Nutritive Value of Tree Leaves in the Kansas Flint Hills

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Abstract

Leaves from bur oak (*Quercus macrocarpa* Michx.), a bur oak hybrid (bur oak$_H$), red elm (*Ulmus rubra* Muhl.), Osage orange (*Maclura ponifera* (Raf.) Schneid.), and cottonwood (*Populus deltoides* Marsh.) were analyzed for crude protein, in vitro dry matter digestibility (IVDMD), and tannic acid equivalents (TAE) from mid September through late October during 1979 and 1980. Samples were taken biweekly from the trees and from the ground after leaf fall. Cottonwood was significantly lower over the season in crude protein than all other species except bur oak. Crude protein content declined with advancing season in all species although not significantly. Leaves on the trees were considerably higher in crude protein than True Prairie understory vegetation or leaves on the ground although leaves on the ground had equal or greater crude protein levels than True Prairie understory vegetation. Sample date and species significantly affected digestiblity. Digestiblity generally increased during middle sample periods and returned to initial levels in late October. Averages over all dates showed digestibility of Osage orange > cottonwood > red elm > bur oak$_H$ > bur oak. Leaves on the tree were generally more highly digestible than those on the ground. Red elm, Osage orange and cottonwood leaves on the tree were more digestible than True Prairie understory vegetation. Osage orange and cottonwood leaves on the ground were more digestible than True Prairie understory vegetation. Tannic acid equivalents of bur oak$_H$ = bur oak > red elm and cottonwood > Osage orange. Tannic acid equivalents generally increased during the middle sample periods and returned to initial levels in late October. There were no TAE differences between leaves on the trees and those on the ground. Overall quality ranking based on the constituents measured showed Osage orange and red elm to be the highest quality leaves of the group, bur oak poorest, and cottonwood and bur oak$_H$ intermediate. On the basis of these limited tests, Osage orange and red elm would provide the best roughage source in times of severe drought or as a roughage substitute in cattle finishing rations.

Tree products such as aspen sawdust (Mellenberger et al. 1971), aspen bark silage (Hanke et al. 1978), oak sawdust (El-Sabban et al. 1971), and poplar bark (Enzman et al. 1968) have been investigated as ruminant feed sources. Methods of determining and modifying their digestibility have also been studied (Mellenberger et al. 1969, Millet et al. 1970).

The use of tree products for ruminant feed has been focused on residues probably because industry and researchers are concerned with finding a use for the waste and a cheap roughage source at the same time.

Leaves might also be considered a tree residue. In True Prairie areas such as the Kansas Flint Hills, the tons of tree leaves that fall to the ground each autumn are largely ignored by producers as a ruminant roughage source.

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We have observed cattle grazing Flint Hills rangeland in the fall selecting tree leaves from the ground almost to the exclusion of the herbaceous or understory vegetation traditionally thought of as ruminant forage. Esophageal samples from steers at these times are noted to be composed largely of tree leaves. Past studies indicate that some tree leaves are nutritionally desirable for their crude protein (Bissell and Strong 1955, Hagan 1953, Hilgard 1903, Oldemeyer et al. 1977, McHargue and Roy 1932, McLeod 1973, Sampson and Samisch 1935, Tarrant 1950, Tew 1970), digestibility (Bissell and Weir 1957, Joshi and Ludri 1966, McLeod 1973, Mia et al. 1960, Oldemeyer et al. 1977, Sampson and Samisch 1935, Wilson 1977), and intake (Joshi and Ludri 1966, Mia et al. 1960, Wilson 1977).

In an effort to explain livestock preference for tree leaves and to compare leaf quality of different trees, we determined crude protein, in vitro dry matter digestibility, and tannic acid equivalents of tree leaves commonly found in the Flint Hills area.

Study Site and Methods

The study area is near Manhattan on the Kansas State University pastures in the northern Flint Hills. Botanical census of the area shows it to be typical True Prairie with big bluestem *(Andropogon gerardi Vitman)* and indiangrass [*Sorghastrum nutans* (L.) Nash] comprising over 50% of the total vegetation. Numerous other warm-season grasses, forbs, and woody species constitute the remainder. Groves of deciduous trees fill the loamy lowlands between the hills.

