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GAMBEL OAK FOR SPANISH GOATS: A
DIGESTION-BALANCE EVALUATION OF NUTRIENT AVAILABILITY

by
Brian L. Dick

A thesis submitted in partial fulfillment
of the requirements for the degree

of
MASTER OF SCIENCE

in
Range Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1988

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Brian Dick

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ABSTRACT

Gambel Oak for Spanish Goats:
a Digestion-balance Evaluation
of Nutrient Availability

by

Brian L. Dick, Master of Science
Utah State University, 1988

Major Professor: Dr. Philip J. Urness
Department: Range Science

Fresh-harvested Gambel oak (Quercus gambelii) browse was mixed with chopped alfalfa hay to formulate six diets, varying in oak content at two phenological stages. Diets included juvenile oak (65,80,95%), mature oak (40,80%), and an alfalfa control. Diets were evaluated for goats using a series of total-collection digestion-balance trials. Dry matter intake was highest for animals on mature oak diets, and lowest on diets containing a high percentage of juvenile oak, possibly due to differences in diet dry matter content. Apparent digestibility of dry matter and cell wall components was lowest for mature oak diets, and highest for diets high in juvenile oak. Nitrogen and energy balances were positive in all cases, and all diets provided nitrogen and energy in excess of maintenance requirements. This was 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, because high-percentage juvenile oak diets resulted in reduced nitrogen outputs, presumably due to reduced nitrogen intakes for these diets. In comparison with

previous data using pelleted formulations, the fresh-fed material was consistently higher in digestibility of the various fractions, and associated with lower dry matter intakes.

(36 pages).

INTRODUCTION

Increased interest in biological and economical alternatives for manipulating oakbrush communities demands further research into the properties of Gambel oak as a forage for browsing animals. Evaluation of oak on a nutritional basis is essential for determining how well this species meets animal maintenance and production requirements. This research was designed to evaluate the nutrient availability of fresh Gambel oak to wether Spanish goats, fed at several dietary percentages and two phenological stages.

Gambel oak is a major component of millions of acres in several western states, including Colorado, New Mexico, Arizona, and Utah (Engle et al. 1983). In Utah, oakbrush is a prominent vegetation type along the Wasatch Front, at elevations of 5000 to 8000 feet (Kunzler and Harper 1980), and on the Colorado Plateau. The relative merit of Gambel oak as a forage for wildlife and livestock has long been debated. Most current authors consider Gambel oak to be of low value, and reports on methods and problems of oakbrush control are numerous (Engle et al. 1983, Jefferies 1965, Marquiss 1972). Indeed, significant increases in soil moisture, forage production, and beef production have been reported for areas where oak has been successfully controlled (Marquiss 1972). However, properly managed oak and associated plants provide important forage and cover for deer and other wildlife species, as well as valuable spring summer forage for sheep, goats, and cattle (Bowns 1985, Kunzler and Harper 1980, Reynolds et al. 1970, Smith 1957).

Most methods of thinning or controlling Gambel oak have inherent problems. Fire, herbicides, and mechanical manipulations require followup treatments to control vigorous basal sprouting (Davis et al. 1975). Herbicides pose environmental risks, and mechanical treatments may be limited by slope and rough topography, as well as high cost (Knipe 1983). However, goat browsing to thin oakbrush stands, or as a followup to other treatments to control sprouting, has proven effective in many situations (Keng 1956, Davis et al. 1975, Sidahmed et al. 1979, Saxton 1979, 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. In large quantities tannins are considered toxic to livestock, especially cattle (Kingsbury 1964).

Reports of the effect of tannins on the preferences and digestion of goats are contradictory, and the issue is far from settled. In the California chaparral type, goats have shown a preference for scrub oak (Quercus dumosa), at times in excess of 80% of their diet (Sidahmed et al. 1981). Sidahmed et al. (1982) found little correlation between tannins and goat preference or nutrition. Riggs et al. (1988) found a high degree of selection by goats for juvenile oak leaders, in excess of 85% of the diet at times, even when mature foliage and other forage species were available. This juvenile material, both initial and regrowth, is higher in tannins than the mature form (Nastis and Malechek 1981). Nastis and Malechek (1981) also reported reduced intake with increasing oak content in

the diet. Similarly, Provenza and Malechek (1984) found greater goat preference for twigs of blackbrush containing the lowest tannin levels.

