Nutrient Removal Rates from Ruminoreticula of Cattle Grazing Kansas Flint Hills Range

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Abstract

A Hereford steer and heifer were used to compare rumen removal rates of forage nutrients from Kansas Flint Hills range over a 2-year period. Rumens were emptied after an overnight fast and the contents sampled, weighed, and returned to the rumen. The cattle were then fed a known amount of range forage and fasted for 12 hours, at which time the rumen evacuation procedure was repeated. Removal rate calculations were based on change in rumen contents during the 12-hour fast. All nutrients studied passed the rumen more rapidly during spring and summer months than fall and winter months. Fibrous fractions were removed more rapidly than cell solubles and crude protein, which may indicate that optimum utilization of native Flint Hills range forage is not being achieved. Methods which increase microbial attack of plant cell wall contents may significantly improve livestock production on native rangeland.

Nutrient removal rate is the rate at which nutrients are removed from the ruminoreticulum due to digestion, absorption, and passage of undigested residues to the omasum (Yadava and Bartley 1964). Alfalfa diets have shown more rapid removal of soluble than fibrous fractions (Kick and Gerlaugh 1935, Silver et al. 1935, Burroughs et al. 1946, Hale et al. 1947, Radisson 1955, Yadava and Bartley 1964). Krzywanek and Quitteck (1936) (pasture grass and clover); Hamilton et al. (1955) (grass mixture); Stallcup et al. (1956) (clover silage and grass hay); and Jacques (1981) (native range forage) show slower removal of soluble than fibrous fractions.

Objectives of the present study were to determine rumen removal rates of nutrient fractions as range forage quality changed and to compare removal rates among those fractions.

Study Area and Methods

The study area was 5 km northwest of Manhattan, Kans. Vegetation was largely *Andropogon gerardi* (big bluestem), *Sorghastrum nutans* (indiangrass), and *Andropogon scoparius* (little bluestem).

Experimental animals were a ruminally fistulated Hereford steer and heifer 2 to 3 years of age grazing Flint Hills range from May, 1979, to August, 1981. Winter supplementation, when necessary, ceased 10 to 14 days prior to the sample date.

Samples were taken biweekly from May through October and monthly from November through April. Cattle were penned and fasted overnight with water prior to the sample day. The following morning total contents of the rumen were removed as described by Yadava and Bartley (1964). Digesta was placed in a large tub, mixed thoroughly by hand for 3 to 5 minutes, quickly sampled with a 600-ml, 12-cm diameter container and weighed. Digesta was then returned to the rumen.

This method was employed because its successful use at Kansas State University and other institutions and its acceptance in a variety of scientific journals supports its validity for measuring the parameters of interest (Reid 1965).

Forage offered to the cattle was cut with a sickle-bar mower either on the sample morning or the evening before. When cut the evening before, it was refrigerated overnight. Cattle were offered a known amount of forage for 1 hour or until they ceased eating. Refused forage was collected, weighed, sampled for water loss and subtracted from the total amount offered. After feeding, the cattle were fasted with access to water for 12 hours. Then their rumens were emptied, and the contents mixed, weighed, and sampled. Rumen and "forage-fed" samples were weighed, dried in a forced-air oven at 38°C, and weighed again to determine dry matter (DM). They were ground through a Wiley mill (1-mm screen) and cell solubles (CS), cell walls (CW), cellulose (C), and hemicellulose (HC) were determined (Goering and Van Soest 1970). Micro-kjeldahl nitrogen (N) was measured colorimetrically and crude protein (CP) estimated by $N \times 6.25$. We used a randomized complete block type of design with animals as replications. Data were analyzed by analysis of variance with time as treatments. Means were separated using Duncan's new multiple range test ($P<.05$, Duncan, 1955).

Results and Discussion

Forage Fed Characteristics

Greater CP and CS percentages and lower CW, C, and DM percentages were observed during periods of traditionally high forage quality. Crude protein and CS decreased and CW and C increased with maturity. Hemicellulose content varied little with maturity. Our forage quality observations support quality aspects of harvest recommendations for Flint Hills native hay (Launchbaugh and Owensby 1978) which state the best quantity-quality relationship came from mid-July harvesting.

Soluble Fraction Removal among Dates

Removal of soluble fractions (CS, CP) was more rapid ($P<.05$) during periods of high forage quality than low quality periods. Cell soluble removal rates (Fig. 1) represent that phenomenon. Slowest removal rates often occurred during the latter portion of the dormant period. That may have been due to advanced weathering of standing forage and absence of cool-season selection in harvested forage fed to cattle.