Leaf samples were collected from bur oak (*Quercus macrocarpa* Michx.), red elm (*Ulmus rubra* Muhl.), Osage orange (*Maclura ponifera* (Raf.) Schneid.), and cottonwood (*Populus deltoides* Marsh.) at biweekly intervals from mid September to late October in 1979 and 1980. Samples were also collected from trees originally thought to be white oak (*Quercus alba* L.) but later determined to be a bur oak hybrid (bur oak$_H$). We chose these late dates because this is the time when leaves would most likely be harvested for forage or found on the ground and consumed by cattle. Samples were selected randomly from many locations on the tree and combined. Two or more trees were sampled from each species except for Osage orange and cottonwood, where only one tree of each was sampled. Leaf samples from each species were collected from the ground (if present) directly below the sampled trees at the same time trees were sampled. The length of time they may have been on the ground was not known, although they were current year's leaves. After collection, all leaves were dried in a forced-air dryer (60° C), ground through a 1-mm mesh screen, and stored in sealed containers for analyses.

Micro-kjeldahl nitrogen (N) was determined colorimetrically and crude protein estimated by N $\times$ 6.25. In vitro matter disappearance (IVDMD) was determined via the NC-64 two-stage direct acidification method (Marten and Barnes 1980). Tannic acid equivalents (TAE) were determined by the Folin-Denis method (Burns 1963) using a 4-hour extraction period and are reported on a dry matter basis. Experimental design was completely randomized. Data were analyzed by analysis of variance. Crude protein, IVDMD and TAE least squares means were separated at $P < .05$.

Table 1. Two-year (1979-1980) mean crude protein percentages of bur oak, cottonwood, elm, and Osage orange leaves harvested from trees in the Kansas Flint Hills.[1]

Species	Mid Sept.	Early Oct.	Mid Oct.	Late Oct.	Species Mean
Bur Oak-H	10.9 Aa	11.0 Aa	8.1 Aa	7.9 Aa	9.5 A
Bur Oak	10.3 Aa	9.5 Aa	9.0 Aa	6.3 Aa	8.8 AB
Cottonwood	9.8 Aa	8.7 Aa	6.2 Aa	4.9 Aa	7.4 B
Elm	11.3 Aa	10.3 Aa	9.4 Aa	8.8 Aa	9.9 A
Osage orange	11.0 Aa	11.6 Aa	10.0 Aa	9.1 Aa	10.4 A
Date means	10.6 a	10.2 a	8.5 ab	7.4 b	

[1]Inner table least squares means are separated at $P<0.05$. Means within individual columns for dates followed by similar upper case letters and within individual rows followed by similar lower case letters are not significantly different ($P<0.05$).

Youdens' method (1967) was used to rank the trees for forage quality.

Results and Discussions

Crude Protein Content

Overall mean leaf crude protein in our study declined (Table 1) with time. Others (Bissell and Strong 1955, Hagan 1953, Tew 1970) have reported declining protein levels; however, McLeod (1973) showed a significant seasonal effect in only 1 species of 7 in Australia. Withdrawal of protein from leaves to the branches shortly before leaf abscission may explain the leaf protein decline.

Leaves on the tree compare favorably in crude protein content with Flint Hills True Prairie vegetation. Understory vegetation samples taken over the same 2-year period averaged 4.7, 3.9, and 2.5% crude protein during mid September, early October, and late October, respectively (Forwood 1982). That is considerably lower than the 2-year intact leaf average over all tree species of 10.6, 10.2, and 7.4% crude protein for similar dates (Table 1). That cattle may select recently fallen tree leaves over True Prairie understory vegetation is not surprising as protein content of the latter often falls below the subsistence level required by cattle about mid-July (Rao et al. 1973). The crude protein content of fallen tree leaves (Fig. 1) remains practically the same if not greater (3.7%) than understory vegetation in early or late October (3.9 and 2.5%, respectively). We found fallen leaves to contain significantly lower crude protein than leaves on the tree (Fig. 1). Sampson and Samisch (1935) reported similar results.

Digestiblity

Significant differences were found among main effects for date and species (Table 2). Means over all species show the first and last sample dates were not different, although digestibility increased during the 2 intermediate sample dates. A similar trend has been documented in other trees and, like our study, some species show no differences between sample date (McLeod 1973).

Means over all dates showed significant differences in the digestibility of the species studied (Table 2). The range of species means over all dates in our study was between 42.6 to 73.1%. Others have shown digestibility of tree foliage in the 40–60% range (Oldemeyer et al. 1977, Joshi and Ludri 1966, Mia et al. 1960, Wilson 1977). Of

