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NUTRITIONAL QUALITY OF SHINNERY OAK BUDS AND CATKINS IN RESPONSE TO BURNING OR HERBIVORY

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ABSTRACT—Catkins and buds of shinnery oak (*Quercus havardii*) are a food source for the lesser prairie chicken (*Tympanuchus pallidicinctus*) and perhaps other wildlife species. It is therefore important for managers to understand how different vegetation treatments may affect nutritional quality of shinnery oak catkins and buds. Objectives of our study were to determine nutritional quality of shinnery oak catkins and buds, evaluate the effect of grazing on bud nutritional quality, and determine the influence of burning and season of burn on nutritional quality of catkins and buds. The study consisted of 2 grazing treatments and 4 burning treatments. Total phenolics were higher in grazed plots compared to ungrazed plots, but crude protein did not differ by grazing treatment. Fiber content was lower in catkins than grazed or ungrazed buds. Prescribed burning decreased ash content of buds, but no other measure of nutritional quality was affected for either buds or catkins. The nutritional quality of shinnery oak buds and catkins is high, but phenolic levels ranging from 15.0 to 20.4% reduce its forage value for some species.

RESUMEN—Amentos y brotes del encino (*Quercus havardii*) son una fuente de alimento para el pollo menor de la pradera (*Tympanuchus pallidicinctus*) y quizás para otras especies silvestres. Por esa razón es importante que los administradores entiendan cómo los diferentes tratamientos de la vegetación pueden afectar la calidad nutricional de los amentos y de los brotes del encino. Los objectivos de nuestro estudio fueron determinar la calidad nutricional de los amentos y brotes de *Q. havardii*, evaluar el efecto del pasteo en la calidad nutricional de los brotes, y determinar la influencia de los incendios y cuando occuren en la calidad nutricional de los amentos y los brotes. El estudio consistió de 2 tratamientos de pasteo y 4 tratamientos de quema. Los fenoles totales fueron más altos en los sitios con pasteo comparados con los sitios sin pastar, pero la proteína cruda no difirió por tratamiento de pasteo. El contenido de fibra fue más bajo en amentos que en brotes pastados o brotes sin pastar. Quemas prescritas disminuyeron el contenido de ceniza de los brotes, pero no afectaron ninguna otra calidad nutricional ni de los amentos ni de los brotes. La calidad nutricional de los amentos y brotes del encino es alta, pero los niveles fenólicos variando entre 15.0 a 20.4% reducen su valor de forraje para algunas especies.

Shinnery oak (*Quercus havardii*) and associated vegetation widely occur in west central Oklahoma, northern Texas, and southeastern New Mexico. Peterson and Boyd (1998) conservatively estimated that shinnery oak rangelands covered ≥2 million ha in those states. Shinnery oak grassland is important habitat for lesser prairie chickens (*Tympanuchus pallidicinctus*). In 1995, a petition was filed with the United States Fish and Wildlife Service by the Biodiversity Legal Foundation to list the lesser prairie chicken as threatened.

Johnsgard (1983) and Riley et al. (1993) considered shinnery oak the most utilized food in the diet of lesser prairie chickens. In spring, diets of lesser prairie chickens are dominated by plant material, mainly forbs and shinnery oak catkins and buds (Davis et al., 1980; Doerr and Guthery, 1983). Catkins and buds may represent a valuable food source during mid-spring because availability of other food sources is limited (Peterson and Boyd, 1998). Thirty-four percent of the spring diet of lesser prairie chickens was reported to be comprised of the catkins and buds (developing leaves) of shinnery oak, with acorns contributing an additional 15% (Davis et al., 1980).