Fibrous Fraction Removal among Dates

Removal rates of CW showed the same trend of more rapid removal ($P<.05$) during higher quality periods than low quality periods (Fig. 2). Figures (not shown) for DM, C and HC are similar to that for CW.

Increases in forage fibrous fractions (Allinson 1971, Wilkins 1972) and decreases in soluble fractions (Terry and Tiley 1964, Akin et al. 1977) are linked to decreases in digestibility (Connor et al. 1963, Allison 1971, Duble et al. 1971). Since greater digestibility results in increased intake and rate of passage (Blaxter et al. 1956, 1961) and reduced rumen retention time (Balch and Campling

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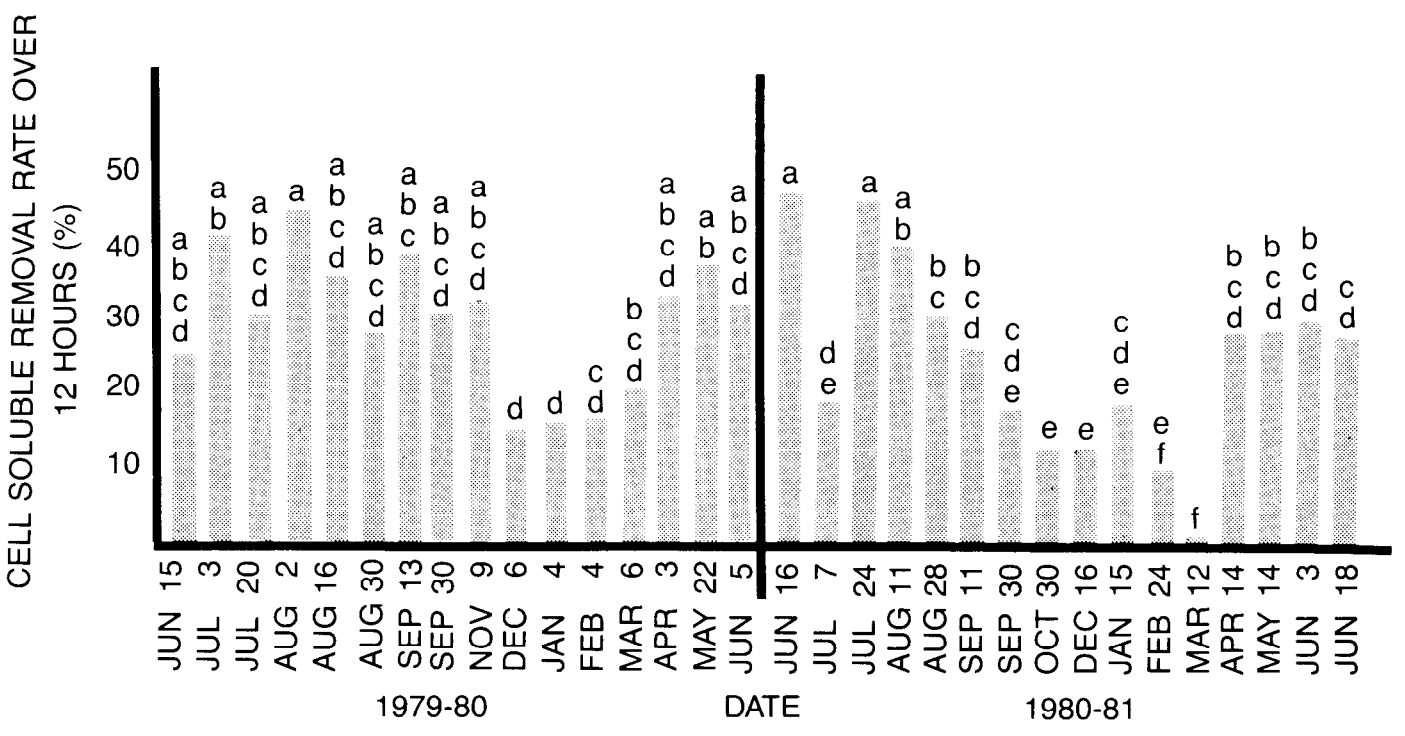

Fig. 1. *Mean percentage cell soluble removal rate over 12 hours from rumen of cattle grazing Flint Hills rangeland. Dates with common letters are not significantly different (P<.05).*

1965), nutrient removal rates from ruminoreticula were more rapid during periods of high range forage quality. Flint Hills studies (Smith and Owensby 1978) showing lower average daily gain (ADG) for July 15 through October 30 than for May 1 through July 14 demonstrate the animal response to forage maturity and removal rate differences. Forage maturity and rates of removal are major reasons why the intensive early stocking system has shown improved ADG and gains per acre compared to a season-long stocking on Kansas Flint Hills rangeland.

