DIGESTIBILITY, INTAKE AND SELECTIVITY OF THREE MIXED-FORAGE PASTURES BY CATTLE

by

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INTRODUCTION

Consumer demand for lean beef and emphasis on the use of grain for human consumption and production of alcohol for fuel, have resulted in greater use of forage for finishing cattle. The Southern Region of the United States has a long growing season, adequate rainfall, good soil conditions, and is, therefore, well suited to forage production. The major setback in year-round production of finished beef on forage is due to the seasonality of forage production. Therefore, defining chemical composition, digestibility, voluntary intake and selective consumption of typical grass-legume pastures during different times of the year would enable cattle producers to establish forage systems for optimum use of pasture land.

The beneficial effects of growing grass-legume mixtures have been well established (Blaser et al., 1969). Micro-organisms supply nitrogen to the legume. An increase in legumes improves animal performance. In addition, the quality of legumes does not decline with age as quickly as grasses (Johnson and Pezo, 1975). Finally, although grasses may have a higher ratio of leaf to stem, legumes have a generally higher digestible nutrient content and a more rapid rate of passage, compared to grasses (Metcalfe, 1976).

Differences in forage quality have been related to species, season, environment and various interactions. Brown et al. (1963) found a sharp increase in total nonstructural carbohydrates in tall fescue during an 11-week period beginning August 14 in Virginia. Smith (1977) also found increased sugar content in tall fescue as temperature declined. Bush et al. (1972) found that perloline, an alkaloid found in tall fescue, decreased digestibility of cellulose and crude protein. Bland and Dent (1962) reported a positive correlation between sugar level and palatability of orchardgrass. Blaser et al. (1969) reported that bluegrass had a comparatively lower grazing yield than orchardgrass. Digestibility of white clover only decreased from 94 to 85% from 14 to 112 days of age (Johnson and Pezo, 1975). This characteristic is also true for other legume species. It has been well established that alfalfa has the highest feeding value among commonly grown hay crops, and makes excellent pasture with grasses such as orchardgrass, bromegrass or timothy (Metcalfe, 1976).

The apparent differences in quality among forages illustrate the need for increased research in this area. Furthermore, there is need to establish uniform forage sampling techniques and adequate indicator methodology. Information on chemical composition, digestibility, intake and selective consumption of typical forage mixtures is needed to allow development of optimum forage systems.

REVIEW OF LITERATURE

Forage Sampling Via Esophageal Fistula

The esophageal fistula has been used for many years in studies concerning salivation. It was used in the horse by Magendie in 1847 and later by the French physiologist, Claude Bernard in 1855. The classic studies of Pavlov in 1897 also involved the use of the esophageal fistula. Much more recently, esophageal fistulation has become widely used in ruminants for the collection of grazed forage (Van Dyne and Torell, 1964).

Sampling of grazed forage via esophageal fistula has been compared to alternate methods. The rumen-evacuation and hand-clipping techniques are two methods frequently employed. Esophageal fistula and rumen fistula sampling were compared by Lesperance et al. (1960a). Esophageal fistula samples of animals fed alfalfa hay contained higher nitrogen-free extract than ruminal fistula samples. Both esophageal and ruminal fistula samples differed in chemical composition from the feeds fed, indicating some degree of selective consumption of component feeds.

The rumen-evacuation technique presents considerable disadvantage in comparison to hand-clipping or esophageal fistula collection. It is not well suited for repeated sampling since it is much more time consuming than esophageal fistula sampling or hand-clipping. Furthermore, it has been shown that emptying the rumen has a depressing effect upon the ability of the animal to digest forage. Therefore, repeated sampling may be deleterious to the animal and alter grazing performance (Lesperance and Bohman, 1963).

Hand-clipping is a less desirable sampling technique than esophageal or ruminal fistula sampling because it does not account for animal selectivity. Galt et al. (1969) reported that the species composition of rumen samples differed markedly from hand-clipped samples of available forage. The crude protein content of the rumen samples was greater than the protein values for hand-clipped samples, presumably due to animal selctivity of specific plants and plant parts.

Forage samples taken from esophageal cannulated animals have undergone a wide variety of chemical analyses. Of primary concern in chemical analysis of esophageal cannula samples is contamination by rumen contents and saliva. Contamination by regurgitated rumen contents is not a serious problem as long as collection time does not exceed 2 h (Cook, 1964). Salivary contamination, however, is unavoidable and will vary depending on the type of collection bag used.

Salivary contamination of forage samples in conjunction with high-temperature drying may bias lignin values. It has been shown that excessive moisture and high drying temperature cause a non-enzymatic browning reaction in which carbohydrate degradation products condense with protein, forming an acid-insoluble product which may bias lignin determination (MacDougall and DeLong, 1942; Van Soest, 1962). Gaillard (1962) indicated that this acid insoluble material may be modified xylans. Thus, it is advisable to keep the forage as dry as possible by use of screen-bottom or mesh collection bags and to dry at relatively low temperatures.

