemical characteristics of meat, or the acceptability of meat for human consumption. Our objectives were to determine if the type of legume in the mixture, tall fescue with either sainfoin or alfalfa, affected cattle foraging behavior, performance, meat quality, and consumer acceptance of meat.

MATERIALS AND METHODS

We determined the foraging behavior and performance of cattle offered a choice of a grass (tall fescue) and tannin-containing sainfoin or saponin-containing alfalfa. Grazing trials were conducted at the Utah State University (**USU**) pasture research facility in Lewiston, Utah (41°56′ N, 111°52′ W), according to procedures approved by the Utah State University Institutional Animal Care and Use Committee (approval 1424).

Pasture Design

Three blocks, each 3.6 ha in size, were established at the research facility in spring of 2009. Each block was divided into two 1.8-ha plots, one seeded with tall fescue (*Schedonorus arundinaceus* variety Kentucky 31) and alfalfa (*Medicago sativa* variety Vernal) high in saponins (Pedersen et al., 1976) and the other seeded with tall fescue and sainfoin (*Onobrychis viciifolia* variety Shoshone) high in tannins (Terrill et al., 1992; Hedqvist et al., 2000). Within a plot, there were three 0.6-ha strips approximately 30.5 m wide × 132.6 m long seeded with tall fescue, legume, and tall fescue–legume combinations. Thus, in each plot cattle had a choice of fescue, legume, and a fescue-legume mixture: fescue-alfalfa mix (treatment **ALF**) and fescue-sainfoin mix (treatment **SAN**). The grass-legume mixes were predominantly tall fescue (80% [period 1] to 90% [periods 2 and 3] of the biomass available for consumption). Thus, selection of the grass-legume mix involved a high proportion of tall fescue. There were 3 spatial replications of each treatment. The perimeters of the experimental plots were fenced using t-posts and electric fence.

Grazing Trials

Pastures were grazed from May 20 through September 7, 2010, with 12 fall-born Angus calves per treatment per plot and from June 4 through September 13, 2012, with 8 fall-born Angus calves per treatment per plot. The calves averaged 384 and 353 ± 1.7 kg initial BW in 2010 and 2012, respectively. They strip-grazed pastures with temporary electric fences moved daily to allow access to the grass, legume, and grass-legume mix daily. Plant DM in each paddock was assessed once a week by taking 15 random readings of a 0.1089-m^2 rising plate meter (Scrivner et al., 1986). Throughout the grazing trials animals had free access to water and trace mineral salt blocks.

To allow plants to regrow after being grazed, temporary electric fence was set behind and in front of the animals. This allowed us to move the calves back to the areas they had grazed initially (a new grazing period) once they reached the final section of each plot. Pastures were in the vegetative stage of growth at a height of 25 to 35 cm, and all plots provided forage ad libitum to cattle. The electric fences were moved daily to provide approximately 120% of the total forage, determined on a whole-plot basis, that animals consumed on the previous day. There were 3 grazing periods in 2010 (period 1: May 20 to June 21, period 2: July 8 to August 5, and period 3: August 17 to September 7) and 3 grazing periods in 2012 (period 1: June 4 to July 9, period 2: July 23 to August 22, and period 3: August 30 to September 13). Between periods animals grazed on an overflow pasture of endophyte-free tall fescue until forages were ready to graze again. Calves were weighed at the beginning and end of the grazing trials, and they were not given feed and water from 1700 h until the next morning when they were weighed at 0800 h.

Because of the low availability of forage by the end of period 2 in 2010, 4 animals in each treatment per plot were removed from the trial. Animals were selected at random with the restriction that animals observed during scan sampling remained in the trial. Thus, for the last period of the trial (period 3), 8 calves per treatment per plot strip-grazed the experimental pastures.

Scan Sampling

Three mornings each week, immediately after the calves had been given access to fresh forage, we observed their foraging behavior. One observer, assigned to each rep-

lication, recorded grazing patterns for 4 ear-marked calves in each treatment. Calves were differentially marked using 4 different colored ear tags. The foraging behavior of calves was recorded by each observer from a 3-m high observation tower adjacent to each experimental block.

We used scan sampling (Altmann, 1974) at 5-min intervals from 0730 to 0930 h to assess the incidence of feeding on each of the forage species and bouts of inactivity. Frequency of feeding on each species was calculated as a percentage of the total number of scans in which animals were feeding. The total number of scans of grazing events and nongrazing events (bouts of inactivity such as not eating, fighting, resting, and searching) was also recorded. Groups of cattle normally grazed together (>95% of the time) on the same plant species. If individuals were performing different behaviors, each behavior was recorded for each individual.

Estimated Daily Intake

A rising plate meter (**RPM**) was used to estimate the amount of forage removed from the pastures by the calves. Once a week RPM recordings were taken for each of the forages in each of the pastures to compare biomass estimates before and after grazing. Calibration samples were cut, oven-dried (60°C) for 2 d, and then weighed to determine the DM content of each forage. The DM of RPM calibration samples was regressed on the corresponding RPM readings to develop a linear regression equation for alfalfa, sainfoin, tall fescue, tall fescue–alfalfa mixtures, and tall fescue–sainfoin mixtures. Pre- and postgrazing pasture DM readings were predicted from these equations, and DM removed by the animals on a given day was calculated as the difference between pre- and postgrazing pasture DM.

Chemical Analyses

Rising plate meter calibration samples were also used to determine the chemical composition of the forages in each pasture. Samples were dried at 60°C and then ground using a Wiley Mill (Thomas Scientific, Swedesboro, NJ) with a 1-mm screen. They were analyzed for CP, NDF, and ADF using near-infrared spectroscopy (NIRS; AOAC, 1990).

Forages were analyzed for condensed tannins (sainfoin; Terrill et al., 1992), ergovaline (tall fescue; Rottinghaus et al., 1991), and saponin (alfalfa; Lee et al., 2001). Fresh forage samples from plants randomly selected along a paced transect across each pasture were harvested by hand, placed in plastic bags, covered with dry ice, and transported to a freezer at –20°C until they were freeze-dried and ground through a Wiley mill with a 1-mm screen before analyses.

Meat Analyses

Animals were randomly selected from each plot (3 calves/treatment in 2010 and 8 calves/treatment 2012) for meat analyses. Animals were slaughtered at the USU South Farm abattoir (2010) and at a commercial facility (2012). The calves were 22 to 24 mo old and weighed between 220 and 277 kg (2010) and 481 and 574 kg (2012) hanging carcass weight. Carcass quality and yield grade (Hale et al., 2013) were determined for each animal, including marbling score of the LM (longissimus dorsi), taken at the 12 to 13th rib. Carcass yield grade measurements included HCW, back fat thickness (**BF**), and LM area (**REA**) at the 12 to 13th rib, and the amount of kidney, pelvic, and heart (**KPH**) fat as a percent of carcass weight. The primal ribs (longissimus dorsi muscles) of each animal were then removed, vacuum packaged, shipped to the Department of Nutrition, Dietetics, and Food Sciences at USU, and frozen at –20°C for later analyses.

Oxidative Stability and Color Measurements. Metmyoglobin reducing activity (**MRA**) was measured as described by Mancini et al. (2008). Rib steak color was measured during 12-d storage in a dark cooler at 1°C. Steaks (2 per animal) were placed in Styrofoam trays overwrapped in clear, oxygen-permeable polyvinyl chloride film, allowing formation of red oxymyoglobin (bloom development). Meat color was determined with a HunterLab Miniscan portable colorimeter (Hunter Associates Laboratory Inc., Reston, VA) with a 5-mm diameter aperture, set to use illuminant D-65. Lightness (L*), redness (a*), and yellowness (b*) were measured in triplicate on each steak through the packaging film on d 0, 3, 6, 9, 12 of storage at 1°C.

Fat. Ether-extractable fat content of uncooked rib steaks was done by the solvent extraction (Williams, 1984) using petroleum ether as the solvent.

pH. Raw beef pH was measured on 10-g finely chopped samples, diluted to 100 mL in distilled water, allowed to equilibrate at room temperature for 30 min, and then filtered; pH was measured with a Fisher Accumet pH meter model 610 A (Fisher Scientific Inc., Salt Lake City, UT) equipped with a combination pH electrode calibrated just before use to pH 4.0 and 7.0.

Fatty Acid Chemical Composition. Fatty acids were analyzed using the method developed by O'Fallon et al. (2007).

Headspace Volatile Analysis. The volatile profile of heated meat was determined as described by Vasta et al. (2010).