Comparison of Removal Rates among Fractions

Subtracting the percentage removal of the fiberous fractions from soluble fractions, both study years showed faster removal of DM, CW, C, and HC than CP and CS. Figures for all comparisons are not shown, but the CW-CS comparison (Fig. 3) is representa-

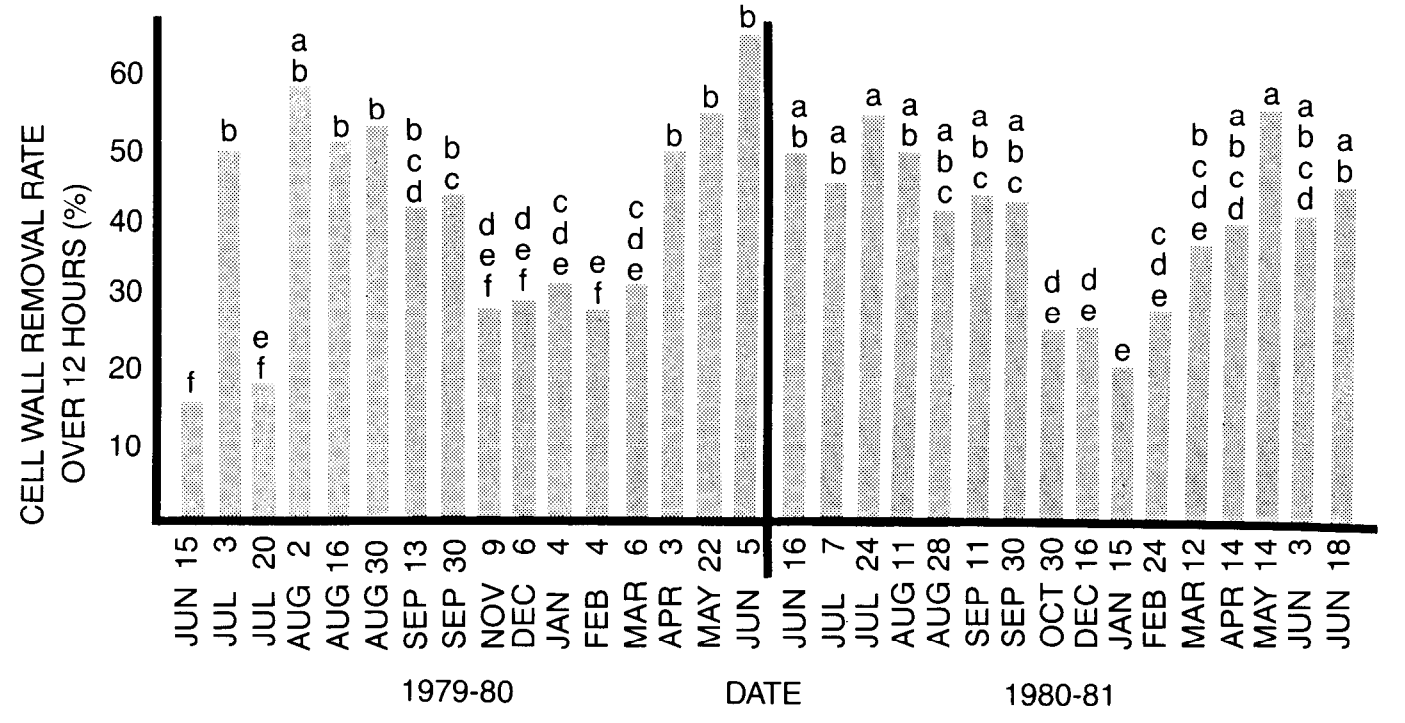

Fig. 2. *Mean percentage of cell wall removal rate over 12 hours from rumens of cattle grazing Flint Hills rangeland. Dates with common letters are not significantly different (P<.05).*

Table 1. Kansas Flint Hills harvested range forage composition (% dry matter) fed to cattle and cattle rumen ingesta composition after 12-hours digestion.