Nastis and Malechek (1981) found immature oak foliage in pelleted form to be low in available protein and metabolizable energy, and suggested that diets with a high percentage of oak may be submaintenance. Other researchers have observed favorable weight responses by free-ranging goats ingesting diets exceeding 85% green oak (Sidahmed et al. 1982, Riggs et al. 1988). This difference may be due in part to the effect of pelleting on digestibility of the diet.

Grinding and pelleting reduce forage particle size, which increases rate of passage out of the reticulo-rumen. This rapid removal of material reduces exposure to bacterial fermentation, and hence may lower digestibility of the forage (Fonnesbeck et al. 1981). This would be especially important for goats, since they have a relatively small rumen and consequently, a low digestive ability (Huston 1978).

Another factor that may affect digestibilities of pelleted diets is the Maillard reaction, which may occur during drying of the plant material prior to pelleting. This reaction reduces digestibility of the feedstuff by producing insoluble polymers with physical and chemical properties similar to lignin (Van Soest 1982). Tannin/protein complexing during drying, grinding, and pelleting may also be different from that which occurs when animals masticate fresh material. Hence, pelleted diet formulations may not accurately

reflect nutrient availability of material consumed fresh by free ranging animals.

The digestion-balance trials outlined here attempted to delineate the nutritional value of fresh-fed Gambel oak for Spanish goats, as well as the effects of phenology and level of oak in the diet on these relationships. The results of this evaluation have important implications for further research and use of goats in oakbrush vegetation types.

STUDY AREA

The study area is located near Henefer, Utah (UTM 45800E 4540500N). Specifically, the site lies in the Owen's Canyon drainage, within the Henefer-Echo Wildlife Management Area administered by the Utah Division of Wildlife Resources. These foothills of the Wasatch Mountains range in elevation from 1600 to 2400 meters, and have an average precipitation of 350 mm.

Vegetation on this area is typical of this elevation and geographic location, with dense Gambel oak mottes dominating cooler north-facing slopes, and big sagebrush/grass associations occupying warmer, drier southern exposures. Major shrub species include Gambel oak, big sagebrush (Artemisia tridentata), serviceberry (Amelanchier alnifolia), snowberry (Symphoricarpos oreophilus), and green rabbitbrush (Chrysothamnus viscidiflorus). Understory grass/forb components include a wide variety of associated species, dominated by Kentucky bluegrass (Poa pratensis).

MATERIALS AND METHODS

Hand-harvested Gambel oak was mixed in various proportions with chopped alfalfa hay and fed fresh to twelve mature wether Spanish goats, in a series of total-collection digestion-balance trials. These trials were conducted during the summers of 1986 and 1987, in on-site open-air digestion-balance cages. The diets tested 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). All dietary percentages were on a dry matter basis.

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, less than 15 cm in length, and included the twig and associated leaves. Juvenile material was selectively harvested in late May and June, prior to leaf/twig hardening, while mature browse was collected in late July and early August. Each sequential trial tested one of the diets, and was scheduled to coincide with oak phenology in the area. The alfalfa was chopped with a hammermill through a one inch screen to prevent rejection of stem material by the animals.

The diets were fed to twelve mature Spanish goat wethers, arranged in three replications of four animals each. A single replication consisted of four cages grouped together, spatially separated from the other groups by a minimum of 50 meters, allowing social interaction within a replication, but not between replications. Replications were fed as a group, and the rations

weighed and mixed separately for each animal. Animals that had behavioral problems with confinement in the cages, indicated by extreme nervousness, vocalizations, and refusal to eat, were removed from the trial, and data from these animals were not used in the subsequent analyses. The animals that were removed were not replaced, and analysis was based on unequal sample sizes.

