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EFFECT OF MEADOW HAY QUALITY ON VOLUNTARY INTAKE, RATE OF PASSAGE AND RATE OF STRUCTURAL DEGRADATION IN GROWING CATTLE

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EFFECT OF MEADOW HAY QUALITY ON VOLUNTARY INTAKE, RATE OF PASSAGE AND RATE OF STRUCTURAL DEGRADATION IN GROWING CATTLE

By

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TITLE

Effect of meadow hay quality on voluntary intake, rate of passage and rate of structural degradation in growing cattle

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EFFECT OF MEADOW HAY QUALITY ON VOLUNTARY INTAKE, RATE OF PASSAGE AND RATE OF STRUCTURAL DEGRADATION IN GROWING CATTLE

Michael A. Worrell, Ph.D.

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Advisor: Donald C. Clanton

Initial growth of a mixed of cool- and warm-season species was harvested as hay at three times during the growing season from a subirrigated Nebraska Sandhills meadow. The hay was fed ad libitum to rumen fistulated steers for evaluation of: (1) voluntary intake; (2) rate of passage, retention time and ruminal pool sizes of different size particles estimated by fecal excretion of ruminally administered markers; (3) rates of particle degradation and passage estimated by rumen concentrations of ruminally administered markers and (4) in vitro analysis of hay nutrient content and digestibility.

Forage quality estimated by digestible organic matter intake decreased ($P<.01$) from hay 1 to hay 2 or 3. Average daily gain (ADG) was highest ($P<.04$) for steers fed hay 1, there were no differences ($P>.1$) for the later two harvests. Rate of passage estimated by fecal excretion decreased ($P<.10$) with increasing forage maturity. Passage rates estimated by a two compartmental fecal model were numerically lower than those estimated by a one compartmental model but were numerically higher than those estimated by a peak decay model. Pool sizes of the three particle size groups increased ($P<.09$) from hay 1 to 3. Pool sizes estimated by a one compartmental fecal model tended

to be larger than the same pools estimated by a two compartmental model. Retention times were less ($P<.03$) for hay 1 than for hay 2 or 3. Retention times estimated by a two compartmental model were approximately 50% longer than those estimated by a one compartmental model.

A three pool rumen model was used for the estimation of particle degradation and passage from the rumen. There were no differences ($P>.10$) in particle disappearance from either the 1680 or the 1680/850 particle pools for the three hays. However, hay 2 had faster ($P<.006$) rate of degradation from the 1680 to the 1680/850 particle pools and slower ($P<.05$) rate of degradation from the 1680/850 to the 850 particle pools than the other hays. Rate of passage from the 850 particle pool decreased ($P<.002$) from hay 1 to 3. Rate of passage for the 1680/850 particles was lowest ($P<.006$) for hay 3.

The model used for the estimation of particle degradation and passage appears to have merit, however, further refinement by including the digestibility of the different particle fractions appears desirable.

To Becky -

For the sacrificies of the past
Let's take joy in the present
and together, the future will be ours

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EFFECT OF HARVEST DATE ON MEADOW HAY QUALITY.
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INTRODUCTION

Forages are the major source of feed for ruminant animals. Forage quality is ultimately expressed in animal performance when fed as the sole source of digestible nutrients. Animal performance obtained from feeding forages is a function of both the digestibility of the forage and the quantity of the forage consumed. Digestibility of forages can be estimated rapidly and with acceptable accuracy under laboratory conditions. However, forage intakes can only be determined by expensive feeding trials. At the present time, no single laboratory analysis or set of analyses can estimate voluntary intake with the necessary accuracy or precision for predicting animal performance. While much is known about factors influencing forage consumption, it is apparent that more information must be obtained concerning the interactions between the forage and animal before successful prediction becomes a reality. Presently, much effort is directed at physical attributes of forage, particularly rates of passage and forage particle degradation in vivo.

The objectives of this research were: (1) characterize the quality of grass hay harvested at different times during the growing season and; (2) develope a dynamic rumen model to estimate the structural degradation and passage of different size forage particles as related to voluntary intake in growing cattle.

REVIEW OF THE LITERATURE

Forage quality has been defined as animal performance when the forage being measured is the sole source of digestible energy and protein, when fed to animals that have the potential for production (Moore and Mott, 1973). When determining forage quality, the quantity of forage should not be limited so that animal performance is affected only by the quality of the forage (Mott, 1959; Mott and Moore, 1969). Other expressions of forage quality include digestible energy intake (DEI), digestible dry matter intake (DDMI) and digestible organic matter intake (DOMI).

Expressions of forage quality are highly correlated with animal performance (Heaney, 1969). This is because of the combining of two separate but interrelated concepts -- nutritive value and voluntary intake of the forage by the animal. These two components of forage quality, nutritive value and voluntary intake, have been considered as separate parts of forage quality (McCullough, 1959; Reid et al., 1959; Crampton et al., 1960; Donefer et al., 1960; Reid, 1961; and Raymond, 1969), however, neither has meaning without the other when expressing quality.

