Nutritional value of fresh Gambel oak browse for Spanish goats

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Abstract

Little information is available on the nutritional value of fresh browse for ruminants. This study examined the nutritive value of Gambel oak (*Quercus gambelii* Nutt.) for Spanish goats. Fresh Gambel oak browse was harvested at 2 phenological stages and mixed with chopped alfalfa hay to formulate 6 diets, varying in oak content. Diets included 95% juvenile oak/5% alfalfa (95J), 80% juvenile oak/20% alfalfa (80J), 65% juvenile oak/35% alfalfa (65J), 80% mature oak/20% alfalfa (80M), 40% mature oak/60% alfalfa (40M), and an alfalfa control (ALF). Diets were evaluated for goats using a series of digestion-balance trials, in a completely randomized design. Dry matter intake was highest ($P<0.01$) for animals on diets with mature oak (80M-37.8, 40M-34.5 grams • kg^{-1} • day^{-1}), and lowest on diets containing juvenile oak (95J-23.6, 80J-31.6, 65J-29.9 grams • kg^{-1} • day^{-1}). Digestibility of dry matter and cell wall components was lower ($P<0.01$) for mature oak diets, and higher for juvenile oak diets. Digestibility coefficients for dry matter were as follows: 80M-57.8%, 40M-58.8%, 95J-68.6%, 80J-65.3%, 65J-66.3%. Digestibility coefficients for cell wall were: 80M-33.1%, 40M-37.4%, 95J-53.7%, 80J-45.8%, 65J-47.3%. All diets provided nitrogen and energy in excess of maintenance requirements, as reflected by weight gains for all animals in every trial. Fecal and urinary nitrogen losses did not appear to be related to tannin content of the diets, since juvenile oak diets resulted in reduced nitrogen outputs, presumably due to reduced nitrogen intakes for these diets. We conclude that Gambel oak, even juvenile material in high dietary percentages (95%), provides adequate nutrients and should be considered a valuable forage for goats in oakbrush habitats.

Key Words: intake, nitrogen balance, digestible energy, diet quality, *Quercus, Capra*

Recently, interest has increased in using browsing ruminants in shrubland types, both as a means of brush control and as a potential source of animal production (Davis et al. 1975, Riggs et al. 1988). Gambel oak (*Quercus gambelii* Nutt.) is a shrub species of particular importance to resource managers since it dominates millions of hectares of Intermountain foothill rangelands, is generally considered to be poor forage, and reduces production of associated plant species (Engle et al. 1983). Oak is low in palatability for most herbivores, but goats have shown an ability to utilize oak species effectively, with potential for a high degree of control (Davis et al. 1975, Riggs et al. 1988).

Oak species contain high levels of tannins, especially in immature foliage. Tannins form complexes with protein, and can adversely affect animals' nitrogen balance. Robbins et al. (1987a) found reduced protein digestibility and voluntary intake when mule deer and elk consumed high-tannin forages. Nastis and Malechek (1981) found immature oak foliage in pelleted form to be associated with reduced intakes and low in available protein and metabolizable energy, suggesting that diets with a high percentage of oak may be submaintenance. Consistent with this, Nuñez-Hernandez et al. (1989) found reductions in nitrogen and dry matter digestibilities when goats were fed diets including gray oak foliage, and Villena and Pfister (1990) found similar reductions using sand shinnery oak. Data from controlled digestion trials using fresh Gambel oak browse, similar to that consumed by free-ranging animals, is lacking in the literature, as Wilson (1977) noted for trees and shrubs generally. The objective of this study was to determine the nutritive quality of fresh-fed Gambel oak for Spanish goats by evaluating the influence of oak browse on digestibility, intake, and nutrient balance.

Materials and Methods

We examined the nutritional response of goats to various dietary levels of oak browse in a completely randomized experimental design. The study was conducted near Henefer, Utah (UTM 45800E 4540500N). Hand-harvested Gambel oak was mixed with chopped alfalfa hay and fed fresh to Spanish goats in a series of digestion-balance trials. Trials were conducted during the summers of 1986 and 1987.