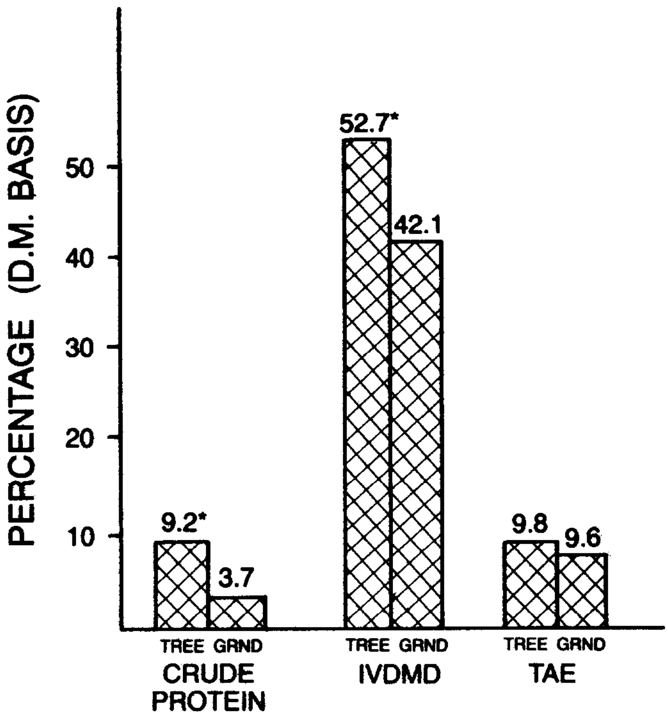

Fig. 1. *Crude protein, in vitro dry matter disappearance (IVDMD) and tannic acid equivalents (TAE) of leaves from 5 Flint Hills tree species sampled while on the tree and after leaf fall. Values are averages from 2 years (1979–80) over all species and dates. Significant differences (P<.05) between leaves on trees or on ground for a quality parameter are indicated by an asterisk.*

Table 2. Two-year (1979-1980) mean in vitro dry matter digestibility percentages of bur oak, cottonwood, elm, and Osage orange leaves harvested from trees in the Kansas Flint Hills.[1]

Species	Mid Sept.	Early Oct.	Mid Oct.	Late Oct.	Species Mean
Bur Oak-H	40.3 Da	46.5 Da	44.3 Ca	39.5 Ca	42.6 A
Bur Oak	36.1 Ea	39.3 Da	38.6 Da	33.9 Ca	36.9 B
Cottonwood	57.7 Ba	63.0 Ba	62.8 Ba	57.0 Ba	60.1 E
Elm	48.2 Ca	53.8 Ca	50.7 Ca	49.8 Ba	50.6 C
Osage orange	72.0 Aa	75.0 Aa	74.5 Aa	70.9 Aa	73.1 D
Date means	50.8 a	55.5 b	54.2 b	50.2 a	

[1]Inner table least squares means are separated at $P<0.05$. Means within individual columns for dates followed by similar upper case letters and within individual rows followed by similar lower case letters are not significantly different ($P<0.05$).

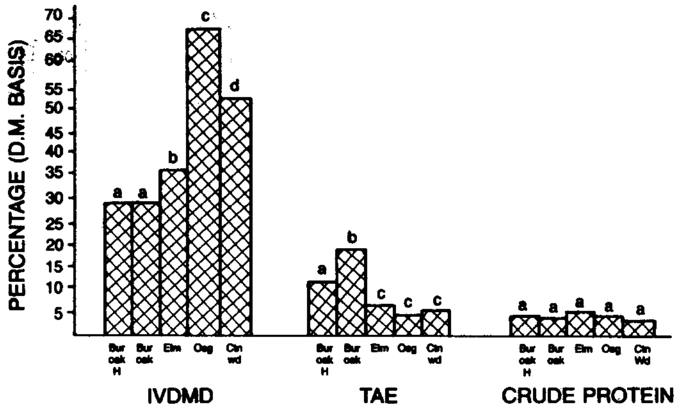

Fig. 2. *In vitro dry matter disappearance (IVDMD), tannic acid equivalent (TAE), and crude protein from bur oak, elm, Osage orange, and cottonwood leaves after leaf fall in the Kansas Flint Hills. Values are averages from 2 years (1979–80) over all dates. Bars with common letters are not significantly different (P<.05).*

the species we studied, 60% were above 50% digestibility (Table 2). McLeod (1973) stated 68% of the species he studied were below 50% digestibility while all species sampled by Oldemeyer et al. (1977) after July were below 43%. Differences in digestiblity between the oak species and others may be explained by high TAE levels in the oaks and known inhibition of cellulolytic and pectinolytic enzymes by tannins (Bell et al. 1965).

Fallen leaves were significantly less digestible (42.1%) than those on the tree (52.7%) (Fig. 1).