Sensory Evaluation Tests

Descriptive Analysis. A group of people were recruited from the local community and trained to identify and quantify the flavor characteristics of the meat obtained

from cattle fed the ALF and SAN diets. Panelist screening and training were performed as described in Maughan et al. (2012) and Maughan and Martini (2012). A lexicon of 18 terms was used to describe the flavor of the meats. These terms included astringent, barny, bitter, bloody, brothy, browned, gamey, grassy, juicy, fatty, livery, metallic, oxidized (warmed-over flavor), roast beef, salty, sour, sweet, and umami. The intensity of each attribute was rated using a 15-point category scale. Descriptive tests were performed with meat obtained from the trial conducted in 2010.

Consumer Tests. A consumer panel of 120 people rated the meats obtained from cattle fed the ALF and SAN diets in 2010 and 2012 for degree of liking (acceptance) on a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely). Panelists were asked to comment on the flavor of each sample and answer basic demographic questions such as gender, age, and frequency of steak consumption. Samples were presented in an incomplete block design in a random and balanced order with 3-digit blinding codes on the sample container. Each panelist was presented with two 6.5-cm^2 pieces of steak, 1 from ALF-fed cattle and 1 from SAN-fed cattle. For both descriptive and consumer panels, samples were prepared following the guidelines from the American Meat Science Association (1995).

Statistical Analyses

Behavioral data were analyzed as a repeated measures design with 2 treatments: fescue-alfalfa mix (ALF) and fescue-sainfoin mix (SAN) nested within 3 spatial replications. The response variables were the percentage of scans recorded on each species relative to the total number of grazing events and scans recorded as total grazing events.

Average daily gain and DM per unit gain were analyzed with a split-plot design with animals nested within treatments (ALF, SAN). Forage chemical composition was analyzed in a repeated measures analysis.

Foraging behavior, animal performance, and forage chemical composition were analyzed using a mixed-effects model (SAS Inst. Inc., Cary, NC; version 9.1 for Windows). The variance-covariance structure was selected on the basis of the lowest Bayesian information criterion. The model diagnostics included testing for a normal distribution of the error residuals and homogeneity of variance. Means were analyzed using pairwise differences of least squares means.

Meat analyses were done in triplicate for each treatment. A complete randomized design with the PROC GLM function was used for MRA, FRAP, fatty acid profiles, and headspace volatiles. A repeated measures design in a mixed-effects model, using Tukey adjustment to obtain differences of least squares means, was used for raw meat color and thiobarbituric acid (**TBA**) test.

Descriptive and consumer data were analyzed using a 2-way ANOVA (SAS 9.3, SAS Inst. Inc.) and a *t* test (Prism 6 for Windows, version 6.01, GraphPad Software Inc., La Jolla, CA), respectively.

RESULTS

Chemical Composition of the Forages

Chemical Composition in 2010. Concentrations of NDF and ADF in sainfoin increased from May 26 to June 16 (Fig. 1A) and then decreased until the end of the trial (time effect; $P = 0.0001$). Concentration of CP for sainfoin was highest at the beginning of the trial, decreased to the lowest levels on July 14, and then increased until the end of the trial (time effect; $P = 0.006$).

Like sainfoin, concentrations of NDF and ADF for alfalfa increased from the beginning of the trial until June 16 and then decreased until the end of the trial, with the exception of a slight increase on July 28 (time effect; $P = 0.0002$ and 0.0001 for NDF and ADF, respectively). Concentrations of CP decreased from the beginning of the trial to June 16 and then steadily increased until the last sampling date (time effect; $P = 0.0003$; Fig. 1B).

Concentrations of NDF and ADF in tall fescue fluctuated throughout the trial (time effect; $P = 0.006$ for NDF and 0.003 for ADF). Concentrations of CP generally decreased from the beginning of the trial until June 16, remained steady from then until August 20, and then increased until the end of the trial (time effect; $P = 0.14$; Fig. 1C).

Concentrations of tannins in sainfoin did not differ over time (4.8% to 7.7%; time effect; $P = 0.3617$). Saponin concentrations in alfalfa increased from May to the end of the trial with values ranging from 0.4% to 0.8% (time effect; $P = 0.08$). No ergovaline was found in tall fescue.

Chemical Composition in 2012. Concentrations of NDF and ADF in sainfoin fluctuated throughout the trial, but no time effect was detected ($P = 0.17$ and 0.35 for NDF and ADF, respectively; Fig. 1D). Likewise, no differences in concentration of CP were detected throughout the trial (time effect; $P = 0.39$).

Concentrations of NDF and ADF in alfalfa increased from the beginning of the trial until July 3, then decreased until July 25, and then gradually increased until the end of the trial (time effect; $P = 0.08$ for NDF and ADF). Concentrations of CP in alfalfa decreased from the beginning of the trial to July 3, increased to their highest levels by July 25, and then decreased toward the end of the trial (time effect; $P = 0.007$; Fig. 1E).

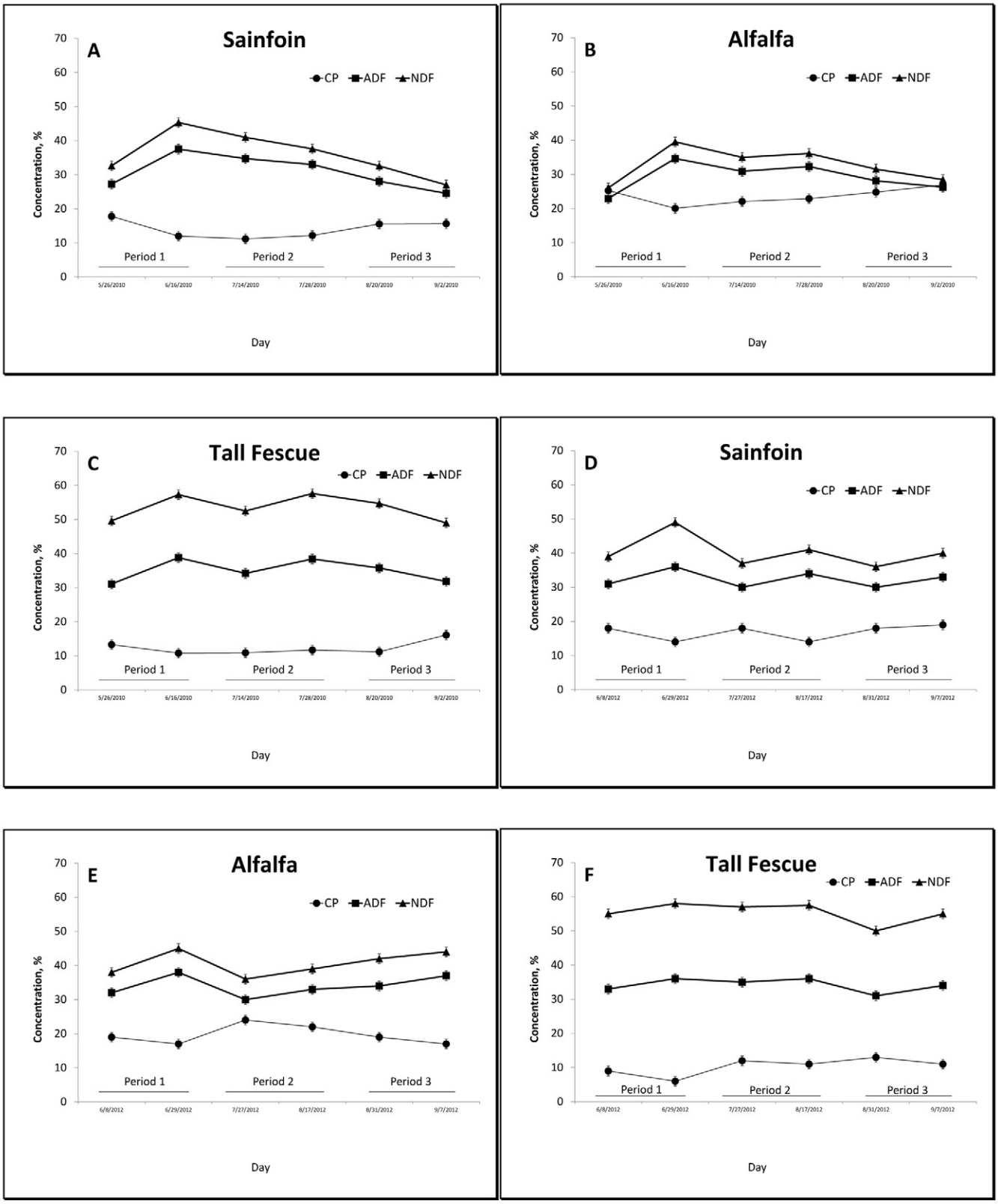

Figure 1. Concentrations of CP, NDF, and ADF in (A–C) 2010 and (D–F) 2012.