Diet formulations included 95% juvenile oak/5% alfalfa (95J), 80% juvenile oak/20% juvenile (80J), 65% juvenile oak/35% alfalfa (65J), 80% mature oak/20% alfalfa (80M), 40% mature oak/60% alfalfa (40M), and an alfalfa control (ALF). Diets were formulated on the basis of average values for dry matter determinations made just prior to the collection period of each trial. Dry matter content of fresh browse varies due to phenology and plant water status, and these vary diurnally, day to day, among plants, and among different leaders on the same plant. As a result, the mean oak content of the diets varied from the test diet designation. Average dry matter oak content for the test diets was as follows: 80M-80.2%, 40M-44.5%, 95J-94.9%, 80J-84.6%, 65J-62.3%.

We scheduled each sequential trial to test a single diet. Each trial was scheduled to coincide with oak phenology in the area. Diets 80J, 80M, and 40M were tested in 1986. Diets 95J, 65J, and the alfalfa control were tested in 1987. Gambel oak browse used to formulate the diets was harvested at the study site and fed within a few hours of collection. It consisted of terminal leader sections of current annual growth which were less than 15 cm in length, and included the twig and associated leaves. We selectively harvested juvenile material in late May and June, before leaf/twig hardening. Mature browse was collected in late July and early August. The alfalfa hay for all diets was from a single harvest and was chopped with a hammermill through a 2.5-cm screen. Animals had free access to water and trace mineral salt throughout the trials.

The diets were fed to 12 mature Spanish goat wethers (average initial body weight 40kg) in open air digestion-balance cages. Cages were arranged in 3 replications of 4 animals each, spatially separated from the other groups, thereby allowing social interaction within but not between replications. Replications were fed as a group, and the rations weighed and mixed separately for each animal. The cages were located in a shaded creek bottom, sheltered from wind and rain. Three animals in different trials that did not acclimate to confinement in the cages, as indicated by extreme nervousness, vocalizations, and refusal to eat, were removed from

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the trial, and the data for these animals omitted from the analysis. The same animals were used in both years of the study.

Each trial consisted of a 10-day preliminary period, followed by a 7-day collection period. During the collection period, ad libitum intake was measured; diet samples, feces, urine, and orts were collected, weighed, and subsampled. To prevent volatilization of nitrogen from the urine, 75 ml of 9.2N sulfuric acid were added to the urine collection containers daily. All samples were immediately frozen for storage.

Daily samples of feces, urine, and orts for each trial were pooled for individual animals and freeze-dried prior to laboratory analysis. Oak and alfalfa samples were freeze-dried, ground, and analyzed separately. Nitrogen was determined colorimetrically (Hach et al. 1985). Oxygen-bomb calorimetry (AOAC 1960) was used to determine energy content. Feed, feces, and orts were analyzed for cell wall, hemicellulose, cellulose, and lignin, using sequential fiber analysis. In this analysis, neutral detergent fiber (NDF) was used to estimate cell wall, and the difference between acid detergent fiber (ADF) and NDF used to estimate hemicellulose. Lignin was estimated using the permanganate lignin technique (Goering and Van Soest 1970). In vivo digestibility was then calculated by difference for each fraction.

Tannin content of the oak samples was determined using 2 different techniques (Martin and Martin 1983, Hagerman and Butler 1978). Tannin assays vary widely in methodology and the actual phenolic fraction measured. Both methods used in this study attempt to quantify the protein-precipitating capacity of plant extracts. This provides a measure of the property of tannins which is presumed to be most important in defending plants against herbivory. The Martin and Martin (1983) assay has been shown to correlate well with protein digestion in wild ruminants (Robbins et al. 1987a) and was chosen for this reason. This technique involves an estimation of mg of protein (Bovine Serum Albumin) precipitated per mg of plant sample. The Hagerman and Butler (1978) assay, a colorimetric estimation of protein precipitation, was included as an additional measure for comparison. Total-phenolics methods were not used because of their poor correlation with palatability and protein availability (Robbins et al. 1987a).