Despite the importance of shinnery oak as forage its nutritional quality has never been evaluated for catkins and buds. High phenolic content of leaves, mainly tannins (Harper et al., 1988), has been shown to induce malaise and reduce intake and conception rates in cattle (Dollahite, 1961; Jones and Pettit, 1984; Allison, 1994). It is therefore important for managers to understand how different vegetation treatments may affect nutritional quality of shinnery oak catkins and buds. Objectives of this study were to determine: 1) basic nutritional quality of shinnery oak catkins and buds when leaves first emerge, 2) potential differences in bud nutritional quality between plots grazed and ungrazed by cattle, and 3) potential differences in nutritional quality of catkins and buds due to prescribed burning and season of burn.

MATERIALS AND METHODS—This study was conducted in west-central Oklahoma with 2 sites on the Black Kettle National Grassland in Roger Mills Co. (35°32′44″N, 99°43′39″W), and a third site at the Packsaddle Wildlife Management Area in Ellis Co. (36°4′22″N, 99°54′5″W). Sites were chosen subjectively to be representative of shinnery oak communities found on sandy soils within western Oklahoma. Prior to our study, these sites had not burned for ≥10 years.

Soils were fine sands (Nobscott-Brownfield Association) with no limiting layers of clay in the top 150 cm (United States Department of Agriculture, 1982). Shinnery oak, a deciduous, clonal species, was the dominant shrub with lesser amounts of sand sagebrush (*Artemisia filifolia*) and Oklahoma plum (*Prunus gracilis*). Dominant grasses and forbs included little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), sand bluestem (*Andropogon gerardii*), sand lovegrass (*Eragrostis trichodes*), sideoats grama (*Bouteloua curtipendula*), western ragweed (*Ambrosia psilostachya*), erect dayflower (*Commelina erecta*), and sundrop (*Calylophus berlandieri*). Mean annual precipitation was 65.6 cm and mean growing season (March–August) precipitation was 40.6 cm from 1931 to 1955 (USDA, 1982).

Four 60 by 30-m plots were located at each study site. Each plot was surrounded by a 7-m plowed fire break. Fences were erected in fall 1995 to exclude these plots from cattle grazing. These plots were grazed lightly with cattle during the growing season prior to fall 1995 but remained ungrazed throughout the course of our study. Herbivory was primarily concentrated on the herbaceous understory, however, cattle do consume oak foliage during the early growing season and incidental consumption may take place throughout the growing season. One randomly selected plot at each site was burned in fall 1996 (23–24 October), winter 1997 (4–5 February), or spring 1997 (28–29 April) and a fourth plot served as a control (unburned). One grazed, unburned plot (60 by 60-m) was located adjacent to each of the 2 sites at Black Kettle National Grassland; all grazed plots were grazed lightly throughout the growing season for the duration of our study.

Plots were burned using a strip-headfiring technique (Wright and Bailey, 1982). The downwind and flank sides of plots were ignited and allowed to burn about 5 m into the plot. We then ignited a series of headfires about 10 m upwind from the backfire. All burns were conducted with relative humidity >20%, air temperature <29°C, and a surface wind speed of <16 km/h. We estimated fire behavior characteristics for all headfires and determined pre-burn fuel loading and fuel consumption from quadrats clipped before and after burning. Fire behavior and fuel characteristics are described in Boyd (1999).

In 1997, a total of 40 g of buds was hand-collected from 5 randomly selected shrubs, from each of the ungrazed control (n = 3) and grazed (n = 2) plots during the first week of April when buds began to emerge. This was the first growing season after burning and re-sprouts on burned plots did not produce catkins or buds. Catkins were hand-collected in a similar fashion during an early stage of development when most were about 1 cm long. Catkins were not collected in grazed plots because they had not yet developed at the time of sampling (early April).

In 1998, buds and catkins were collected from burned and unburned control plots during the first week of April. Buds and catkins collected in 1998 were at a similar phenological stage as those collected in 1997. Catkin collections in 1998 were made only on the Black Kettle National Grassland sites (n = 2) because the site at Packsaddle Wildlife Management Area was not producing catkins at the time of our collection. Data were not collected on grazed plots in 1998 because 1 of the 2 grazed plots was accidentally burned the previous winter.