Digestiblity of understory prairie vegetation is 42.0 and 39.0% during September and October (Rao et al. 1973) making elm, Osage orange, and cottonwood leaves still on the tree (Table 2) and Osage orange and cottonwood leaves on the ground (Fig. 2) considerably more digestible than understory vegetation. The rate at which their digestiblity declines is unknown, but it does not appear to be extremely rapid.

Tannins

Comparison of the lowest average oak TAE level was 8.8 percentage points above the greatest average TAE level of non-oak species (Table 3).

Hilgards' (1903) study of 6 California oak species showed tannins to be about 10% during fall and winter. Samples of sand shin oak *(Quercus havardii)* show tannin levels of 7.7 and 4.2% in August and October, respectively (Pigeon et al. 1962).

Leaves on the trees did not differ from fallen leaves in TAE content. This may be due, in part, to the location of tannins within the plant. Several theories are that tannins reside (1) in vacuoles and are released only by breaking cell walls or membranes (Barnes and Gustine 1973), (2) in vesicles inside organelles within the the cytoplasm (Swain 1965), and (3) in larger cells surrounded by insoluble sacs (Thatcher 1921). Any of the above combined with the inhibition of cellulolytic and pectinolytic enzymes by tannins (Bell et al. 1965) may explain the similarity in TAE between fallen and unfallen leaves.

Nutritive Value of Fallen Leaves

Over the 2-year study period, species differences in IVDMD and TAE but not crude protein were apparent in leaves on the ground (Fig. 2). Leaves from these trees showed high digestibility values associated with low TAE levels. Donnelly and Anthony (1969) reported similar results with sericea lespedeza.

Determining which of the tree leaves studied would be the better forage is probably not possible. However, using the method of Youden (1967), we ranked the trees from best (rank 5) to worst (rank 1) for each date. The totals for each tree species in each analysis were added and a rank assigned (Table 4).

Table 4. Point totals and forage quality ranking of leaves by Youden's method of 5 tree species found in the Kansas Flint Hills based on crude protein, in vitro dry matter digestion and tannic acid equivalents.[1]

Tree species	Point total	Forage quality ranking
Osage	59**	1
Elm	41**	2
Cottonwood	35	3
Bur Oak-H	27	4
Bur Oak	18*	5

[1]Youden's method specifies that for this number of tests and species, species with point totals over 40 or under 20 are significantly superior and inferior, respectively, at the 5% level.
*Inferior forage quality.
**Superior forage quality.

Osage orange clearly had highest quality forage in the group. Based on the analyses, Osage orange accumulated 59 of 60 possible ranking points. Although cottonwood ranked highly in IVDMD and TAE analyses, its low crude protein level resulted in a mediocre final quality ranking. Bur oak received the poorest quality ranking due to low digestibility and high TAE levels. Interestingly, the bur oak$_H$ ranked significantly higher in forage quality than bur oak.

Browse eaten sparingly in feeding trials is sometimes observed to be eaten readily in the field (Wilson 1977). Single species are rarely eaten in the field as opposed to tests conducted in feeding or laboratory trials. In addition, components resulting in enhancement or inhibition of digestion may be accentuated in a single species test. Generally, however, leaves from these Flint Hills trees and from other areas are grazed by livestock in the presence of other available forages. This study indicates that leaves from these trees contain desirable quality components and at times may be of higher quality than True Prairie understory vegetation. Nutritional value of tree leaves is useful not only to those interested in browse for wildlife but also when severe drought conditions or

Table 3. Two-year (1979-1980) mean tannic acid equivalent percentages of bur oak, cottonwood, elm, and Osage orange leaves harvested from trees in the Kansas Flint Hills.[1]

Species	Mid Sept.	Early Oct.	Mid Oct.	Late Oct.	Species Mean
Bur Oak-H	15.5 Aa	16.1 Ba	14.5 Aa	15.1 Aa	15.3 A
Bur Oak	16.6 Aab	19.3 Aa	16.1 Ab	14.4 Ab	16.6 A
Cottonwood	4.9 BCa	6.6 Ca	6.1 Ba	6.5 Ba	6.0 B
Elm	6.6 Ba	6.9 Ca	6.9 Ba	5.5 Ba	6.5 B
Osage orange	3.6 Ca	5.4 Ca	5.7 Ba	3.9 Ba	4.6 C
Date means	9.4 b	10.8 a	9.9 ab	9.1 b	

[1]Inner table least squares means are separated at $P<0.05$. Means within individual columns for dates followed by similar upper case letters and within individual rows followed by similar lower case letters are not significantly different ($P<0.05$).

other factors warrant additional roughage supplies, a roughage substitute in finishing rations is needed, or for the general information of producers or researchers who observe livestock ingesting considerable amounts of tree leaves.

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