The data were compared using analysis of variance for a nested, completely randomized design, with mean differences indicated by orthogonal contrasts based on a priori comparison (Dowdy and Weardon 1983). Differences were considered significant at an alpha level ≥ 0.01. Contrasts included ALF vs. all oak diets, mature oak diets vs. juvenile, 80M vs. 40M, 80M vs. 80J, and a test for linearity among juvenile oak diets.

Results

Chemical composition of feed components is presented in Table 1. Dry matter, cell wall, and lignin content increased with maturity, while nitrogen content decreased. Gross energy content was relatively constant across all feed components. Tannin content of oak browse, as indicated by both assays, declined with maturity.

Table 1. Chemical composition of feed components of diets fed to goats (based on samples from 1986 only).

	Juvenile oak	Mature oak	Alfalfa
Dry matter (%)	35.2	44.8	92.2
Cell wall (%)	36.2	43.8	38.0
Lignin (%)	7.8	11.8	5.8
Nitrogen (%)	2.1	1.9	2.5
Gross Energy (Kcal/g)	4.6	4.3	4.6
Tannin (mg/mg)[a]	0.231	0.176	---
Tannin (mg/g)[b]	40.4	34.7	---

[a]Martin and Martin (1983) (mg prot. precip/mg samp.)
[b]Hagerman and Butler (1978) assay (mg tannic acid equiv./g)

In all analyses, the 80M vs. 80J contrast provided the same results as the mature vs. juvenile oak diet contrast. For this reason, the 80M vs. 80J contrast is not included in the results of this paper.

Dry matter intake (Table 2) showed no difference between the alfalfa control and oak-containing diets. Mature oak diets resulted in higher dry matter intakes than juvenile oak diets.

Table 2. Average daily dry matter intake (grams • kg^{-1} • day^{-1}) and digestibility coefficients (%) for dry matter and fiber components of 6 oak-alfalfa diets consumed by goats.

Diet[5]	Intake[1,3]	Dry matter[3]	Cell wall[1,2,3,4]	Hemicellulose[1,2,3]	Cellulose[2,3,4]
ALF	30.3	64.4	47.9	52.4	53.1
80M	37.8	57.8	33.1	52.3	34.8
40M	34.5	58.8	37.4	53.2	39.7
95J	23.6	68.6	53.7	67.2	50.7
80J	31.6	65.3	45.8	59.6	46.7
65J	29.9	66.3	47.3	57.1	50.7
SE	3.9	2.4	3.4	3.4	3.9

[1]Linear treatment effect for juvenile oak diets ($P<0.01$).
[2]Treatment difference, alfalfa control vs. oak diets ($P<0.01$).
[3]Treatment difference, mature vs. juvenile oak diets ($P<0.01$).
[4]Treatment difference, 80M vs. 40M ($P<.01$).
[5]Diet designations are alfalfa control (ALF), 80% mature oak (80M), 40% mature oak (40M), 95% juvenile oak (95J), 80% juvenile oak (80J), and 65% juvenile oak (65J). Standard error is designated as SE.

Digestibility coefficients for dry matter and fiber fractions were similar (Table 2). Digestibility for dry matter, cell wall, hemicellulose, and cellulose showed lower digestibility for mature oak diets when compared to juvenile oak diets. The alfalfa control had higher digestibility of cell wall and cellulose, and lower digestibility of hemicellulose when compared to oak-containing diets. Dry matter digestibility did not differ between alfalfa and oak-containing diets. Dry matter digestibility for all the diets was highly correlated to cell wall digestibility (r = 0.98). Cell wall digestibility was in turn correlated with cellulose digestibility ($r = 0.93$).