Concentrations of NDF and ADF in tall fescue remained fairly stable throughout the trial except for September 5, when they reached their lowest levels (time effect; $P = 0.004$ and 0.0043 for NDF and ADF, respectively). Concentrations of CP reached their lowest levels during July 3 and then increased toward the end of the trial (time effect; $P = 0.007$; Fig. 1F).

Table 1. DM availability during 2010

Item	Period 1		Period 2		Period 3	
	May 20	June 21	July 8	August 5	August 17	September 7
ALF treatment[1]						
Pregrazing biomass, t/ha						
Legume	20.2 ± 0.6	43.7 ± 4.6	18.9 ± 0.8	32.9 ± 2.5	19.6 ± 2.5	18.4 ± 1.8
Mix	34.5 ± 2.7	51.4 ± 3.5	35.2 ± 3.2	34.1 ± 2.0	24.5 ± 2.4	26.4 ± 1.2
Fescue	33.0 ± 3.5	46.9 ± 8.2	34.9 ± 7.3	30.4 ± 2.4	24.4 ± 3.4	24.4 ± 1.5
Postgrazing biomass, t/ha						
Legume	7.8 ± 2.2	15.0 ± 2.8	8.8 ± 2.8	11.2 ± 2.5	9.7 ± 2.2	8.2 ± 2.6
Mix	20.5 ± 3.1	35.5 ± 2.0	21.4 ± 3.0	20.5 ± 2.0	19.9 ± 3.5	18.7 ± 2.2
Fescue	20.5 ± 3.1	39.4 ± 7.7	23.4 ± 3.6	20.7 ± 1.9	19.5 ± 1.8	18.2 ± 2.6
SAN Treatment[2]						
Pregrazing biomass, t/ha						
Legume	29.9 ± 5.4	81.1 ± 10.1	43.6 ± 8.3	29.0 ± 4.0	19.5 ± 2.5	7.4 ± 2.6
Mix	40.0 ± 0.5	52.3 ± 7.6	31.6 ± 2.6	28.4 ± 3.9	22.4 ± 1.5	17.1 ± 0.4
Fescue	37.1 ± 3.4	50.5 ± 7.6	34.7 ± 3.0	28.0 ± 3.1	24.1 ± 1.2	17.1 ± 0.6
Postgrazing biomass, t/ha						
Legume	6.6 ± 1.2	10.7 ± 0.7	9.4 ± 0.8	6.1 ± 1.1	7.3 ± 0.5	3.5 ± 1.2
Mix	18.5 ± 2.4	30.8 ± 0.7	20.8 ± 2.7	12.9 ± 0.6	16.5 ± 0.2	12.0 ± 0.6
Fescue	17.6 ± 3.1	36.6 ± 2.9	20.0 ± 1.9	14.8 ± 0.9	15.5 ± 2.0	15.8 ± 0.8

[1]Tall fescue and alfalfa.

[2]Tall fescue and sainfoin.

Tannin concentrations in sainfoin declined from 8% initially to 3% at the end of the trial (time effect; $P = 0.009$). Saponin concentrations in alfalfa declined after the first month of the trial from 0.9% to 0.3% (time effect; $P = 0.06$). As in 2010, no ergovaline was found in tall fescue.

Forage Availability

In 2010. DM was greater for sainfoin than alfalfa in period 1 and the beginning of period 2, but that pattern reversed by the end of period 3 (Table 1). Fescue DM was greater for SAN than ALF in period 1, but the pattern reversed by the end of period 3.

In 2012. DM was greater for sainfoin than for alfalfa in period 1 and until the end of period 2; the pattern reversed in period 3 (Table 2). Tall fescue DM availability was similar in SAN and ALF treatments for period 1 and was greater in ALF than in SAN for periods 2 and 3.

Scan Sampling

Total Grazing Events in 2010. *T*he incidence of grazing was greater for animals in SAN than in ALF (90% vs. 82% ± 2% scans/120 min; $P = 0.03$), mainly because of differences between treatments from May 25 to June 3 (period 1), July 14 to July 26 (period 2), and August 19 until the end of the trial (period 3; treatment × date interaction; $P = 0.007$; Fig. 2).

Total Grazing Events in 2012. As in 2010, animals in SAN had more total grazing events than animals in ALF (90% vs. 78% ± 2% scans/120 min per 32 d; $P = 0.006$). This effect was mainly due to differences between treatments during period 1, the beginning of period 2, and the majority of period 3 (treatment × date interaction; $P = 0.001$; Fig. 2).

Use of Legumes in 2010. Animals spent most of the daily 2-h sessions grazing legumes (25% to 70% of scans compared with 7% to 39% for the grass). Use of legumes was low at the beginning of the trial, but as time progressed, the number of scans in both SAN and ALF increased (date effect; $P = 0.0001$; Fig. 3). Differences in legume use between treatments occurred from July 12 to July 30 (period 2, Fig. 3), when there more scans on sainfoin than on alfalfa (treatment × date; $P = 0.04$). Overall, scans on legumes decreased across time during the daily 2-h sessions (time effect; $P = 0.0001$), and they were greater during periods 2 and 3 than during period 1 (period effect; $P = 0.004$; Fig. 4B). No differences were detected between treatments during the different time intervals ($P = 0.45$). No incidence of bloat was recorded for cattle in the ALF treatment.

Use of Legumes in 2012. As in 2010, animals spent most of the daily 2-h sessions grazing legumes (45% to 95% of scans compared with 2% to 38% for the grass; Fig. 3). More scans were recorded for SAN than for ALF (85% vs. 72% ± 3%; $P = 0.04$). These differences occurred in period 1 and during the first half of period 2 (treatment × date; $P = 0.0001$; Fig. 3). As in 2010, scans on legumes decreased across the 2-h observation period (time effect; $P < 0.0001$; data not shown), and they were greater during periods 2 and 3 than during period 1 (period effect; $P < 0.0001$). No incidence of bloat was recorded for cattle in the ALF treatment.

Table 2. DM during 2012

	Period 1		Period 2		Period 3	
Item	June 4	July 9	July 23	August 22	August 30	September 13
ALF treatment[1]						
Pregrazing biomass, t/ha						
Legume	43.5 ± 0.3	63.2 ± 2.6	47.1 ± 4.2	42.6 ± 3.8	45.7 ± 3.3	41.9 ± 1.2
Mix	32.8 ± 2.8	34.1 ± 2.1	23.0 ± 3.1	32.4 ± 0.5	30.4 ± 3.4	30.6 ± 4.1
Fescue	36.9 ± 4.4	29.8 ± 4.2	25.3 ± 2.8	33.9 ± 2.0	32.6 ± 3.3	33.0 ± 2.5
Postgrazing biomass, t/ha						
Legume	22.6 ± 3.7	18.6 ± 3.1	12.3 ± 2.9	15.9 ± 1.6	14.7 ± 2.8	14.1 ± 3.0
Mix	27.0 ± 2.6	28.5 ± 1.5	22.1 ± 3.4	25.0 ± 2.1	22.0 ± 4.3	21.1 ± 4.6
Fescue	30.2 ± 2.1	25.8 ± 2.7	21.6 ± 1.5	22.7 ± 2.5	25.5 ± 3.2	22.9 ± 3.4
SAN treatment[2]						
Pregrazing biomass, t/ha						
Legume	59.3 ± 9.3	107.3 ± 1.1	39.8 ± 4.3	63.9 ± 1.5	35.5 ± 6.7	27.1 ± 5.4
Mix	31.5 ± 1.9	34.3 ± 5.0	22.7 ± 2.0	30.3 ± 1.8	27.1 ± 1.7	28.6 ± 1.3
Fescue	36.7 ± 3.5	32.8 ± 3.6	22.1 ± 1.3	29.4 ± 0.5	28.5 ± 3.2	25.5 ± 1.8
Postgrazing biomass, t/ha						
Legume	14.7 ± 1.5	21.8 ± 2.5	13.1 ± 0.4	12.3 ± 1.9	10.2 ± 0.9	10.5 ± 0.6
Mix	24.5 ± 1.7	24.0 ± 2.6	16.1 ± 0.5	20.0 ± 1.4	20.4 ± 1.6	20.7 ± 3.0
Fescue	27.6 ± 1.9	24.3 ± 0.5	16.0 ± 1.4	19.9 ± 0.3	18.7 ± 2.6	19.0 ± 1.1

[1]Tall fescue and alfalfa.

[2]Tall fescue and sainfoin.