	Crude protein		Cell solubles		Cell walls		Cellulose		Hemicellulose	
	diet	rumen	eiet	rumen	diet	rumen	diet	rumen	diet	rumen
					Year 1 (1979–80)					
					(%)					
Growing season	5.64	15.0	29.3	40.8	71.2	59.2	31.8	17.6	28.4	19.8
SE	±1.22	±0.68	±5.63	± 4.44	±5.25	±3.45	±5.20	±6.95	±1.94	±6.94
(June - Oct)										
(Apr - June)										
Dormant season	2.06	8.7	18.0	31.0	82.3	63.7	41.7	28.3	27.4	21.9
SE	±1.41	±0.83	±6.50	±5.44	±6.43	±4.22	±6.00	±7.87	±2.19	±7.87
(Nov - Mar)										
					Year 2 (1980–81)					
Growing season	5.78	12.3	27.9	38.9	72.1	60.8	32.9	19.3	29.9	22.4
SE	±1.08	±0.73	±4.93	±3.61	±4.68	±3.61	±1.38	±4.26	±4.47	±1.45
(June - Oct)										
(Apr - June)										
Dormant season	3.1	7.03	21.6	30.0	78.4	70.0	39.3	26.7	26.7	21.1
SE	±1.52	±0.90	±6.6	±4.42	±5.59	±4.42	±1.69	±4.83	±4.78	±1.65
(Nov - Mar)										

tive of the others. Average percentages of fibrous fractions were lower and CP and CS percentages higher in ruminoreticula 12 hours post feeding than in harvested forage fed (Table 1) indicating faster removal of fibrous and slower removal of CP and CS fractions.

Past work showed more rapid removal rates of soluble fractions such as CP and nitrogen-free extract (NFE) compared to fibrous fractions (Burroughs et al. 1946, Radisson 1955, Yadava and Bartley 1964) and 12-hour post-feeding rumen contents higher in crude fiber (CF) and lower in CP and NFE than that of the feed (Silver et al. 1935, Kick and Gerlaugh 1935, Hale et al. 1947, Yadava and Bartley 1964). Work using ^{14}C revealed a removal sequence (fastest to slowest) of soluble sugar, pectin, protein, lipid, cellulose, hemicellulose, and lignin (Alexander et al. 1969). The authors mentioned above fed alfalfa hay with the exception of Radisson (1955), who fed a brome and alfalfa hay mix with grain (2:1).

Hamilton et al. (1955) fed a grass hay (largely timothy) plus a mixed grass and clover silage while Krzywanek and Quittex (1936) fed an unknown pasture grass and clover hay. Both studies showed increased rumen CP and CF percentages compared to the feed as digestion progressed over 12 hours. Stallcup et al. (1956) compared nutrient removal rates of sericea lespedeza *(Lespedeza cuneata),* 3 Korean lespedezas, and upland prairie hay. Upland prairie hay and most of the lespedezas had faster removal rates of DM and C than CP. Jacques (1981), feeding Kansas Flint Hills range forage, showed faster removal over 12 hours of HC and C than CS. French's (1957) review of tropical grass nutritional value reveals quite a number of in vivo digestibility studies confirming the higher digestibility of crude fiber than nitrogen free extract and protein in tropical species.

Differences in the sequence of removal of fractions from the rumen in our study compared with previous studies may be due to species microanatomical differences in leaf tissue undergoing microbial attack and leaf structures inhibiting attack. Comparison of tropical and temperate grasses show differences in microanatomy to affect digestion. More rigid parenchymal bundle sheaths and their slower digestion in tropical grasses, a greater percentage and more rapid degradation of easily digested mesophyll and phloem in temperate species, and a greater percentage of slowly digested tissues in tropical species have been reported (Akin and Burdick 1975, Hanna et al. 1973). Our study indicates that in Kansas tropical grasses, large amounts of CW constituents may have to be degraded first before fractions such as CP and CS can be digested.

Alfalfa leaf and stem cuticle, digestive inhibitors, are rapidly sloughed (Monson and Burton 1972, Monson et al. 1972) increasing exposure of more rapidly degradable material to microbial attack (Brazle and Harbers 1977) whereas tropical species such as big bluestem show cuticular layers, spongy mesophyll and vascular tissue remaining after 72 hours exposure time to rumen microorganisms (Brazle et al. 1979). Legume cell walls are more highly lignified and less digestible but are digested more rapidly than grass CW (Smith et al. 1972), which indicates faster microbial leaf entry and tissue degradation. Large intercellular leaf spaces and thin epidermal cuticle found in legumes likely explain the apparent anomaly.

