Intake and digestibility response of sheep and goats fed Arctostaphylos canescens with and without PEG supplementation[1]

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Introduction

More than 4.5 million ha of California's rangelands are dominated by the *Chaparral* plant community. This Mediterranean type brush community is one of the most fire-prone plant communities in the world. With the rapidly expanding urbanization in California, vegetation management is becoming a critical need in order to reduce the risk of catastrophic wildfires threatening the loss of life and property. There is growing interest in and application of so-called 'pre-scribed grazing' with small ruminants, particularly goats, in effort to reduce fire fuels in California Chaparral communities. However, very little is known about the nutritional and anti-nutritional properties of the plant species intended to be consumed by domestic ruminants in Chaparral management programs. This information is essential to design management protocols required to ensure health maintenance of the animals and predict efficacy of their use.

The study was conducted to determine intake and digestibility *in vivo* in sheep and goats of manzanita (*Arctostaphylos canescens*), a key species in the Chaparral fire matrix and of considerable concern also in forest plantations. We hypothesized that the very strong astringency of manzanita leaves, caused by tannins, serves as a major deterrent to herbivory. Astringency is caused by the rapid complexation of mucoproteins lining the oral cavity (Haslam and Lilley, 1988) by tannins. Polyethylene glycol (PEG) is an inert and unabsorbed molecule that can form a stable complex with tannins, preventing the binding between tannins and proteins (Badran and Jones, 1965). Recent work from Israel has shown that overcoming the astringency effect by ad libitum supplementation with PEG leads to rapid increases in consumption of vegetation containing extremely high levels of tannins by herbivores (Silanikove et al. 1994, 1996 and 1997; Degen et al. 1998; Decandia et al. 2000). To the best of our knowledge, this is the first experiment to test the effects of PEG on intake and digestibility of manzanita in goats and sheep in California.

Material and Methods

Study area. The feeding experiment was conducted in October – November 2000 in the Hopland Research and Extension Center (HREC), located at 39° 00’N latitude and 123° 4’W longitude with elevation from about 170 to 1,000 m. Four principal vegetation types (grass, woodland-grass, dense woodland, and chaparral) include more than 800 species and cover 95% of the Center's property.

Plant material. Fresh plant material was hand-harvested every morning from a homogenous stand (in terms of species and age) of *Arctostaphylos canescens*. Harvesting of branches was done in a matter consistent with browsing patterns of sheep and goats in order to minimize refusals.

Animal management. The experiments were conducted with Kiko goats (average initial weight 32±3.0 kg) and Targhee sheep (average initial weight 55±3.0 kg). All animals were castrated males. Animals were housed in individual metabolism crates. Experimental treatments consisted of different supplementation levels of polyethylene glycol (PEG, mol. Wt 4000). PEG was introduced for consumption in drinking water at 4 levels (0.3%, 0.15%, 0.05% and 0% of body weight. Because of the very low nutritive value of manzanita (Sidahmed et al., 1981), animals were supplemented with pelleted lucerne at 1.5% of their body weight. The highest PEG supplementation level was the initial treatment; subsequently, PEG supplementation was reduced until it reached 0% in the last period. This design minimized carry-over effects of potentially anti-nutritious action of manzanita. Each experimental period (PEG level) lasted for 14 days (7 days for adjustment and 7 days for sample collection). One exception was the first period (0.3% PEG), which lasted for 16 days (7 days for adjustment and 9 days for sample collection).

Measurements. Feed intake and *in vivo* diet digestibilities were measured by total fecal collection during the 4 periods. Daily subsamples from the fresh feed offered and from composited total feed refusals for each individual animal were weighed and taken for DM determination and further analyses. Samples of feed on offer, refusals and feces were dried in a forced-air oven (50°C for 48 h) and ground to pass a 1 mm-screen in a Wiley mill (Arthur A. Thomas, Philadelphia, PA) and stored until analysis. Animal weight was recorded at the beginning and the end of each experimental period.

Laboratory analyses. Feed on offer and individual refusal and fecal samples were analyzed for dry matter (DM), organic matter (OM), ash, and crude protein (CP) according to AOAC (1975). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) was determined following Goering and Van Soest (1970). Condensed tannins (CT) were measured according to Price et al. (1978).