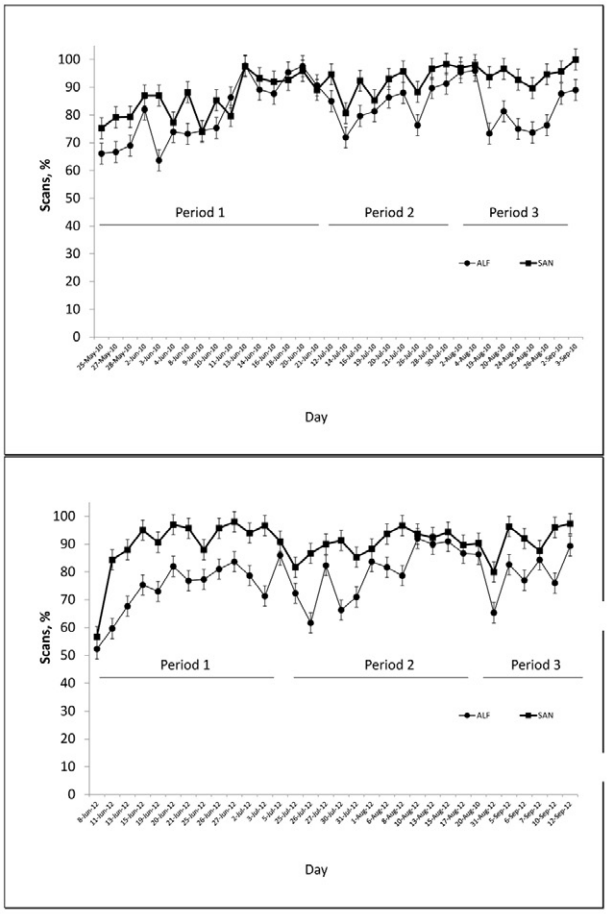

Figure 2. Total grazing events (as a percentage of total scans) for cattle allowed to strip-graze every day a choice of tall fescue, alfalfa, and alfalfa-fescue mix (ALF) or tall fescue, sainfoin, and sainfoin-fescue mix (SAN) in (A) 2010 and (B) 2012. Their preferences for the different forages were monitored using scan sampling.

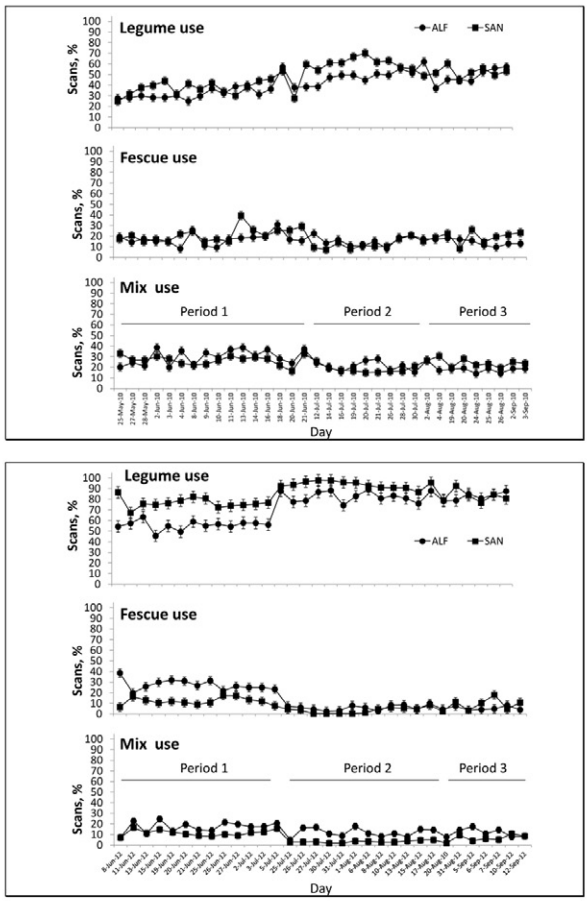

Figure 3. Daily grazing events for cattle that strip-grazed every day a choice of tall fescue, alfalfa, and alfalfa-fescue mix (ALF) or tall fescue, sainfoin, and sainfoin-fescue mix (SAN) in (top) 2010 and (bottom) 2012. Preferences for the different forages were assessed using scan sampling (represented as a percent of total grazing scans).

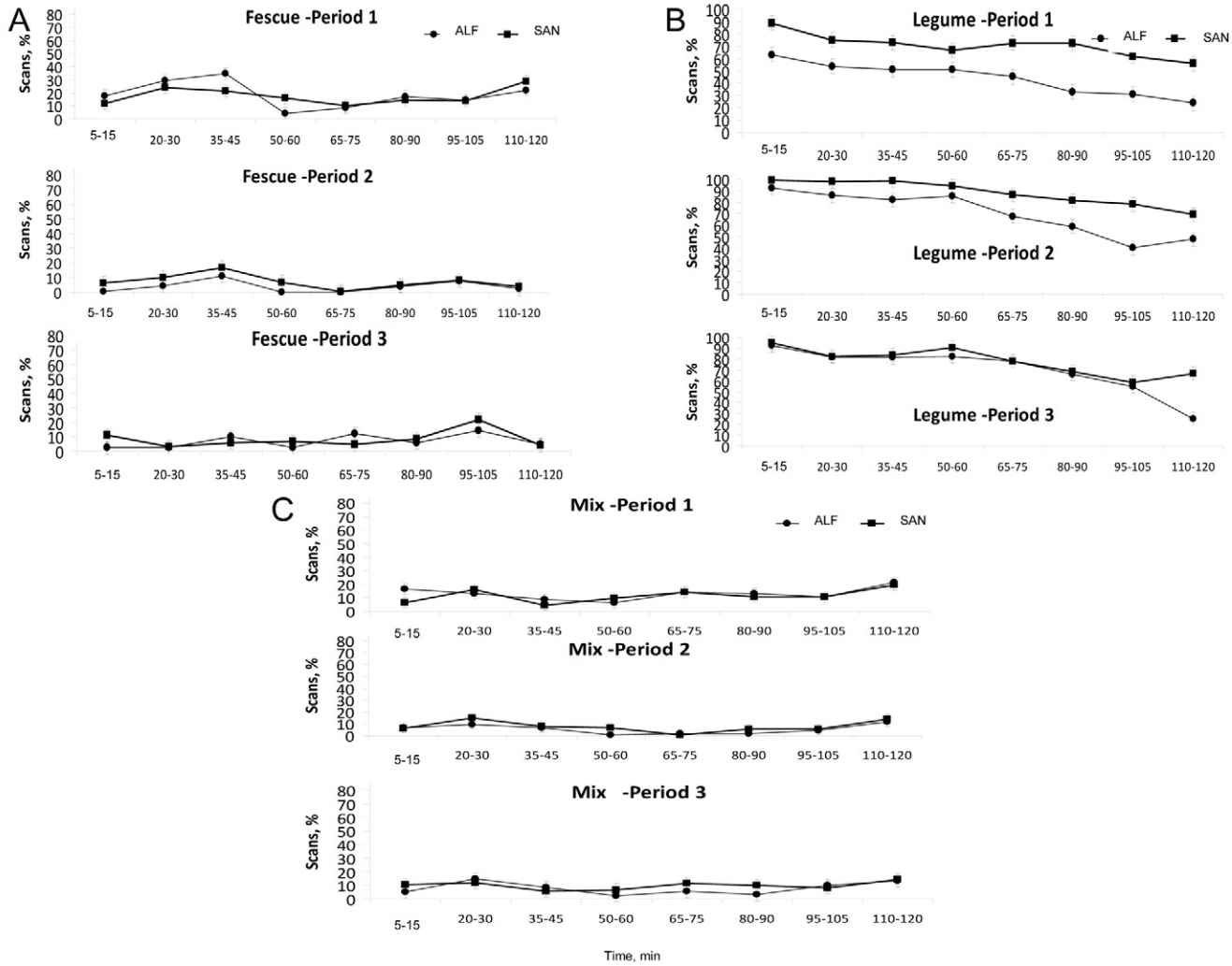

Figure 4. The 2010 short-term grazing events during the 2-h scan sampling period broken into 10-min intervals when cattle had a choice of (A) tall fescue, (B) legume, and (C) a mix of legume and fescue. Cattle strip-grazed every day a choice of tall fescue, alfalfa, and alfalfa-fescue mix (ALF) or tall fescue, sainfoin, and sainfoin-fescue mix (SAN).

Use of Tall Fescue in 2010. Cattle in both ALF and SAN had the least scans on tall fescue (treatment; P = 0.56; Fig. 3), but SAN had more scans than ALF on tall fescue on some days: June 4, 13, and 21 (period 1), July 12 (period 2), and September 3 (period 3; treatment × date interaction; P = 0.01; Fig. 3). Use of tall fescue was low initially and gradually increased to highest levels at the end of the 2-h observation period (time effect; P = 0.0005; Fig. 4A) with no differences between treatments (treatment, P = 0.70; treatment × date, P = 0.96).