All samples were stored frozen until they could be freeze-dried. Samples were then ground in a Wiley mill to pass a 1-mm mesh screen. Samples were analyzed in triplicate for crude protein, acid detergent fiber (ADF), ash, and total phenolics. Percent crude protein was determined with a PE 2410 Series II Nitrogen Analyzer (Perkin Elmer, Norwalk, Connecticut). Acid detergent fiber was determined using an ANKOM[200] Fiber Analyzer (ANKOM Tech., Fairport, New York). Ash content was calculated by comparing dry sample weights to residue weights after samples

TABLE 1—Nutritional quality measures for shinnery oak catkins and buds collected in 1997 in western Oklahoma. Values are expressed as percent dry matter.

		% Crude protein		% Phenolics		% Acid detergent fiber		Ash	
Treatment	*n*	$\bar{X}$	*SE*	$\bar{X}$	*SE*	$\bar{X}$	*SE*	$\bar{X}$	*SE*
Buds									
Grazed plots*	2	18.1	2.3**	20.4	0.9a	24.6	2.2a	3.9	0.2
Ungrazed plots	3	19.1	0.4	16.6	0.4b	22.3	0.5a	3.7	0.1
Catkins***									
Ungrazed plots	3	22.3	0.1	17.5	0.4b	16.6	0.2b	4.5	0.3

* Data were collected after the first growing season (i.e., 1997) following grazing.
** Means within a column with no letters or the same letters are not significantly different (LSD) at alpha = 0.05.
*** Insufficient catkins on grazed plots for collection.

were placed in a muffle furnace for 4 h at 500°C. Total phenolics were measured colorimetrically (absorbance at 765 nm) with Folin-Ciocalteu reagent and gallic acid as a standard (Singleton and Rossi, 1965). All values are expressed as a percentage on a dry-weight basis.

Total phenolics were converted into gallic acid equivalents by regression analysis of absorbance readings on the gallic acid standard. One-way analysis of variance was used to test for treatment effects on crude protein, ADF, ash, and total phenolics (SAS, 1985). The General Linear Models (SAS, 1985) procedure was used because this procedure allows for analysis of unbalanced designs. Data were unbalanced in 1997 because of limited availability of grazed sites. When significant *F*-values were found ($P \leq 0.05$), we tested differences among treatment means using Fisher's Least Significant Difference test ($P = 0.05$; SAS, 1985).

RESULTS—In 1997, concentration of crude protein did not differ by plant part and grazing treatment ($P = 0.138$; Table 1). Phenolic content differed by plant part and grazing treatment ($P = 0.009$). Buds in grazed plots had higher phenolic content than buds in ungrazed plots. Phenolic levels of catkins did not differ from those of buds in ungrazed plots, but levels were lower than buds in grazed plots. Content of ADF differed by plant part and grazing treatment ($P = 0.004$) and was lower for catkins as compared to buds in grazed or ungrazed plots. Concentration of ash did not differ by plant part and grazing treatment ($P = 0.109$).

In 1998, burning treatment did not influence crude protein ($P = 0.221$), phenolic ($P = 0.450$), or ADF content ($P = 0.208$) of buds, however, ash content of burned plots was greater than unburned plots ($P = 0.017$; Table 2). Similarly, burning treatment did not affect crude protein ($P = 0.539$), phenolic ($P = 0.211$), ADF ($P = 0.519$), or ash content ($P = 0.472$) of catkins. Season of burn did not affect any nutritional quality measure of buds or catkins ($P > 0.05$).