Energy balances were positive for all animals in all trials (Table 3). Following dry matter intake trends, gross energy intake was lower for juvenile oak diets when compared to mature oak diets. However, fecal losses were also lower for juvenile oak, resulting in no differences in amounts of digestible energy (DE) provided. Urinary energy losses were lower for the alfalfa control compared to oak diets, resulting in higher metabolizable energy (ME) for the alfalfa diet.

Table 3. Average daily energy balance (Mcal/day) for goats on oak-containing diets and an alfalfa control diet.

Diet[5]	Amount[1,3] consumed	Fecal[2,3] losses	Amount digested	Urinary[2] losses	Amount[2] metabolized
ALF	5.75	1.75	4.00	0.20	3.81
80M	6.33	2.71	3.62	0.36	3.26
40M	6.14	2.51	3.64	0.31	3.33
95J	4.72	1.43	3.28	0.34	2.94
80J	4.92	1.73	3.18	0.32	2.87
65J	5.98	2.03	3.95	0.39	3.56
SE	0.66	0.31	0.45	0.08	0.43

[1]Linear treatment effect for juvenile oak diets ($P<0.01$).
[2]Treatment differences, alfalfa control vs. oak diets ($P<0.01$).
[3]Treatment difference, mature vs. juvenile oak diets ($P<0.01$).
[4]Treatment difference, 80M vs. 40M ($P<.01$).
[5]Diet designations are alfalfa control (ALF), 80% mature oak (40M), 95% juvenile oak (95J), 80% juvenile oak (80J), and Standard error is designated as SE.

Table 4. Average nitrogen balance (grams/trial) for goats on oak-containing diets and an alfalfa control diet.

Diet[5]	Amount[1,2] consumed	Fecal[1,2,3] losses	Amount[1,2,4] digested	Urinary[2] losses	Amount[1,2] metabolized	% DN[1,2,3,4,6]	% MN[2,6]
ALF	282.1	67.3	214.8	119.0	95.8	76.2	33.8
80M	195.9	97.5	98.3	82.9	15.4	50.2	7.8
40M	218.0	84.2	133.9	101.8	32.1	60.9	14.4
95J	163.0	61.3	101.7	78.0	23.2	62.3	13.5
80J	163.9	70.5	93.4	61.6	31.8	56.6	18.6
65J	262.3	94.0	168.3	105.4	62.9	64.2	23.7
SE	26.3	11.8	19.7	15.6	14.6	4.2	6.0

[1]Linear treatment effect for juvenile oak diets ($P<0.01$).
[2]Treatment difference, alfalfal control vs. oak diets ($P<0.01$).
[3]Treatment difference, mature vs. juvenile oak diets ($P<0.01$).
[4]Treatment difference, 80M vs. 40M ($P<.01$).
[5]Diet designations are alfalfa control (ALF), 80% mature oak (80M), 40% mature oak (40M), 95% juvenile oak (95J), 80% juvenile oak (80J), and 65% juvenile oak (65J). Standard error is designated as SE.
[6]Designations for digestible nitrogen (DN) and metabolizable nitrogen (MN).

Average nitrogen balances were also positive across all trials (Table 4). In comparing the alfalfa control to oak-containing diets, animals on alfalfa had higher nitrogen intakes, higher digested nitrogen (DN), and higher metabolized nitrogen (MN). Comparing mature oak with juvenile oak diets, mature oak diets were associated with higher fecal nitrogen losses, but there was no difference in DN or MN provided. MN decreased linearly with increasing juvenile oak in the diet.

Discussion

Chemical composition of Gambel oak followed expected trends for woody browse species, with increased cell wall and lignification with maturity (Van Soest 1982). Consistent with Nastis and Malechek (1981), tannin content declined with maturity.