Each 17-day trial consisted of a 10-day preliminary period, to allow the animals to become accustomed to the diet and eliminate digestive residues, followed by a 7-day collection period. During the collection period, intake was carefully measured; diet samples taken; feces, urine, and orts were collected, weighed, and subsampled for later analysis. To prevent volatilization of nitrogen from the urine, 75 ml of 25% sulphuric acid were added to the urine collection containers daily. All samples were immediately frozen, and stored in this state. During the trials, animals had free access to water and trace mineral salt.

Feces, urine, and orts samples were composited for the 7-day period for each animal and freeze-dried. Feces and orts were ground prior to laboratory analysis. Oak and alfalfa samples were freeze-dried, ground, and analyzed separately. All samples were then analyzed for nitrogen, using the Hach colorimetric method (Hach et al. 1985), and for energy, using oxygen bomb calorimetry (A.O.A.C. 1960). Feed, feces, and orts were analyzed for cell wall, hemicellulose, cellulose, and lignin, using the sequential fiber procedure (Goering and Van Soest 1970). Apparent in vivo digestibilities for the various fractions were then calculated as the

difference between net intake and fecal output of a given fraction. Tannin content of the oak samples was determined using two different techniques (Martin and Martin 1983, Hagerman and Butler 1978).

The data were compared using analysis of variance for a nested, completely randomized design, with mean differences indicated by LSD tests of all possible comparisons (Dowdy and Wearden 1983). Probability levels ≤ 0.05 were considered significant.

RESULTS AND DISCUSSION

I. General relationships between diets

The notation for the various diets (e.g. 80J, 80M) indicates the dry matter percentages of juvenile and mature Gambel oak in the feed formulations. In the case of the fresh-fed diets used in this study, a cautionary statement is in order concerning these percentages. Diets were formulated on the basis of average values for dry matter determinations made just prior to the collection period during each trial. However, fresh browse varies in dry matter content diurnally, day to day, between plants, and between different leaders on the same plant, due to slight differences in phenology, plant water status, and individual variations. Because of this, the average dry matter oak content of the diets varied somewhat from the test-diet designation (Table 1).

TABLE 1. Average oak content (% on dry matter basis) of diets fed to goats.

Diet	%Oak
ALF	00.0
80M	80.2
40M	44.5
95J	94.9
80J	84.6
65J	62.3

The chemical composition of the feed components (Table 2) followed expected trends, and agreed well with previous determinations of Gambel oak and alfalfa (Nastis and Malechek 1981). Dry matter, cell wall, and lignin increased with maturity in oak samples, while protein (nitrogen x 6.25) content decreased. These effects are expected, especially for woody browse species (Van Soest 1982). Gross energy content was relatively constant across all feed components. Tannin concentration, measured by both the Martin and Martin (1983) and Hagerman and Butler (1978) assays, showed decreased activity with maturity in the oak browse. This follows earlier observations by Nastis and Malechek (1981) using a total phenolics assay.

TABLE 2. Chemical composition of feed components of diets fed to goats (based on 1986 samples).

	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
Energy (Kcal/g)	4.6	4.3	4.6
Tannin (mg/mg) ¹	0.231	0.176	---
Tannin (mg/g) ²	40.4	34.7	---

¹ Martin and Martin (1983) assay (mg prot.precip/mg samp.)

² Hagerman and Butler (1978) assay (mg tannic acid equiv./g)

Dry matter intakes for the diets containing mature oak (80M, 40M) were significantly higher than those for juvenile diets or the alfalfa control, and the 95J diet had the lowest intake of the diets tested (Table 3). Intakes for the 80J and 65J diets were not significantly different from the control. Goats on low-percentage oak diets (65J, 40M) or mature foliage appeared to reach gastrointestinal fill after a few feedings, and refused substantial amounts of feed by the end of the day. Conversely, animals on the 95J and 80J diets fed almost constantly, and very few refused feed. Therefore, ad libitum levels may not have been reached for all animals every day of these trials.

TABLE 3. Average daily dry matter intake (grams * kg⁻¹ * day⁻¹) of six diets fed to goats.