Use of Tall Fescue in 2012. Use of tall fescue declined from period 1 to periods 2 and 3 (date effect; P < 0.0001; Fig. 3), and there was a trend for greater use of tall fescue for ALF than for SAN (15% vs. 8% ± 3% scans/120 min per 32 d; P = 0.15; Fig. 3) because of more scans on tall fescue for ALF than SAN during period 1 (treatment × date interaction; P < 0.0001; Fig. 3). As in 2010, use of tall fescue started low and then gradually increased toward the end of the 2-h observation interval (time effect; P < 0.0001; data not shown).

Use of the Legume–Tall Fescue Mix in 2010. No differences were observed between treatments over time (P = 0.52; Fig. 3). The use of the mix during the 2-h grazing period was consistent throughout period 1 and then fluctuated during period 2 (date effect; P = 0.0001). By the end of the trial, cattle in SAN consumed amounts of mix similar to cattle in ALF (treatment × date; P = 0.18; Fig. 3). Use remained fairly constant across time, with a slight increase toward the end of the 2-h grazing session. Scans were the lowest for the 0- to 15-min interval (date effect; P = 0.008; Fig. 4C). Cattle used more mix during period 1 than during periods 2 and 3 (period effect; P = 0.001). No differences were detected between treatments during the different time intervals (treatment, P = 0.29; treatment × date, P = 0.81; Fig. 3).

Use of the Legume–Tall Fescue Mix in 2012. Cattle in ALF had more scans on the tall fescue–legume mix than

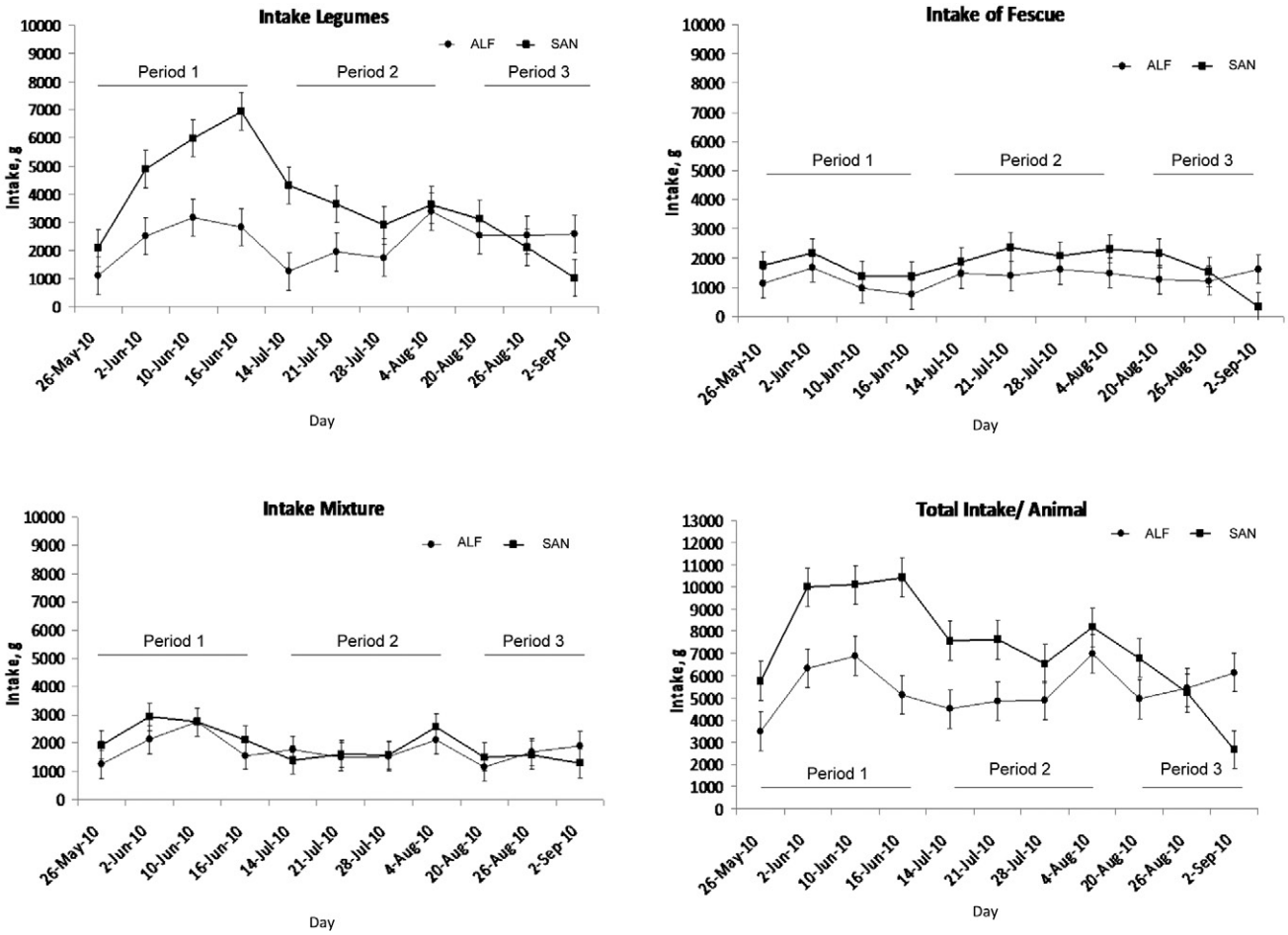

Figure 5. The 2010 estimated amounts of legumes, fescue, a mix of legumes and fescue (mixture), and total amount of forage (legumes + fescue + mix) removed from the pastures/animal (intake) using a rising plate meter (RPM). Cattle strip-grazed every day a choice of tall fescue, alfalfa, and alfalfa-fescue mix (ALF) or tall fescue, sainfoin, and sainfoin-fescue mix (SAN).

cattle in SAN (14% vs. 7% ± 1%; $P = 0.02$; Fig. 3). Use of the legume–tall fescue mix during the 2-h grazing period was constant across time, but fluctuations between treatments caused a treatment × time interaction ($P < 0.0001$; data not shown). Cattle used more mix during period 1 than during periods 2 and 3 (period effect; $P = 0.002$; Fig. 3).

Pasture Intake

Pasture Intake in 2010. Legume consumption, estimated as the difference between pregrazing and postgrazing pasture DM, increased from the beginning of the trial until June 16 (period 1), and then it declined until the end of the trial (day effect; $P = 0.0001$; Fig. 5). From June 2 to July 21 (periods 1 and 2), animals used more sainfoin than alfalfa (treatment × date; $P = 0.04$). Intake of tall fescue was similar between treatments throughout the trial ($P = 0.33$), and there were no differences between treatments in the amount of legume–tall fescue mix consumed (treatment effect, $P = 0.69$; treatment × date, $P = 0.77$; Fig. 5). Averaged across time, cattle in SAN ate more total forage than cattle in ALF (7.35 vs. 5.41 ± 0.53 kg·animal^{-1}·d^{-1}; $P < 0.06$).

Pasture Intake in 2012. Intake of legumes increased during period 1 (day effect; $P < 0.0001$; Fig. 6). Averaged for all days, legume intake was greater for the SAN than for the ALF treatment (8.9 vs. 6.5 ± 0.42 kg·animal^{-1}·d^{-1}; treatment effect; $P = 0.02$; Fig. 6). However, this pattern reversed for period 3 (treatment × day interaction; $P = 0.0001$; Fig. 6). The ALF and SAN groups both ate similar amounts of tall fescue (14.18 vs. 14.25 ± 2.59 kg·animal^{-1}·d^{-1}; treatment effect; $P = 0.99$; Fig. 6). There were no differences in intake of the legume–tall fescue mix between treatments (treatment effect, $P = 0.99$; treatment × day, $P = 0.24$; Fig. 6). Averaged across time, animals in SAN ate more forage than the animals in ALF (11.7 vs. 9.3 ± 0.54 kg/animal; $P = 0.03$). Cattle in the SAN group ate more forage than animals in ALF in periods 1 and 2, but the pattern reversed in period 3 (treatment × day; $P = 0.001$; Fig. 6).