Statistical analysis. Data were analyzed in mixed model-maximum likelihood linear models for analysis of repeated measure data with a 2 x 4 factorial arrangement of treatments, using SAS 8.1 software (SAS, 1999). The model included animal species, treatment, species by treatment interaction, and maximum daily temperature for measurement day as covariate. The heterogeneous compound symmetry covariance structure was fitted to the intake data, as indicated by Akaike's Information Criterion. Observed values for crude protein digestibility were transformed with the arcsine square root transformation to approximate normal distribution. Where the species – treatment interaction was significant, treatment means were separated in individual analyses for each animal species. Treatment and species effects on body weight differences were estimated with a fixed factor linear model.

Results and Discussion

The chemical properties of feedstuffs are summarized in Table 1. The concentration of condensed tannins was very high. By comparison, Pritchard et al. (1992) found 9.6±7.9 g/100 g DM in *Acacia anuera*; Ben Salem et al. (2000) measured 3.2 g/100 g DM in *Acacia cyanophylla*. Thus, our values are among the highest found for forage species. Analysis of the difference in body weight between beginning and end of the experimental period yielded treatment as a significant effect (p=.0014) (Table 2). The difference between sheep and goats was not significant. The results indicate that especially goats in manzanita control are likely to maintain body condition under appropriate PEG supplementation, when given a minimal amount of good quality roughage as a supplement.

Parameters	Manzanita[a]	Lucerne
Dry matter (%)	52.9±0.1	93
Organic matter (%)	97.1±0.5	88.8
Ash (%)	2.9±0.5	11.2
Crude protein (%)	4.3±0.7	20.3
NDF (%)	31.3±2	37.3
ADF (%)	21.5±1.6	28.8
CT[b] (g/100 g DM)	23.1±0.4	0

Table 1. Chemical composition (%DM) of the Manzanita and of the alfalfa pellets offered to the animals.
[a] Means ± S.D.
[b] CT, methanol extractable condensed tannins equivalent catechin (g/100gDM)

Species		Treatment (PEG levels (% of BW))			
	Body weight difference(kg)	0.3	0.15	0.05	0
Goat		-0.76±1.09	0.35±0.07	-0.23±0.30	-0.20±0.30
Sheep		-1.98±1.58	0.92±0.74	-0.23±0.32	-0.11±0.38

Table 2. Weight change of experimental animals

Table 3 summarizes the response data. The strong effect of PEG supplementation on protein digestibility demonstrates the effectiveness of PEG in improving the N status of ruminants browsing foliage with high tannin contents. Very strong effects on NDF and ADG digestibility coefficients suggest substantial negative impact of unsuppplemented manzanita foliage on fiber digestion. For all response variables, the interaction between treatment and animal species was significant. The effect of animal species on the NDF digestibility coefficient was approaching significance (p=0.0514).

Intake of manzanita in gram DM per kg body weight was significantly affected by animal species (p=.0007), treatment (P<.0001), and their interaction (p<.0001). There were no significant differences in digestibility between sheep and goats, but treatment effects were highly significant (p<.0001). The interaction between treatment and animal species was significant (p=.0092). The same applied to crude protein digestibility, with treatment significant (p<.0001) and a significant interaction (p=.0275). Maximum daily temperature was not significant in any of the analyses.

The amount of PEG needed to produce a maximal increase in feed intake by goat varies with shrub species (Silanikove et al., 1996). In our study, the amount of PEG required to produce a maximal increase in manzanita intake (0.15%) was the same amount required to produce a maximal increase in DM digestibility. However, maximal increases in CPD, NDFD and ADFD were obtained with the highest level of PEG (0.3%BW). For the practical application in brush control programs, the 0.15% PEG level seems to be sufficient.