Diet	Intake	Average Initial Body Weight (kgs)
ALF	30.3±4.4 b	41.4
80M	37.8±3.8 a	36.6
40M	34.5±4.5 a	40.0
95J	23.6±2.9 c	43.5
80J	31.6±4.4 b	34.5
65J	29.9±2.6 b	43.8

Means followed by the same letter are not different (P=.05).

The dry matter content of the feed has been shown to affect intake. Kenney et al. (1984) found an overall decrease in intake rate with increasing moisture content of the feed, even though wet intake increased. Due to the low dry matter content of juvenile oak browse, approximately 35%, animals on diets with high percentages of these materials would need to process relatively larger amounts of as-fed material to supply the same quantity of dry matter, when compared to diets containing mature browse (45% DM). Diets which contained relatively high percentages of the dry alfalfa hay (92% DM) should also provide more dry matter. This relationship between intake and dry matter content can be modified by fiber content and lignification, as they relate to rates of passage and rumination time (Van Soest 1982); but it is unknown to what extent these factors operated in this study.

Another observation is relevant to these results. During the alfalfa (control) trial, many of the animals appeared to be deterred by the dusty nature of the chopped hay when it was offered alone, while in other trials, offered in a mixed diet, it was avidly consumed. This may explain in part the relatively lower intake of the alfalfa diet when compared with mature browse formulations.

Apparent digestibility coefficients for dry matter and fiber fractions are shown in Table 4. Dry matter and cell wall (neutral detergent fiber) digestibilities followed similar trends. In general, mature oak diets were significantly less digestible than the

TABLE 4. Average apparent digestibility coefficients (%) for dry matter and fiber components of six diets consumed by goats.

Diet	Dry matter	Cell wall	Hemicellulose	Cellulose
ALF	64.4 b	47.9 b	52.4 c	53.1 a
80M	57.8 c	33.1 d	52.3 c	34.8 d
40M	58.8 c	37.4 c	53.2 c	39.7 c
95J	68.6 a	53.7 a	67.2 a	50.7 a
80J	65.3 b	45.8 b	59.6 b	46.7 b
65J	66.3 b	47.3 b	57.1 b	50.7 a

Means in the same column followed by the same letter are not different ($P=0.05$).

alfalfa or juvenile oak diets, probably due to increases in cell wall and lignification of the cell wall with advancing maturity. The 95% juvenile oak diet had the highest digestibility; significantly higher than any of the other diets tested. Hemicellulose followed a similar trend, except that the values for alfalfa were lower than those for juvenile oak diets, and not significantly different from those for mature oak diets. Cellulose digestibility was depressed in diets containing mature oak, possibly due to lignification, and this is probably the major determinant of lower total cell wall digestibilities for these diets. Increased digestibilities in the high-percentage juvenile diets (95J, 80J) may partially or completely compensate for the lower dry matter intakes on these diets in terms of nutrients supplied to the animal. This is readily observed in the nitrogen and energy balances.

Energy balances were positive for all animals in all trials, and resulted in no significant differences in quantities of digestible or metabolizable energy provided by any of the test diets (Table 5). The gross energy intakes with high-percentage juvenile oak diets (80J, 95J) were significantly less than with the other diets, due to reduced dry matter intakes; however, they had the lowest fecal energy losses, resulting in similar digested amounts. Urinary energy losses were not significantly different between the diets.

TABLE 5. Average daily energy balance (Mcal/day) for goats on oak-containing diets and an alfalfa control diet.

Diet	Consumed	Fecal	Digested	Urinary	Metabolized
ALF	5.749 a	1.747 c	4.001 a	0.196 a	3.806 a
80M	6.329 a	2.711 a	3.619 a	0.358 a	3.261 a
40M	6.144 a	2.506 a	3.638 a	0.309 a	3.329 a
95J	4.715 b	1.433 d	3.282 a	0.339 a	2.943 a
80J	4.917 b	1.734 c	3.183 a	0.317 a	2.866 a
65J	5.975 a	2.029 b	3.946 a	0.387 a	3.559 a

Means in the same column followed by the same letter are not different (P=.05).