In general, intake and scan sampling data revealed similar patterns of forage use. This suggests that 2-h scan sampling during the beginning of the daily allowance of forage was representative of estimations of biomass removed daily. Nevertheless, during period 3 of 2012

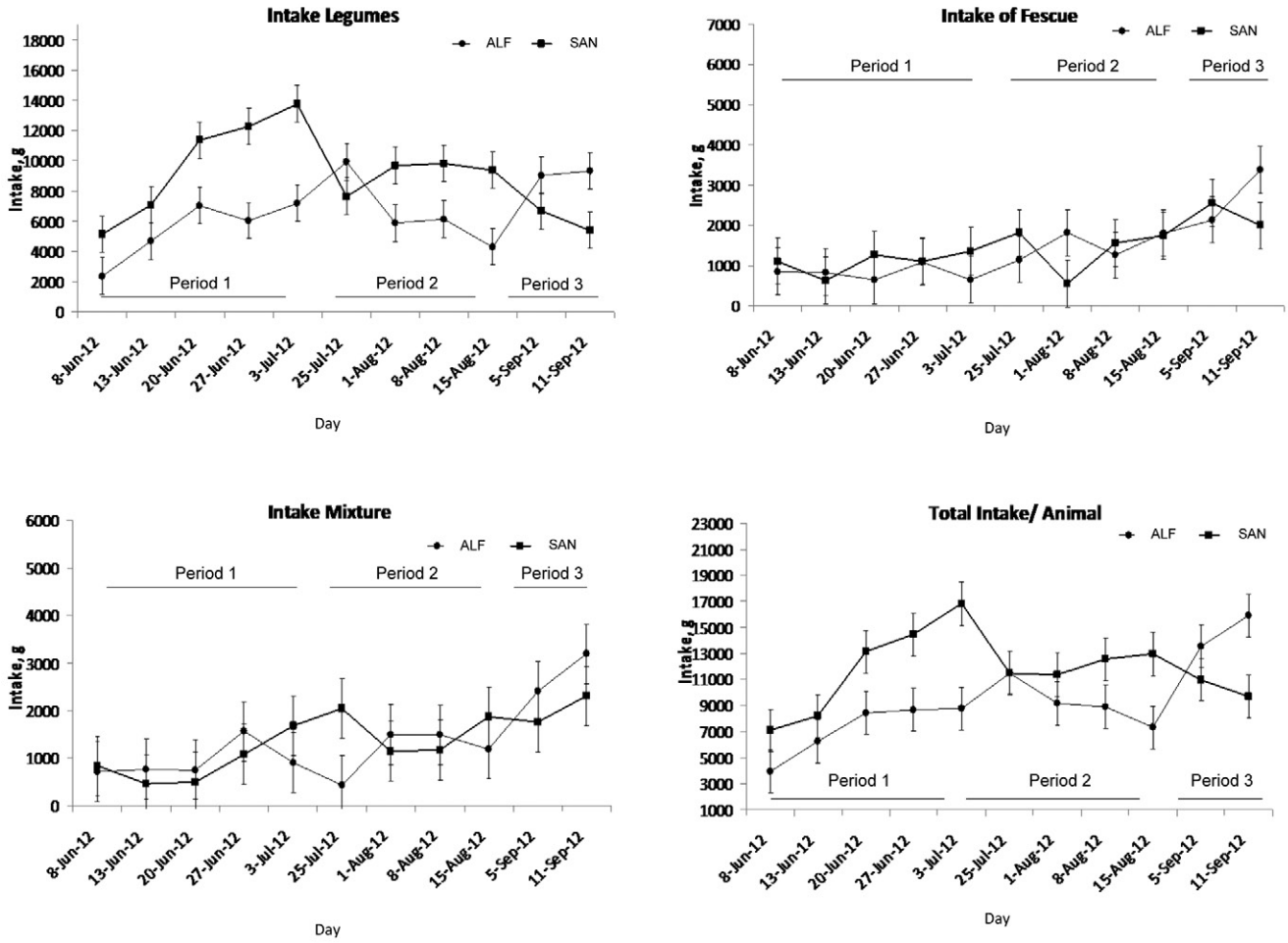

Figure 6. The 2012 estimated amounts of legumes, fescue, a mix of legumes and fescue (mixture), and total amount of forage (legumes + fescue + mix) removed from the pastures/animal (intake) using a rising plate meter (RPM). Cattle strip-grazed every day a choice of tall fescue, alfalfa, and alfalfa-fescue mix (ALF) or tall fescue, sainfoin, and sainfoin-fescue mix (SAN).

intake for ALF increased for all forages, an increase not observed for the scan sample data.

Average Daily Gains

ADG in 2010. Cattle in SAN and ALF gained 1 ± 0.05 kg/d from the beginning (May 20) to the end (September 7) of the trial (treatment $P = 0.98$). Cattle had greater intake of forage per kilogram of gain in SAN than in ALF (7.6 vs. 5.8 ± 0.33; $P = 0.0003$).

ADG in 2012. Cattle in SAN gained 1 ± 0.04 kg/d, and cattle in ALF gained 0.98 ± 0.04 kg/d from the beginning (June 4) to the end (September 13) of the trial (treatment $P = 0.69$). There was a slight trend for intake of forage per kilogram of gain to be greater for SAN than ALF (11.9 vs. 10.9 ± 0.54; $P = 0.19$).

Meat Analyses

In 2010 ($n = 3$), no differences between treatments were found in marbling score or quality grade ($P > 0.10$). The marbling score was "slight" for animals in ALF, corresponding to USDA "Select" quality grade. Two cattle in SAN had lower marbling score of "traces," corresponding to USDA "Standard" quality grade (data not shown). During 2012 ($n = 8$), cattle in SAN had greater ($P < 0.01$) marbling score and quality grade than cattle in ALF (Table 3). The SAN-finished cattle graded Select, compared to Standard for cattle finished on ALF pasture. Cattle in SAN also had more back fat ($P < 0.03$) and a tendency towards higher amount of kidney, pelvic, and heart (**KPH**) fat and yield grade (Table 3).

In 2010, there were no differences between the 2 treatments regarding L* ($P < 0.05$) and a* ($P < 0.05$), which are descriptors of raw rib steaks in retail packaging (polyvinyl chloride film overwrapping Styrofoam trays), during a 12-d color stability trial (1°C storage temperature, dark cooler). Yellowness was lower in ALF ($P < 0.01$), but there was no interaction effect on b* values between diet treatment and storage time for any given day. During both years mean rib muscle pH was similar between treatments ($P > 0.05$), and there were no

Table 3. Effect of pasture type on 2012 beef carcass characteristics

Pasture type	Marbling score	Quality grade[1]	Carcass weight (CW), kg	Rib eye area (REA), cm^2	Back fat thickness (BF), cm	Kidney, heart, pelvic fat (KHP), % CW	Yield grade[2]	Rib % fat	Rib pH	Rib steak MRA[3]
Sainfoin (n = 8)	3.5[a]	Select[a]	243	63.5	0.48[a]	2.06	2.30	5.20	5.43	29.89
Alfalfa (n = 8)	2.11[b]	Standard[b]	249	65.2	0.25[b]	1.63	1.94	4.43	5.43	39.36
P-value	0.01	0.01	0.21	0.52	0.03	0.08	0.14	0.1	0.97	0.16

[a,b]Means in a column with different superscripts differ ($P < 0.05$).

[1]Quality grades were assigned numerical values to run statistics, where 1 = Standard-, 2 = Standard+, 3 = Select, 4 = Choice-.

[2]Yield grade = 2.5 + (0.984252 × cm BF) + (0.2 × %KHP) + (0.008378 × kg CW) − (0.0496 x sq.cm REA)

[3]Metmyoglobin (MMb) reducing activity (% MMb reduced) = [(initial % MMb − final % MMb)/initial % MMb] × 100. Initial = d 0 of color stability study = day when rib primals were fabricated into steaks.

changes in percent of metmyoglobin (**MMb**) reduced in meat samples between diet treatments ($P < 0.05$; Table 4; data only shown for 2012). During 2012, pasture type and storage days affected rib steak color during 12-d refrigerated storage (1°C). Steaks from cattle finished on SAN were more red ($P < 0.05$) than steaks from cattle finished on ALF (a* values of 14.9 and 14.0, respectively; Table 4). Storage time affected all color parameters. After 12 d of storage, steaks were lighter and less red than on d 0 (L* = 34.9 and 33.0; a* = 12.9 and 14.6, respectively). All steaks remained red (a* > 10) for 12 d, in part because of the low storage temperature (1°C) in a dark cooler (Table 4).

Ether-extractable fat content did not differ in 2010 or 2012. In 2010, meat samples from the ALF group had 6.1% ± 1.5% fat, whereas those from SAN had 4.4% ± 1.5% fat ($P > 0.05$). In 2012, fat content of steaks from ALF (quality grade Standard) was 4.4% ± 1%, and fat content from SAN (quality grade select) was 5.2% ± 1.3% ($P > 0.05$). The fat content of rib steaks was higher relative to quality grade. Savell et al. (1986) reported mean beef longissimus fat content of 1.8%–2.5% for Standard grade carcasses and 3.4% for Select grade carcasses.

In both years, 44 fatty acids were detected in meat. Twenty-nine were known fatty acids based on retention time, and they were over 96% of the total fatty acid mass. The 12 fatty acids present in greater than 1% of the total are shown in Fig. 7. In general, there were few differences in the fatty acid profiles of meat from SAN and ALF. In 2010, the only difference was more 20:1n9 in steaks from ALF (data not shown). In 2012, there was more 16:1n7t, 22:0, 20:5n3, 22:5n3, and 22:6n3 in steaks from ALF and less 16:0 and 16:1n7 (Fig. 7).