Forage Nutritive Value

The major determents of forage nutritive value are chemical composition and digestibility. Nutritive value may be expressed as digestible organic matter (DOM), digestible dry matter (DDM), total digestible nutrients (TDN), or as digestible energy (DE).

Chemical Composition.

The traditional chemical components of feed included in the "proximate analysis" are crude protein (CP), ether extract (EE), crude fiber (CF), ash and nitrogen-free extract (NFE). Morrison (1976) cited Henneberg and Stohmann (1860) who developed the Weende system of analysis. They used a procedure of ether extraction followed by boiling in dilute acid and alkali to separate the less digestible components (CF) from the more digestible plant carbohydrates (NFE). However, this system of boiling in dilute acid and alkali not only removed the soluble carbohydrates but also some of the less digestible structural carbohydrates. As a result, many forages had higher CF digestibilities than NFE digestibilities (Crampton and Maynard, 1938; and Morrison, 1956).

Van Soest and Wine (1967) developed a separation technique using detergents to separate the a-carbohydrates, the highly digestible intracellular carbohydrates, from the b-carbohydrates, the structural carbohydrates with lower and more variable digestiblity. The intracellular carbohydrates which are extracted by refluxing in the neutral detergent solution contain either fructans (C3 plants) or starches (C4 plants) as the storage form of readily available energy for the plant. In addition to the a-carbohydrates, the neutral detergent solubles also contain much of the plant's pectin, lipids and protein. The residue after refluxing, neutral detergent fiber (NDF) has been shown to be comprised of the plant's structural carbohydrates; cellulose, hemicellulose and lignin (Van Soest and

Wine, 1967). The structural carbohydrates or the plant's cell walls provide support to the plant and its composition has a direct influence on the quality of the forage. The composition of cell walls can vary in two important ways: (1) a change in the total amount of structural compounds, or (2) a change in the composition of the structural elements (Jarrige, 1960; and Gaillard, 1962).

Digestibility

When referring to the digestibility of forages, two related aspects should be examined; the extent of digestion; and the rate of digestion.

Extent of Digestion. Digestibility is primarily influenced by forage characteristics and only to a slight extent by the animal. It has been long recognized that as forages mature their digestibility decreases (Kamstra et al., 1958; Dehority and Johnson, 1961; Dehority et al., 1962; Smith et al., 1972; Ventura et al., 1975; Abrams, 1980; and Moore et al., 1981). This decline in digestibility corresponds with increases in cell wall content and lignin (Ventura et al., 1975; and Hartadi, 1980).

The digestiblity of individual cell wall components has been measured. Minson (1971) reported a range of cellulose digestibilities from 49 to 88 percent. Tilley et al. (1969) found that the digestibility of cellulose decreased with advancing maturity. This decrease was attributed to increases in the indigestible cellulose fraction while the digestible cellulose fraction remained constant. Hemicellulose digestiblity has been found to vary similarly with that

of cellulose. Minson (1976) reported that lignin digestibility varied from -29 to +50 percent.

The main factor limiting the extent of cell wall digestion is lignin (Moore and Mott, 1973). There appears to be a close relationship between increasing lignification and decreasing digestibility of cellulose (Kamstra et al., 1958; and Tomlin et al., 1965). Duble et al. (1971) found a correlation (r = -.76) between acid detergent lignin and in vitro cell wall digestion for warm season grasses.

Adding isolated lignin to in vitro cultures appears to have no effect on cell wall digestibility. Evidence has accumulated that the inhibitory effect of lignin on cell wall digestibility can be attributed to chemical linkage of lignin subunits to the structural carbohydrates. Dehority and Johnson (1961) found increased in vitro cellulose digestibility after ball-milling temperate grasses. Wilkins and Minson (1970) reported increases ($P<.001$) in vitro digestibility of four grasses ground through a 0.5 mm screen compared to a 1 mm screen. Worrell (1982) reported increased NDF digestibilities of four particle size fractions of five tropical grasses harvested at different maturities when ground through two different size screens (4 mm vs 0.5 mm). This increased digestibility was more pronounced for later maturities which were higher in both cell wall content and lignin. These differences were attributed to increases in the disruption of the ligno-cellulose complexes by the physical treatment.

Rate of Digestion. Several studies using multiple sampling times

have determined digestion rate constants of forages. Gill et al. (1969) determined the rate constants for in vitro cellulose digestion of alfalfa to be from .078 to .102 fraction per hour. Smith et al. (1972) reported a range of values for cell wall digestion from .040 to .309 fraction per hour on samples representing 15 temperate grass and legume species.