Average nitrogen balances were also positive for all trials (Table 6). High-percentage juvenile oak diets (80J, 95J) were again associated with the lowest gross nitrogen intakes and reduced fecal nitrogen losses. However, in the case of nitrogen, increased digestibilities were not adequate to completely compensate for reduced nitrogen intakes. Digested amounts of nitrogen were significantly different between the diets, with alfalfa providing significantly greater amounts of DN than any other diet, followed in order by 65J, 40M, and the high-percentage oak diets (80M,80J,95J) providing the least. In general, urinary nitrogen losses were higher for diets providing the most digestible nitrogen (ALF, 65J,40M) and lowest for the high percentage oak diets (80M,80J,95J), but again, this effect did not completely compensate for lower nitrogen intakes.

Metabolizable nitrogen was significantly higher in the alfalfa diet, followed by 65J; the remainder of the diets did not differ.

To evaluate nitrogen and energy balance values in a practical context, it is necessary to compare end results with published maintenance requirements for comparable animals. Unfortunately, basic information for Spanish goats is lacking. Nastis and Malechek

TABLE 6. Average nitrogen balance (grams/trial) for goats on oak-containing diets and an alfalfa control diet.

Diet	Amount Consumed	Fecal Losses	Amount Digested	Urinary Losses	Amount Metabolized
ALF	282.1 a	67.3 c	214.8 a	119.0 a	95.8 a
80M	195.9 b	97.5 a	98.3 d	82.9 bc	15.4 c
40M	218.0 b	84.2 b	133.9 c	101.8 ab	32.1 c
95J	163.0 c	61.3 c	101.7 d	78.0 c	23.2 c
80J	163.9 c	70.5 c	93.4 d	61.6 c	31.8 c
65J	262.3 a	94.0 a	168.3 b	105.4 ab	62.9 b

Means in the same column followed by the same letter are not different ($P=.05$).

(1981) used the values provided by Huston et al.(1971), and later reported in Huston (1978) for Angora goats. Table 7 compares the maintenance values for digestible energy (DE) and digestible nitrogen (DN) for comparable-sized Angora goats with the values determined in this study for Spanish goats on potentially best (ALF) and worst (95J) diets. Huston (1978) recommended DE levels of 3.5 Mcal/day and DN levels of 13.0 grams/day as maintenance requirements. Both best and worst cases provided DN in excess of this amount, but the 95J

diet appears to be slightly submaintenance in DE, as speculated by Nastis and Malechek (1981). However, as Huston (1978) pointed out, these figures are determined with high production mohair animals, and values for Spanish or feral goats should be lower.

TABLE 7. Comparison of daily digestible energy (Mcal) and digestible nitrogen (grams) for goats on 95% juvenile oak and an alfalfa control diet with published maintenance requirement for a 40 kg Angora goat (Huston 1978).

	DE	DN
Maintenance	3.5	13.0
ALF	4.0	30.7
95J	3.3	14.5

Oliveira (1987) reviewed 19 studies involving the maintenance energy requirements for goats, including domestic and native species. It is interesting to note that with values ranging from 87 to 165 Kcal ME * BW^{-.75} * day⁻¹, the values for Angora goats cited from Huston (1978) are the highest. The average for this cross-specific comparison, expressed as daily requirement of metabolizable energy on a metabolic body weight basis, is approximately 106 Kcal ME * BW^{-.75} * day⁻¹. This is probably a more reasonable approximation of Spanish goat requirements. The average values for the alfalfa control and 95J trials in this study were 234 and 174 Kcal, respectively. Using these criteria, all diets provided metabolizable energy well in excess of maintenance requirements.

Nitrogen and energy available above maintenance was also

reflected in goat weight gains. Average gains for each trial (Table 8) were not compared statistically, because the diets were tested consecutively, resulting in potential carry-over effects. Dates for trials are given in table 8 to provide a basis for interpretation of differences. For example, relatively low gains for the 95% juvenile oak diet may have been due to gains on the previous alfalfa control diet. What is worth noting, however, is positive weight responses for all diets. With the exception of three animals removed from various trials due to behavioral problems with confinement in the metabolism cages, all animals in all trials gained weight. This provides further evidence that the diets supplied nutrients in excess of maintenance.