There were few differences in the headspace volatiles for meat in either year. Forty-five volatiles were identified using both linear retention indices and mass spectra. In 2010, there was more nonanoic and decanoic acids in meat from ALF than from SAN ($P < 0.05$). In 2012, there was more toluene and octanoic acid methyl ester detected in meat from SAN than from ALF ($P < 0.05$).

Sensory Evaluation. Flavor characteristics of meats from cattle in ALF and SAN did not differ ($P < 0.05$; Table 5). The flavor attribute found in higher intensity was juicy (ratings of 4.06 ± 0.15 for ALF and 3.59 ± 0.53 for SAN) followed by fatty (3.91 ± 0.18 for ALF and 3.78 ± 0.17 for SAN). Umami was rated with values close to 3 for meats obtained from both treatments. Attributes such as salty, sour, roast beef, and astringent were given intensities of approximately 1 for both types of meat, whereas the other attributes were found in intensities below 1. No differences ($P < 0.05$) were obtained in the acceptability of meat (overall liking; values of 6.7 ± 0.3 for ALF and 7.0 ± 0.1 for SAN in 2010 and 6.3 ± 0.5 for ALF and 6.4 ± 0.6 for SAN in 2012). Data obtained from the consumer panel in both 2010 and

Table 4. Pasture and storage time effects on 2012 Hunter color values of beef rib steaks

Item	n	L*	a*	b*
Main effect: pasture				
Sainfoin	240	34.0 ± 2.4[a]	14.9 ± 2.00[a]	16.0 ± 1.5[a]
Alfalfa	240	33.9 ± 2.3[a]	14.0 ± 1.7[b]	15.5 ± 1.3[b]
Main effect: storage day (1°C)				
0 d	96	33.0 ± 2.1[c]	14.6 ± 1.9[b,c]	16.3 ± 1.3[b]
3 d	96	32.2 ± 2.0[d]	15.1 ± 1.6[a,b]	16.0 ± 1.2[b]
6 d	96	34.1 ± 2.0[b]	15.5 ± 1.4[a]	16.8 ± 1.0[a]
9 d	96	35.5 ± 1.9[a]	14.2 ± 1.4[c]	14.9 ± 0.8[c]
12 d	96	34.9 ± 1.9[a]	12.9 ± 1.9[d]	14.6 ± 1.3[c]
Pasture × storage day interaction				
Sainfoin × 0 d	48	32.8 ± 1.9[d]	15.7 ± 1.5[a]	17.0 ± 1.2[a]
Sainfoin × 3 d	48	32.4 ± 1.8[d]	15.8 ± 1.2[a]	16.5 ± 1.1[b]
Sainfoin × 6 d	48	33.9 ± 1.9[b,c]	15.9 ± 1.3[a]	16.9 ± 0.9[a,b]
Sainfoin × 9 d	48	35.5 ± 1.7[a]	14.8 ± 1.3[b]	15.2 ± 0.8[c,d]
Sainfoin × 12 d	48	34.8 ± 2.3[a,b]	12.3 ± 1.9[e]	14.4 ± 1.3[f]
Alfalfa × 0 d	48	33.3 ± 2.1[c]	13.6 ± 1.6[d]	15.6 ± 1.0[c]
Alfalfa × 3 d	48	32.1 ± 2.2[d]	14.3 ± 1.6[c]	15.5 ± 1.1[c]
Alfalfa × 6 d	48	34.3 ± 2.2[b]	15.0 ± 1.5[b]	16.8 ± 1.0[a,b]
Alfalfa × 9 d	48	35.6 ±2.1[a]	13.7 ± 1.3[c,d]	14.6 ± 0.7[e]
Alfalfa × 12 d	48	35.0 ± 1.4[a,b]	13.4 ± 1.8[c,d]	14.9 ± 1.4[d,e]

[a–e]Main or interaction means with the same superscript letter are not different ($P > 0.05$).

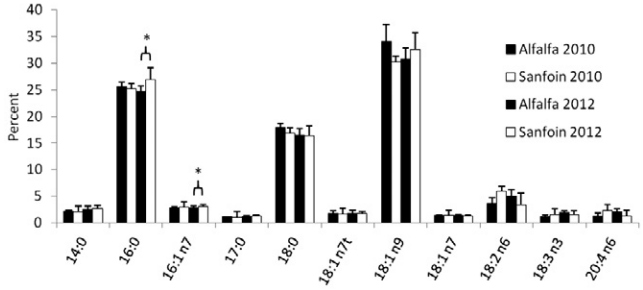

Figure 7. Fatty acid composition of longissimus dorsi steaks from 2010 and 2012. Only fatty acids with amounts greater than 1% in all samples are shown.

2012 are reproducible, and therefore a descriptive panel was not performed for the 2012 samples.

DISCUSSION

Our objectives were to determine if the type of legume in the mixture (tall fescue with either sainfoin or alfalfa) affected cattle foraging behavior, performance, meat quality, and consumer acceptance of meat. The choices between tall fescue growing either with alfalfa (saponins) or with sainfoin (tannins) influenced foraging behavior and meat yield and quality, but they did not affect animal performance or consumer acceptance.

Biomass Availability and Foraging Behavior

On the basis of scan samples and assessments of biomass removed, the greatest intake of legumes occurred during period 1 in 2010 and 2012. Cattle used sainfoin more than alfalfa when both legumes were abundant, but the pattern reversed as the studies progressed and the abundance of sainfoin declined much more than that of alfalfa. This reversal likely compensated for the greater intake of sainfoin at the beginning of the trial and led to similar ADG in both treatments. Intake of forage per kilogram of gain was greater for SAN than ALF in 2010 (7.6 vs. 5.8 ± 0.33) and showed a tendency to be greater for SAN than ALF in 2012 (11.9 vs. 10.9 ± 0.54).

Animals in ALF grazed tall fescue more than animals in SAN. This response may have been due to subclinical bloat induced by alfalfa as animals learn to avoid foods that cause rumen distension (Villalba et al., 2009). Alfalfa is a bloating legume, whereas sainfoin is not (Cooper et al., 1966). Nevertheless, no cases of clinical bloat were recorded in animals grazing alfalfa, despite the fact that cattle had ad libitum access to the legume. Thus, the presence of tall fescue likely reduced the incidence of bloat. In addition to the possible subclinical influence of bloat, other factors, such as greater biomass availability for sainfoin, the nutrient profiles of the legumes, and the presence of tannins or saponins, may have contributed to the differential consumption of fescue in both 2010 and 2012. Although saponin concentrations were low in the variety of alfalfa we used, tannin concentrations in sainfoin were in the range that can positively affect nutrient use (Waghorn et al., 1987). Tannins in sainfoin can reduce methane emissions (Guglielmelli et al., 2011), thus increasing the efficiency of nutrient use (Broderick, 1995). More non-ammonia nitrogen reaches the small intestine when sheep are fed sainfoin compared to similar forages without tannins (Waghorn et al., 1987), which improves the ratio of essential amino acids to energy. Tannins in bird's-foot trefoil improve the use of nitrogen to a greater extent than do saponins in alfalfa (Owens et al., 2012a,b). Sainfoin added to an alfalfa diet reduces rumen degradation of protein without adversely affecting the digestibility of the nonprotein fraction. In addition, protease activity, ammonia and methane production, and the incidence of bloat all decline as sainfoin increases in an alfalfa-sainfoin diet (McMahon et al., 1999). Thus, tannins in sainfoin may have contributed to the increased use of the legume and to the reduced use of tall fescue relative to alfalfa.

Table 5. Identification and quantification of flavors in meat obtained from alfalfa- and sainfoin-fed cattle

Item	Alfalfa	Sainfoin	*P*-value
Astringent	1.07 ± 0.13	1.13 ± 0.15	0.6582
Barny	0 ± 0	0 ± 0	0.0000
Bitter	0.47 ± 0.15	0.47 ± 0.13	0.3679
Bloody	0.84 ± 0.31	0.88 ± 0.29	0.2224
Brothy	2.12 ± 0.33	2.15 ± 0.14	0.6397
Browned	0.31 ± 0.11	0.04 ± 0.03	0.0664
Fatty	3.91 ± 0.18	3.78 ± 0.17	0.8121
Gamey	0.47 ± 0.16	0.57 ± 0.10	0.8469
Grassy	0.60 ± 0.31	0.61 ± 0.12	0.6405
Juicy	4.06 ± 0.15	3.59 ± 0.53	0.2159
Livery	0.11 ± 0.15	0.18 ± 0.07	0.8022
Metallic	0.22 ± 0.09	0.25 ± 0.13	0.5673
Oxidized	0.18 ± 0.06	0.14 ± 0.03	0.9385
Roast beef	1.37 ± 0.08	1.16 ± 0.37	0.1183
Salty	1.91 ± 0.17	1.98 ± 0.29	0.5299
Sour	1.59 ± 0.32	1.38 ± 0.25	0.2441
Sweet	0.23 ± 0.09	0.23 ± 0.07	0.4532
Umami	2.97 ± 0.05	2.95 ± 0.18	0.6202

Pattern of Forage Use during Scan Sampling

During both years, use of legumes decreased during the 2-h scan session, whereas use of tall fescue increased, and no clear pattern emerged for the mix. This response can be explained by the depletion of the legumes, which caused animals to increase consumption of lower-quality fescue. Thus, cattle traded off the quantity and quality of these forages in ways that balanced nutrient intake and the amounts of forage consumed (Edouard et al., 2010).