Attempts to relate chemical composition to rate of digestion have been inconsistant. Van Soest (1965) suggested that rates of digestion could be predicted from ligno-cellulose ratios. Mertens (1977) reported no correlation between rate of digestion and the ligno-cellulose ratio. This dicrepancy can be attributed to morphological and anatomical differences in the forages studied. It is apparent that not all tissues are digested at the same rate (Akin, 1979; Brazle et al., 1979; Hanna et al., 1973, 1975; and Harbers et al., 1980). Mesophyll and phloem appear to be rapidily digested, epidermis and bundle sheaths more slowly digested, while xylem and sclerenchyma are essentially indigestible. This would suggest that morphological and anatomical differences would effect rate of digestion to a great extent. Poppi et al. (1981a) reported that leaves had faster rates of digestion than stems (.0408 vs .0305, fraction of potentially digestible per hour, $P<.05$) in several tropical grass species. In addition, Adkin and Burdick (1975) reported that C4 grasses had higher proportions of xylem and sclerenchyma and lower mesophyll than C3 grasses. This anatomical difference between the two grass groups can explain some of the differences in correlations between rates of

digestion and ligno-cellulose ratios.

Particle size of the forage can have a major effect on the rate of digestion. Decreasing forage particle size tends to increase the rate of fiber digestion in vitro (Dehority, 1961; Dehority and Johnson, 1961; Robles et al., 1980). These increases in rate of fiber digestion may be attributed to either of two mechanisms: (1) increases in forage particle surface area allowing for increases in microbial attachment; and(or) (2) increases in the disruption of the ligno-cellulose complexes allowing for more fiber digestibility.

Waldo et al. (1972) proposed a model for cellulose digestion in the rumen which has been used in many studies concerning fiber digestion kinetics. The model assumes that fiber digestion is a first-order process, meaning that the amount of fiber being digested at any given time is a constant proportion of the digestible fiber that is still available for digestion. The equation for describing the digestion kinetics of fiber can be written as:

$$R = I + De^{(-kdt)}$$

where; R = mass of fiber residue at any given time (t>0); I = mass of indigestible fiber; D = initial mass of digestible fiber; kd = digestion rate constant; and t = time.

Mertens (1977) reported a significant departure from linearity in the semilogarithmic transformation of the fiber digestion curves using different endpoints in the estimation of the potentially digestible

fiber pool. He attributed this to mean that there exists two potentially digestible fiber pools; a fast digesting , and a slow digesting pool. Additionally, Mertens (1977) reported that there was a definite interval between inocculation of forage samples and beginning of fiber digestion. This delay before digestion occured was termed 'lag time'. The lag effect, while real, is not very well understood. It is hypothesized that the lag could be a function of several competing interactions. First, the lag phenomena could be substrate-related in that hydration, chemical and(or) physical alterations of the fiber must occur before digestion can proceed, which suggests inaccessibility of the fiber for microbial association. Lag may also be due to lack of microbial attachment to the fiber or to be in close proximatity (Akin, 1979) with the fiber. This implies that either microbial numbers or enzymes may be limiting at the start of digestion. Finally, digestion lag may be a result of preferential digestion, suggesting that soluble carbohydrates are digested and utilized before the fiber becomes the fermentation substrate. Cause for the digestion lag is probably a combination of several factors, however, more research is necessary before a definite conclusion can be drawn.

Mertens and Ely (1982) suggested incorporating two potentially digestible fiber pools and a discrete lag time into a dynamic fiber digestion model. The equation is:

$$R = I + Fe^{-k1(t-l)} + Se^{-k2(t-l)}$$

where; R = undigested fiber residue at time = t; I = indigestible fiber fraction; F = fast digesting fiber fraction; S = slow digesting fiber fraction; k1 = digestion rate constant for the fast digesting fiber fraction; k2 = digestion rate constant for the slow digesting fiber fraction; t = time; and l = discrete lag time (Mertens and Ely, 1982).

Voluntary Intake

Voluntary intake is generally defined as the quantity of feed an animal will consume when the amount of feed is not limited. Raymond (1969) suggested that forage availability of 15 percent above the consumption rate is needed to insure ad libitum intake. There appears to be two main mechanisms which govern or regulate the quantity of feed the animal ingests. With the more digestible feedstuffs such as grains or high quality forages, intake is probably controlled by metabolic energy balances via hypothalmic monitoring (chemostatic mechanism). However, with the majority of forages, DEI does not reach this level for energy stasis and voluntary intake becomes more dependent upon physical characteristics of the forage in relationship to animal capacity (distention mechanism).

Blaxter et al. (1961) reported a 70 percent energy digestibility of an all roughage diet in which there were no further increases in DEI with increases in forage digestibility. Conrad et al. (1964) showed this point of diminshing intake with increasing digestibilities at 66 percent DM digestibility for lactating dairy cows fed a mixed