TABLE 8. Average daily weight-specific gains (grams * kg⁻¹ * day⁻¹) for goats on six diets.

Diet	Gain	Trial Dates
ALF	3.95	Early May, 1987
80M	5.07	Late July, 1986
40M	3.72	August, 1986
95J	2.04	Late May, 1987
80J	5.27	June, 1986
65J	4.00	June, 1987

II. Comparison with pelleted diets

Four of the six diets (ALF,80J,80M,40M) are similar to diets fed in pelleted form by Nastis and Malechek (1981). Statistical comparison of the two studies is not valid, due to differences in experimental design. There is also potential for differences in plant chemistry between the two studies, especially secondary compounds, due to differences in resource availability, e.g. nutrients, water, and sunlight (Bryant et al. 1983). Fiber, nitrogen, and energy content of feed components were very similar between the two studies, but use of a nonspecific total phenolics assay in the earlier work precludes comparison of tannin levels. However, care was taken to duplicate digestion trial sampling procedures, lab procedures, oak harvest, and diet formulations of the Nastis and Malechek study, in order to provide a valid comparison.

Pelleting increases intake, by increasing feed density, and decreases digestibility (Van Soest 1982). The reduction in digestibility is a function of the reduction in particle size due to grinding the material. This results in increased rates of passage out of the rumenoreticulum, reducing the exposure of the feed material to microbial fermentation (Van Soest 1982). Such a sequence of events would be especially important in a small ruminant like a goat, already limited in digestion of fibrous feeds by a relatively small rumen and coincident rapid rates of passage (Huston 1978).

Average weight-specific dry matter intakes (Table 9) followed expected trends. Fresh-fed DM intakes were 10-45% less than their pelleted counterparts (Nastis and Malechek 1981). The dramatic

reduction in intake of the chopped alfalfa hay diet may be due in part to the dustiness of the feed, mentioned in the previous section.

Apparent digestibilities also followed expected trends (Table 9). Digestibility coefficients for both dry matter and total cell wall (NDF) were consistently higher for the fresh-fed diets, by as much as 10% in the case of the 80% juvenile oak diet (Figures 1,2). These increased digestibilities may partially or completely compensate for lower dry matter intakes for fresh material.

In the case of energy balance, this compensation was complete. Availability of energy is closely tied to dry matter and cell wall digestibility (Van Soest 1982) and this is reflected in similar relationships for apparent digestibility coefficients for energy (Figure 3). Comparison of energy balance results with the earlier pelleted work (Table 10) shows lower gross energy intake for the fresh-fed diets, but with a reduced fecal loss. This resulted in increased digestibility of energy, and very similar digested amounts

TABLE 9. Dry matter intake (grams * kg⁻¹ * day⁻¹) and apparent digestibility (%) of dry matter and cell wall for goats on three oak diets and an alfalfa control diet.

Diet	DM intake		DM digest.		CW digest.	
	F	P	F	P	F	P
ALF	30.3	54.7	64.4	56.9	47.9	38.1
80J	31.6	35.7	65.3	54.0	45.8	35.3
80M	37.8	42.0	57.8	48.9	33.1	26.2
40M	34.5	46.7	58.8	53.0	37.4	34.7

F - Data for fresh-fed (this study)

P - Data for pelleted (Nastis and Malechek, 1981)