DISCUSSION—Herbivory previously has been reported to alter plant nutrient content (Ouellet et al., 1994; Estel et al., 1996; Ritchie et al., 1998). Herbivory-induced increases in phenolic content are thought to represent a form of plant defense (Feeny, 1976; Rhodes, 1979) and may arise as a result of alterations in plant nutrient balance (Tuomi et al., 1984) or a decrease in phenological age of grazed plant tissue relative to ungrazed material (Provenza et al., 1994). For example, juvenile growth of many woody species may contain higher phenolic levels than more mature growth (Provenza and Malechek, 1984). In our study phenolic content of buds from grazed plots was greater than on ungrazed plots. Seasonal grazing had not yet begun at the time of our sampling, and buds in grazed and ungrazed plots were phenologically similar. The mechanism for induction of phenolic defenses is unclear unless there were sustained effects from the previous year's grazing.

Limitations in soil nutrients can alter plant investment in chemical defenses against herbivory. Several authors have presented evi-

TABLE 2—Nutritional quality measures by season of prescribed burn for shinnery oak catkins and buds collected in 1998 in western Oklahoma. Values are expressed as percent dry matter.

Burning treatment	n	% Crude protein $\bar{X}$	% Crude protein SE	% Phenolics $\bar{X}$	% Phenolics SE	% Acid detergent fiber $\bar{X}$	% Acid detergent fiber SE	Ash $\bar{X}$	Ash SE
				Buds					
Season of burn*									
Control	3	22.4	0.6**	16.1	1.5	23.5	0.7	4.6	0.1
Fall	3	23.2	0.9	18.1	1.0	20.9	1.0	4.3	0.1
Winter	3	22.9	0.6	15.3	1.3	22.5	0.9	4.1	0.2
Spring	3	24.1	0.5	18.6	1.2	22.6	1.1	4.2	0.1
Burn versus no burn									
Control	3	22.4	0.6	16.1	1.5	23.5	0.7	4.6	0.1a
Burned	9	23.4	0.4	17.4	0.8	22.0	0.6	4.2	0.1b
				Catkins					
Season of burn									
Control	2	20.7	0.3	12.2	1.1	18.2	0.3	4.4	0.3
Fall	2	21.1	0.7	15.2	1.9	18.9	1.0	4.3	0.2
Winter	2	21.5	1.5	15.0	2.8	18.2	1.3	4.2	0.2
Spring***	2	21.7	—	15.1	—	21.2	—	3.9	3.9
Burn versus no burn									
Control	2	20.7	0.3	12.2	1.1	18.2	0.3	4.4	0.3
Burned	6	21.3	0.6	15.1	1.3	18.9	0.7	4.2	0.1

* Data were collected after the second growing season (i.e., 1998) following prescribed burning.
** Means within a burning treatment, plant part, and column with no letters or the same letters are not significantly different (LSD) at alpha = 0.05.
*** Only 1 spring-burned plot produced catkins; these plots not included in statistical analysis.

dence that nutrient-limited plants may produce high levels of carbon-based anti-herbivore defenses (e.g., phenolics; Bryant et al., 1983; Coley et al., 1985); however, resource availability theory does not present a clear explanation of differences in phenolic levels we observed between grazed and ungrazed shinnery oak buds. Although shinnery oak communities are generally nutrient-limited (Peterson and Boyd, 1998), and resource availability may play an evolutionary role in influencing levels of carbon-based defenses for shinnery oak as a species, it is less likely to influence the proximate response of individual above-ground shoots to herbivory.

Fire in any season induces vigorous post-burn sprouting of shinnery oak, but canopy cover of oak on burned plots is decreased for at least 2 years post-burn due to the smaller stature of re-spouting plants (Boyd, 1999). Regrowth following a fire event differs from that following grazing in that fire topkills shinnery oak plants and regrowth originates from underground buds located along rhizomes. Comparing nutrient quality of catkins and buds on burned plots to those of unburned plots is similar to comparing nutrient values of mature plants to more juvenile plants. Although ash content of buds was decreased with fire treatment, the biological significance of this change is questionable. The lack of difference in other nutritional quality measures for buds and catkins between burned and unburned plots in our study is somewhat unique. Increased nutrient content of foliar regrowth following burning (Johnston and Elliot, 1998; Skre et al., 1998) or mechanical treatment (Everitt, 1983; Ruthven and Hellgren, 1995) has been reported in other woody plant communities. Such changes are often characterized by increased protein and secondary compound content of foliage (Fulbright, 1997). The lack of nutrient response in our study may be because our samples were collected in the second growing season following burning, when re-sprouts were more mature. Our data also indicate that burning does not induce an increase in phenolic content of catkins or buds, which could decrease the quality of these plant parts as a wildlife forage.