Animals gained experience with the legumes during period 1, and their use of legumes increased during periods 2 and 3, likely because of their synergistic postingestive effects with tall fescue (Provenza, 1995, 1996). Thus, during the morning grazing period, animals spent more time eating legumes as they learned about matching legume intake with grass consumption later in the day. Eating legumes likely led to a self-reinforcing pattern that enhanced preferences as cattle learned about the positive postingestive effects of consuming those foods in combination (Villalba and Provenza, 1997, 1999). Despite the increased use of legumes during periods 2 and 3, intake of legumes declined as the amount of legume on offer declined as the season progressed. As legume availability declined, cattle learned to increase intake of the legume in the morning before they were depleted.

Animals also gained experience with tall fescue during grazing. In contrast to legume use, the lower quality of fescue likely led to a self-reinforcing pattern that decreased preference for tall fescue. Cattle also grazed tall fescue during periods in between trials, which likely reduced preference as increased exposure to a single forage induces mild to strong sensorial and postingestive aversion (Provenza, 1996).

At the beginning of each grazing session, cattle had ad libitum access to tall fescue and alfalfa or sainfoin. Under these conditions, they could have eaten mainly the higher-quality legumes, but they ate a significant proportion of tall fescue, even though legumes were of greater quality than tall fescue. Some suggest the overall increase in intake when grass is included in a legume (clover) pasture occurs because grass allows animals to overcome constraints due to eating pure clover, which is a forage high in protein (Cosgrove et al., 2001; Champion et al., 2004). These constraints likely involve in part the rate of release of ammonia from the soluble protein fraction of the legume and subsequent uptake in the blood, which can condition food aversions (reviewed in Provenza, 1996). By mixing grass with a legume, animals can increase total food intake by better balancing the ratio of energy to soluble protein, which can reduce the rate of accumulation of ammonia in rumen fluid (Hill et al., 2009). This is evidently the case with tall fescue–bird's-foot trefoil mixes (Owens et al., 2012a): tannins in trefoil and sainfoin reduce ammonia in the rumen fluid, which enables grazing animals to consume more legumes.

When monocultures of grass and clover are offered as free choice in 50:50 area ratios, animal performance is no different from a clover monoculture, even though clover is of higher nutritional quality than grass. Thus, all the benefits of clover are available when only half of the grazing area is sown as clover. These observations are in line with the satiety hypothesis (Provenza, 1996), which suggests animals overcome constraints to eating pure clover by adding grass to their diet. The challenge for grassland managers is to present forage in ways that allow animals to select while also allowing high rates of animal production per hectare (Chapman et al., 2007).

Meat Quality

During 2012, SAN cattle graded Select, compared to Standard for ALF cattle. This result is commercially significant, as Select grade carcasses currently sell for $48.50/100 kg carcass weight higher than Standard grade carcasses (USDA, 2013). These differences would likely have been greater had the abundance of sainfoin not declined as the trial progressed. This decrease in forage availability and intake likely attenuated the effects on production of greater intake of sainfoin at the beginning of the trial and then led to similar ADG (1 kg/d) in both treatments.

In both years the fat content of the rib steaks was between 4% and 6%, relatively low values for the longissimus dorsi muscle (Dow et al., 2010). In a prior study, rib steaks from pasture-finished cattle had an ether-extractable fat content of 3.4%, whereas that of grain-finished cattle was 12.4% (Tansawat et al., 2012). The higher back fat of SAN-fed cattle was likely a consequence of the higher forage intake during period 1 and part of period 2.

The fatty acid composition of the steaks was similar to other pasture-finished beef (Tansawat et al., 2012). As expected from previous studies (Daley et al., 2010), the n6:n3 (omega-6 to omega-3) ratios were low for both treatments in 2010 (ALF, 2.5; SAN, 2.7) and 2012 (ALF, 2.0; SAN, 1.8).

There were few differences in volatile compounds measured in either 2010 or 2012. Nonanoic and decanoic acids were more prevalent in ALF than in SAN animals (Tansawat, 2012). The increased proportion of these saturated compounds in alfalfa- relative to sainfoin-based diets may be due to reduce ruminal biohydrogenation inhibition from condensed tannins inhibiting rumen microorganisms (Vasta et al., 2009). In 2012, 5 times more toluene was detected in SAN compared to ALF samples; on the basis of the chromatograms, compounds in the SAN diet promote toluene in meat. However, because of its early elution in the Gas chromatography–mass spectrometry (**GC–MS**), these compounds were not detected in the samples in 2010. In prior research, we found that toluene was significantly associated with pasture-finished beef, compared to grain-finished beef, but it did not correlate with any specific flavor attributes evaluated by a trained panel (Tansawat et al., 2012).

Meat Acceptability to Consumers

Consumer acceptance of meat was similar in 2010 and 2012 to that obtained by Maughan et al. (2012) for pasture-finished beef, with slightly higher levels of ac-

ceptance for both ALF and SAN. The greater acceptance may have been due to lower ratings for negative attributes (astringent, barny, grassy, and livery) and higher ratings for positive attributes (brothy, fatty, juicy, and salty). The intensities of bitter, gamey, metallic, oxidized, roast beef, sour, sweet, and umami flavors for meat from ALF- and SAN-finished cattle in 2010 were similar to those reported by Maughan et al. (2012), but meat from ALF- and SAN-fed animals was lower in astringent, barny, browned, grassy, and livery flavors and higher in brothy, bloody, fatty, juicy, and salty flavors (Maughan et al., 2012).

Although secondary compounds in the diets of herbivores can influence the color, flavor, and quality of meat for human consumption, little is known about their effects on meat quality or flavor (Vasta et al., 2008, 2009, 2010; Vasta and Luciano, 2011). The antioxidant capacity of meat is much greater for pasture-fed than for grain-fed beef (Descalzo et al., 2007). Antioxidants assimilated in cell membranes protect animal tissues against oxidation (Descalzo and Sancho, 2008), which enhances the quality of meat for human consumption. Low-grade systemic inflammation, characterized by an increase in plasma levels of proinflammatory markers such as tumor necrosis factor alpha (**TNF-α**), Interleukin 6 (**IL-6**), and C-reactive protein, is strongly implicated as the cause of much chronic disease in humans (Hotamisligil, 2006). Others have noted similar differences in physiological responses to modern vs. historically consumed meats (Cordain et al., 2002). All of these findings are consistent with anthropological studies that link diet with degree of inflammatory responses and chronic diseases (O'Keefe and Bell, 2007). Future studies should compare postprandial inflammatory responses for people who eat meat from livestock finished on grain with those of people who eat meat from livestock finished on phytochemically rich pastures.

Conclusions

Cattle finished on tall fescue in combination with either sainfoin or alfalfa used the lower nutritional quality fescue, even when legumes were readily available, evidently because of synergies among primary and secondary compounds. Use of tannin-containing sainfoin was greater than use of saponin-containing alfalfa when biomass availability of both legumes was high, but the pattern reversed as sainfoin biomass declined toward the end of the trial. Cattle had greater intake of forage per kilogram of gain in SAN than in ALF in 2010, and there was a trend for intake of forage per kilogram of gain to be greater for SAN than for ALF in 2012. These choices influenced foraging behavior, meat yield, back fat, and quality, which are all greater for SAN than ALF, but they did not affect weight gains, likely because of the lower availability of sainfoin relative to alfalfa toward the end of the trial. Consumer acceptance of meat was slightly higher in our study compared with previous studies, perhaps because of lower ratings for negative attributes and higher ratings for positive attributes. Although the mix of forages can influence the quality and acceptability of meat for human consumption, little is known about how forage complexity affects the foraging behavior and nutrition of herbivores or human beings. Our research, even with simple 2-way mixtures, suggests differences in foraging behavior and meat quality occur and warrant more studies of how phytochemistry affects the nutrition and health of herbivores and human beings.

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