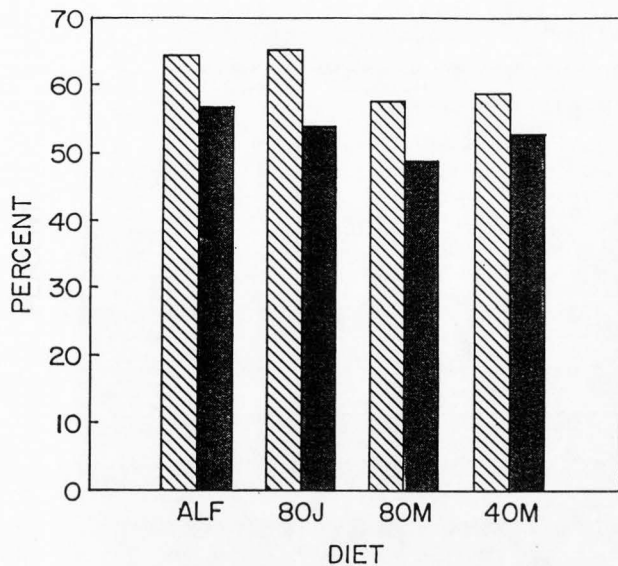


FIGURE 1. Average apparent digestibility coefficients for dry matter of three oak-containing diets and an alfalfa control diet (hatched bars) consumed by goats - comparison (solid bars) with Nastic and Malechek (1981).

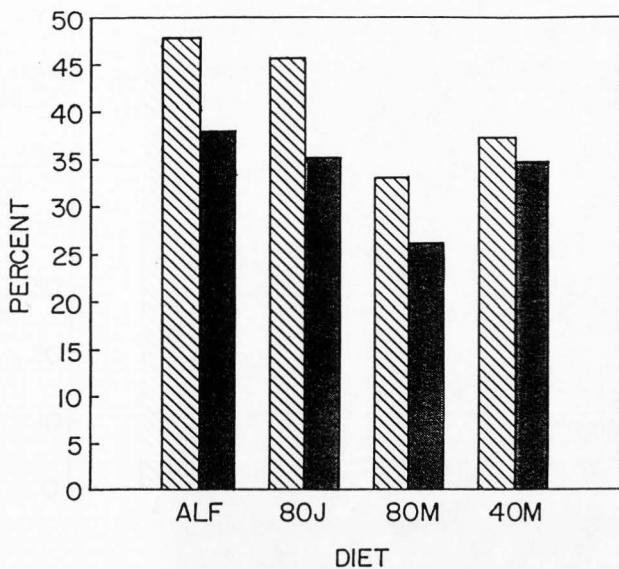


FIGURE 2. Average apparent digestibility coefficients for cell wall (NDF) of three oak-containing diets and an alfalfa control diet (hatched bars) consumed by goats - comparison (solid bars) with Nastis and Malechek (1981).

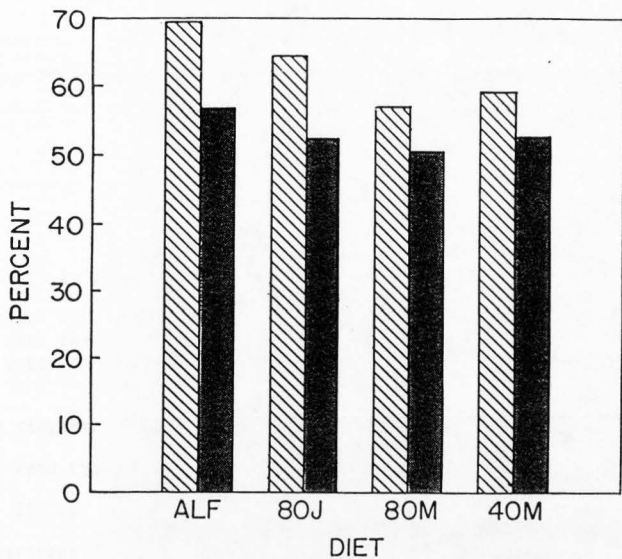


FIGURE 3. Average apparent digestibility coefficients for energy of three oak-containing diets and an alfalfa control diet (hatched bars) consumed by goats - comparison (solid bars) with Nastis and Malechek (1981).

TABLE 10. Daily energy balance (Mcal/animal) for goats on three oak diets and an alfalfa control diet.

Diet	Consumed		Fecal		Digested		Urinary		Metabolized	
	F	P	F	P	F	P	F	P	F	P
ALF	5.7	7.0	1.7	3.0	4.0	4.0	0.2	0.3	3.8	3.7
80J	4.9	5.7	1.7	2.7	3.2	3.0	0.3	0.4	2.9	2.6
80M	6.3	6.9	2.7	3.4	3.6	3.5	0.3	0.4	3.3	3.1
40M	6.1	7.0	2.5	3.3	3.6	3.7	0.3	0.3	3.3	3.4

F - Data for fresh-fed (this study)

P - Data for pelleted (Nastis and Malechek, 1981)

when compared to the pelleted form. Urinary losses were similar in both feed types, resulting in similar metabolizable amounts retained.