Jacques (1981) explained faster removal of C and HC than CS as the result of inadequate protein levels in Kansas Flint Hills prairie hay fed to cattle. She suspected this resulted in decreasing rates of energy digestibility followed by lower intake and rate of passage. Low protein content plus the inaccessibility of protein due to warm-season internal leaf structure may interact to effectively lower performance on native grasslands.

Conclusions

This study indicates optimum utilization of native Flint Hills range forage is not being achieved. Methods of improving utilization such as proper season of use (early intensive grazing) or forage manipulation methods which would expose plant cell contents to rumen microbial attack may significantly improve livestock productivity on Kansas Flint Hills range.

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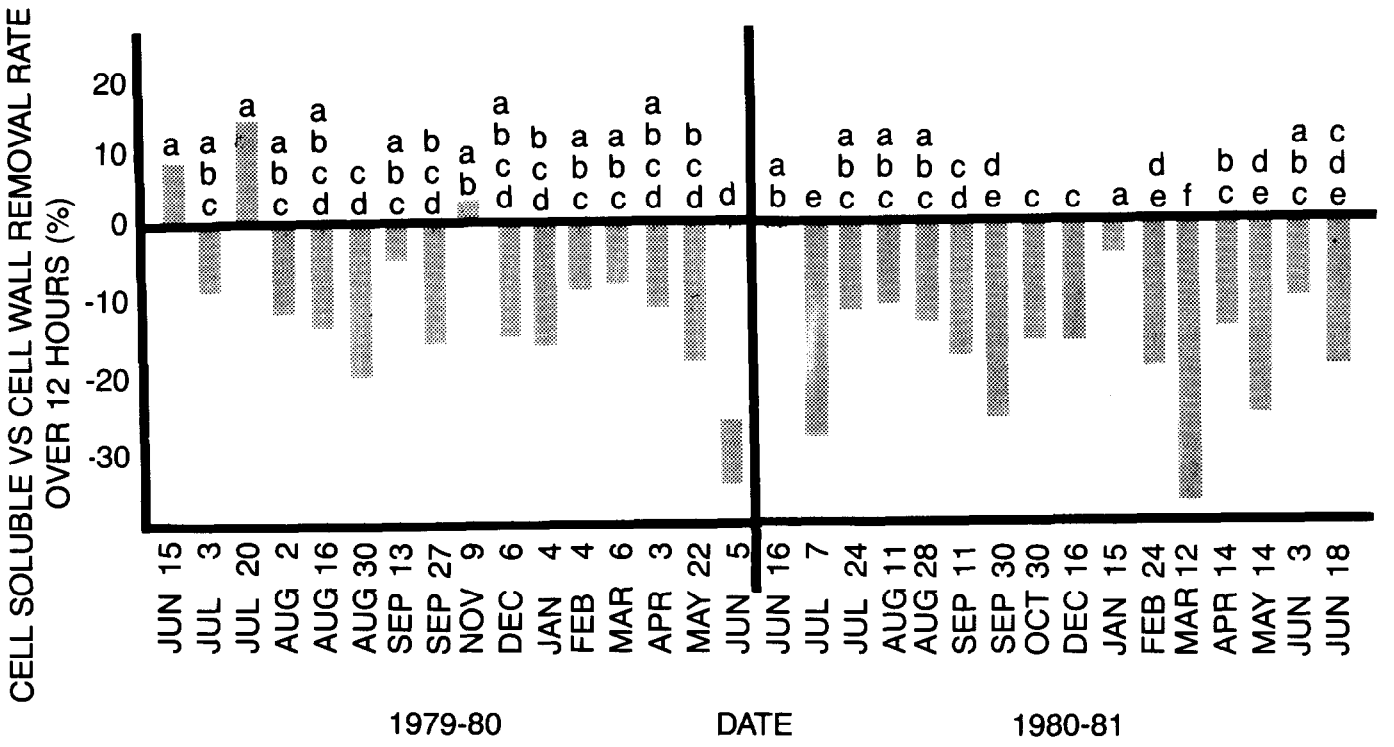

Fig. 3. *Mean percentage cell soluble vs. cell wall removal over 12 hours from rumens of cattle grazing Flint Hills rangeland. Negative values indicate more rapid removal of the latter of the two components. Dates with common letters are not significantly different (P<.05).*

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