The negative responses of some animal species (Dollahite et al., 1962; Kingsbury, 1965; Buchsbaum et al., 1984) to consumption of shinnery oak buds and catkins may be expected, considering the high concentration of phenolics. Phenolic content of shinnery oak buds and catkins in our study was greater than that reported by Martin and Martin (1982) for mature leaves of 6 other oak species (10 to 15% of dry weight). The nutritional quality (e.g., crude protein range = 18 to 24%) of buds and catkins is high, aside from phenolic levels, and helps explain forage selection for these parts of shinnery oak by cattle (Dollahite, 1961; Allison, 1994) and lesser prairie chickens (Davis et al., 1980; Doerr and Guthery, 1983). The high crude protein and low ADF content may help balance potential negative effects of phenolics on animals using shinnery oak. In Scotland, heather (*Calluna vulgaris*) was strongly selected by red grouse (*Lagopus lagopus scoticus*) despite its high tannin content (Moss, 1972). Gauthier and Bedard (1990) considered protein to be a stronger factor in food selection than phenolics. The degree to which protein and tannin content influence diet selection may be affected by a variety of factors including the ability of an animal to detoxify phenolic compounds, its protein balance, and its physiological state (e.g., reproductive versus non-reproductive; Provenza, 1995). Consumption of shinnery oak buds and catkins by lesser prairie chickens coincides temporally with the nesting period, a physiological stage requiring high protein intake to meet reproductive demands.

Effects of shinnery oak phenolics on lesser prairie chickens are unknown. The response of other gallinaceous birds to tannins has been studied and may be indicative of consequences for lesser prairie chickens. Growth rates of Japanese quail (*Coturnix coturnix japonica*) were reduced 14 and 6% by substituting 6% tannin feed for 0.02% tannin feed in diets with 23 and 25% crude protein, respectively (Garwood and Rogler, 1987). Leghorn laying hens lost 39% more weight on diets with 6% tannin than those on 0.03% tannin diets (Sell et al., 1983). Egg production and eggshell thickness were also reduced with the high-tannin diet, but increased dietary protein reduced effects of the tannins. Armstrong et al. (1974) found effects of condensed tannins to be greatest when protein levels were sub-optimal. Weight gains of domesticated turkeys less than 8 weeks old decreased with increasing tannin levels, but older turkeys were unaffected by tannin levels up to about 2% (Douglas et al., 1993). This suggests some birds are either capable of adapting to phenolics, or the gut of a mature bird is better able to deal with the compounds.

In summary, we found that catkins and buds of shinnery oak are high in crude protein and phenolic content, and relatively low in fiber, and catkins have less ADF than buds. Oak buds exposed to cattle browsing were higher in phenolics than those in ungrazed areas. Management implications of this finding are unclear. Although increased phenolic content has the potential to deter consumption and induce maliase, it is not known whether the difference in phenolic content between grazed and ungrazed buds is of sufficient magnitude to alter patterns of consumption or physiological response. Burning did not induce biologically significant alterations of nutritional quality of catkins or buds. Prescribed burning is used as a management tool to both temporarily reduce shinnery oak dominance and increase availability of grasses palatable to grazing livestock. Our data indicate that the use of prescribed fire in management will have little or no impact on nutrient content of catkins or buds.

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