It is difficult to draw conclusions from nitrogen balance comparisons (Table 11) without a statistical basis for differences. Nitrogen intake appears to be reduced in the fresh diets, especially for oak-containing formulations, again due to reduced dry matter intakes. The high fecal losses of nitrogen for high-percentage oak diets suggested in the earlier work were not found in this study. Digested amounts of nitrogen appeared to be similar among all the trials. Urinary nitrogen losses were somewhat higher for the pelleted material, especially for the alfalfa control and 80J diets. This resulted in slightly lower amounts of nitrogen retained for the pelleted control and 80J diets, and slightly reduced retention for both fresh-fed mature oak diets. Therefore, it appears that reduced fecal and urinary losses may compensate for lower nitrogen intakes on fresh diets, especially the 80% juvenile oak formulation.

TABLE 11. Daily nitrogen balance (grams/animal) for goats on three oak diets and an alfalfa control diet.

Diet	Consumed		Fecal		Digested		Urinary		Metabolized	
	F	P	F	P	F	P	F	P	F	P
ALF	40.3	42.2	9.6	11.3	30.7	30.9	17.0	21.3	13.7	9.6
80J	23.4	30.1	10.1	14.9	13.3	15.3	8.8	12.6	4.5	2.7
80M	28.0	34.8	13.9	17.9	14.0	16.9	11.8	9.3	2.2	7.6
40M	31.1	38.4	12.0	15.8	19.1	22.6	14.5	16.4	4.6	6.7

F - Data for fresh-fed (this study)

P - Data for pelleted (Nastis and Malechek, 1981)

SUMMARY AND CONCLUSIONS

This study compared the nutritional value of diets containing various levels of mature and juvenile Gambel oak browse for Spanish goats, using the criteria of intake, digestibilities of various components, energy balance, nitrogen balance, and animal weight gain. Dry matter intake was highest in the mature oak formulations (80M,40M) and lowest in the 95% juvenile oak diet (95J). Dry matter and cell wall digestibilities followed an opposite trend, with reduced coefficients for mature diets, and highest for the 95J diet. Cellulose digestion was lower in the mature oak diets, due to greater lignification, which was probably a causal factor in reduced cell wall and dry matter digestibilities for these diets. Higher digestibility coefficients for the juvenile oak diets compensated for lower intakes, such that quantities of digestible and metabolizable energy provided by the various diets were not significantly different, and were in excess of maintenance requirements for these animals. Available nitrogen was significantly higher for the alfalfa control diet as compared to any oak-containing diet, but all diets provided nitrogen in excess of published requirements. Nutrient availability above maintenance was also indicated by positive weight responses by the animals in every trial. Hence, it can be concluded that Gambel oak, even juvenile material in high dietary percentages (95%), provided adequate nutrients and should be considered a valuable forage for goats used in oakbrush areas for production or brush control.

Comparison of fresh-fed oak diets used in this study with pelleted formulations of the same diets in an earlier study indicates that pelleting may increase dry matter intakes, but results in a consistent underestimation of digestibilities for dry matter, cell wall, and energy. Use of digestion-balance trials to evaluate nutrient availability of browse diets should involve fresh-harvested materials if conclusions are to be drawn on the basis of digestibilities, or if results are to be applied to a free-ranging situation.

The results of this study, while closer to field conditions than pelleted diets, may also be somewhat different from those of free-ranging goats. Animals in the field may select differently from the hand-harvested materials offered in these trials. Leaf:stem ratios can have a significant impact on nutrient composition of the feed, and are probably higher in free-ranging goats browsing on Gambel oak than those pertaining here and in the earlier work. Field trials using esophageally fistulated animals would provide a better understanding of the nutrient composition of goat diets, and would be a useful follow-up to the current study.

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