Dry matter intakes also followed patterns similar to those observed by Nastis and Malechek (1981), with reduced dry matter intakes for juvenile oak diets. However, we did not note the dramatic (50–60% ad lib) reductions in intake found with deer on tanniniferous shrub leaves reported by Robbins et al. (1987a). Goats in our study avidly consumed juvenile oak diets, even at the 95% level, so it is doubtful that tannins reduced palatability.

Reductions in digestibility of dry matter, cell wall, cellulose, and hemicellulose for the mature oak diets is consistent with the effects of increasing total cell wall and lignification as browse matures (Van Soest 1982). Juvenile oak was higher in tannin than mature browse, but had higher digestibilities of dry matter and fiber. Dry matter digestion of all test diets was directly related to cell wall and cellulose digestion. This is consistent with the findings of Robbins et al. (1987b) for mule and white-tailed deer. They concluded that tanniniferous forages did not reduce cell wall digestion beyond that predicted by structural inhibitors. Increased digestibilities of juvenile oak diets may compensate for the lower dry matter intakes on these diets, in terms of nutrients supplied to the animal. This compensation is readily observed in the nitrogen and energy balances.

Nastis and Malechek (1981), using a pelleted form of the 80J diet, found that it provided significantly less ME than mature oak diets. We found that reduced fecal losses offset reduced energy intake so that there were no differences in DE or ME provided by any of the oak-containing diets.

In the case of nitrogen balance, we did not find the increased fecal losses with juvenile oak diets noted by Nastis and Malechek (1981). Mature oak diets were associated with higher fecal losses than juvenile oak diets, and there were no differences in DN or MN provided. However, tannins may have played a role in availability, since the alfalfa control had lower fecal losses and higher DN/MN than oak-containing diets, and MN decreased linearly with increasing juvenile oak content. Animals on the alfalfa control diet had higher urinary nitrogen outputs as compared to oak diets. This is consistent with Nunez-Hernandez et al. (1989) who found reduced urinary nitrogen losses with high-phenolic shrub diets.

Practical evaluation of nitrogen and energy balance values requires a comparison with published maintenance requirements. Unfortunately, basic information for Spanish goats is lacking. Nastis and Malechek (1981) used the values provided in Huston (1978) for Angora goats. Huston recommended DE levels of 3.5 Mcal/day and DN levels of 13.0 grams/day as maintenance requirements for comparable-sized Angora goats (40 kg). All diets provided DN in excess of this amount, but the 95J diet (3.3 Mcal) appears to be submaintenance in DE, as speculated by Nastis and Malechek (1981). However, as Huston (1978) pointed out, these figures were determined with high-production mohair animals, and values for Spanish or feral goats should be lower. Oliveira (1987) reviewed 19 studies involving the maintenance energy requirements for goats, including domestic and native species. It is noteworthy that values for Angora goats (Huston 1978) are much higher than those for other species. The average for this cross-specific comparison, expressed as daily requirement for metabolizable energy on a metabolic body weight basis, is approximately 106 Kcal ME • $BW^{-.75}$ • day^{-1} (range 87–165). This may be a more reasonable approximation of maintenance requirements for Spanish goats. The average DE intake for the alfalfa control and 95J trials in this study were 235 and 174 Kcal, respectively.

Oliveira (1987) also used the carbon dioxide entry rate technique to estimate daily energy expenditures for free-ranging Spanish goats. This estimate includes both maintenance and normal activity costs, and had an average value of 127 Kcal ME • $BW^{-.75}$ • day^{-1}; again much lower than our worst case. Using these criteria, all diets provided metabolizable energy well in excess of maintenance requirements. This was supported by live weight gains for all animals on all tested diets.

In summary, all of the Gambel oak diets we tested provided nitrogen and energy in excess of maintenance requirements for Spanish goat wethers. Hence, it can be concluded that Gambel oak, even juvenile material in high dietary percentages (95%), provides adequate nutrients and should be considered a valuable forage for goats used in oakbrush areas for production or brush control. Tannins did not appear to affect digestibility of dry matter or cell wall, but may have had a limited impact on protein availability.

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