Response	Treatment (PEG levels (% of BW))				Probability level (*** P≤0.001) (Treatment effect)
	0.3	0.15	0.05	0	
Goats					
Dry matter intakes					
Manzanita (g/d)	604.4	601.1	469.3	451.0	***
Manzanita (g/kgBW)	19.4	19.1	14.7	13.9	***
Total diet (g/d)	1159.8	1107.6	943.2	908.6	***
Total diet (g/kgBW)	37.1	35.0	29.5	27.9	***
Digestibility coefficients					
DMD	59.7	58.8	55.7	54.4	***
CPD	63.7	55.4	33.8	14.2	***
NDFD	38.9	28.9	14.3	10.8	***
ADFD	27.9	14.8	-1	-5.7	**
Sheep					
Dry matter intakes					
Manzanita (g/d)	576.5	692.1	519.3	464.2	***
Manzanita (g/kgBW)	10.6	12.8	9.5	8.4	***
Total diet (g/d)	1579.5	1611.4	1378.9	1294.1	***
Total diet (g/kgBW)	29.4	29.8	25.3	23.6	***
Digestibility coefficients					
DMD	56.7	59.8	55.9	53	***
CPD	63.4	54.7	37.9	12.7	***
NDFD	48.9	39.6	21.9	12	***
ADFD	41.1	27.9	11.5	-0.6	***

Table 3. Dry matter intake and in vivo digestibility coefficients in goats and sheep fed A canescens either without or with addition of PEG at a level of 0.3, 0.15, and 0.05% of body weight. P-level given is for treatment differences within animal species.

Literature cited

Association of Official Analytical Chemists. 1975. Official methods of analysis. 12th ed. AOAC, Washington DC.

Badran, A. M., and D. E. Jones. 1965. Polyethylene glycols-tannin interaction in extracting enzyme. Nature, 206:622-623.

Ben Salem, H., A. Nefzaoui, L. Ben Salem, and J. L. Tisserand. 2000. Deactivation of condensed tannins in *Acacia cyanophylla* Lindl. Foliage by polyethylene glycol in feed blocks. Effect on feed intake, diet digestibility, nitrogen balance, microbial syntesis and growth by sheep. Livestock Production Science, 64:51-60.

Decandia, M., M. Sitzia, A. Cabiddu, D. Kababya, and G. Molle. 2000. The use of polyethylene glycol to reduce the anti-nutritional effects of tannins in goats fed woody species. Small Ruminant Research, 38:157-164.

Degen, A.A., T. Mishorr, H. P. S. Makkar, M. Kam, R. W. Benjamin, K. Becker, and H. J. Schwartz. 1998. Effect of *Acacia saligna* with and without administration of polyethylene glycol on dietary intake in desert sheep. Animal Science. 67, 491-498.

Goering, H. K., and P. J. Van Soest. 1970. Forage fibre analyses. Handbook, Agricultural Research Service, United States Department of Agriculture, N° 39.

Haslam, E., and T. H. Lilley. 1988. Natural astringency in foodstuffs a molecular interpretation. Critical Reviews in Food Science and Nutrition 27: 1-40.
Price, L. M.; S. Van Scoyoc, and G. L. Butler. 1978. A critical evaluation of the vanillin reaction as an assay for tannin in Sorghum grain. J. Agr. Food Chem., 26:1214-1218.
Pritchard, D. A., P. R. Martin, and P. K. O'Rourke. 1992. The role of condensed tannins in the nutritional value of mulga (*Acacia aneura*) for sheep. Austr. J. Agric. Res. 43:1739-1746.
Sidahmed, A. E., J. G. Morris, and S. R. Radosevich. 1981. Summer diet of Spanish goats grazing chaparral. Journal of Range Management 34(1):33-36.
Silanikove, N., Z. Nitsan, A. Perevolotsky. 1994. Effect of adaily supplementation of polyethylene glycol on intake and digestion of tannin-containing leaves (*Ceratonia siliqua*) by sheep. J. Agric. Food Chem. 42, 2844-2847.
Silanikove, N., N. Gilboa, I. Nir, A. Perevolotsky, and Z. Nitsan. 1996. Effect of a daily supplementation of polyethylene glycol on intake and digestion of tannin-containing leaves (*Quercus calliprinos*, *Pistacia lentiscus*, and *Ceratonia siliqua*) by goats. J. Agric. Food Chem. 44, 199-205.
Silanikove, N., N. Gilboa, and Z. Nitsan. 1997. Interactions among tannins, supplementation and polyethylene glycol in goats given oak leaves: effects on digestion and food intake. Animal Science. 64, 479-483.
Statistical Analysis Systems Institute (SAS). 1999. SAS User's Guide: Statistics, Version 8.1. SAS Inst. Inc., Cary, NC.