Salivary contamination may also alter the mineral status of the esophageal fistula sample. Sheep saliva contains about .8 % ash (McDougall, 1948) whereas bovine saliva contains from .85 (Lesperance et al., 1960a) to .89 % ash (Bailey and Balch, 1961). Bath et al. (1956) found that salivary contamination increased the ash content of the sample but did not significantly alter other components. The magnitude of the increase in ash from salivary contamination is usually from 1 to 4% (Lesperance et al., 1974). Lesperance et al. (1960a) indicated that salivary contamination significantly increases the content of phosphorous and calcium in the forage sample as well. In addition, nitrogen content may increase in the forage sample due to saliva (Cook et al., 1961). Mayland and Lesperance (1977) reported that fistula samples also had significantly higher concentrations of silica, sodium, zinc and cobalt than the forage offered. Small increases in potassium, mangenese, iron, and molybdenum, and small decreases in magnesium and calcium were noted also. Cook et al. (1961, 1962) attempted to correct for mineral contamination from saliva. This was done by collecting saliva from each animal and saturating a dried sample of ingested forage to obtain the total quantity of saliva absorbed by moisture-free material. The field-moisture content of the forage in the diet was then subtracted from the total saliva withheld by the completely dry material to determine the amount of saliva actually absorbed by the material consumed. Correction was made based on the amount of saliva absorbed by the material and the mineral analysis of the saliva (Cook, 1964). This procedure is subject to criticism since saliva composition and secretion rate are variable and since fistula samples may not be completely saturated with either plant moisture or salivary moisture (Van Dyne and Torell, 1964).

Another method used for correction of salivary contamination is isotope-dilution. This procedure can be used to measure the amount of moisture or various mineral constituents added to fistula forage samples by the saliva (Van Dyne and Torell, 1964). The major drawback to this method is that the amount and composition of saliva can vary considerably, depending on the type of forage consumed (Bailey and Balch, 1961; Somers, 1961). Therefore, saliva would have to be analyzed before and after collection of each forage sample (Van Dyne and Torell, 1964).

A third and much simpler method to eliminate bias due to salivary contamination is to present data on an ash-free basis. Various researchers have reported that the chemical composition of esophageally collected forage samples is similar to fed material except for an increase in ash content (McManus, 1961; Nelson, 1962; Campbell et al., 1968). Another reason that presenting data on an ash-free basis is desirable is that grazed forages are likely to have soil contamination (Van Dyne, 1963).

An advantage to collecting forage samples via esophageal cannula is that botanical composition of samples can be determined and used to measure selectivity. Torell (1965) used a microscope to identify plants consumed from two- or three-species mixed forage pastures. The data obtained indicated that percent observations of different species closely approximated percent weight for simple mixtures. Cook et al. (1958) found that browse plants in esophageal fistula samples could be almost completely identified, while grasses and herbs were often masticated to the point that they could not be identified. Heady and Torell (1959) used the microscope-point technique to determine botanical composition of esophageal fistula samples from sheep as a measure of forage preference. Throughout the 6-month collection period, esophageal samples exhibited a broad variation in species composition and stages of maturity. Lesperence et al. (1960b) used the microscope-point technique to differentiate grasses and broad-leaf plants. Lusk et al. (1961) collected plant parts from various species in the pasture prior to fistula collection to aid in identification.

Since grazing animals often select plants and plant parts from a mixture of species, collecting samples of forage representative of the diet of the grazing animals is a complicated problem. The selectivity of the animal may vary with the species of animal, available plants, stage of maturity, intensity of grazing, and weather conditions (Cook, 1964). Many studies have shown that grazing animals consistantly select higher quality forage than the forage which is available (Lesperance et al., 1974; Kartchner and Campbell, 1979; Van Dyne et al., 1980).

In order to obtain forage samples, via esophageal cannula, which are most representative of the forage consumed over the entire grazing period, sampling procedure is important. Several variations in sampling procedure are apparent in the literature. Some investigators kept animals off feed overnight prior to collection periods (Bath et al., 1956; Cook et al., 1958; Weir and Torell, 1959). Arnold et al. (1963) found that witholding feed had an effect on forage selectivity. Other researchers (Van Dyne and Van Horn, 1959; Van Dyne, 1960) allowed fistulated animals to remain with the herd throughout the grazing trial. Exclusive groups of fistulated experimental animals were grazed by other workers (Cook et al., 1962; Van Dyne, 1962).

Sampling frequency varies, depending on the length of the trial and purpose of the investigation. Most researchers sample only once in a given day, but many sample twice daily (Van Dyne and Torell, 1964). It is essential that the sampling scheme be designed to ensure that fistulated animals graze during the same time and in the same location as the rest of the herd (Van Dyne and Van Horn, 1959; Butcher and Cook, 1960; Van Dyne, 1962, 1963).

Animals withheld from feed for a period of time graze more vigorously with less chance of contamination of samples with regurgitated material (Arnold et al., 1963). However, this vigorous grazing may influence forage selectivity. More frequent collections appear desirable since significant changes can occur in the chemical composition of the diet from day to day, even under relatively uniform conditions (Lesperance et al., 1960b; Arnold et al., 1963).

Some questions have been raised as to whether the grazing behavior of esophageally-fistulated animals differs quantitatively from non-fistulated animals. Arnold et al. (1963) indicated that sucessfully fistulated animals graze normally.

Accuracy of esophageal fistula sampling cannot be established since it is impossible to obtain true grazing samples without some form of cannulation. Weir and Torell (1959) have shown that esophageal fistula forage samples are considerably different from the gross herbage available. Hand-clipped samples taken from areas where animals are observed grazing are often different in composition than average available herbage (Hardison et al., 1954; Edlefsen et al., 1960). Van Dyne and Torell (1964) and Holechek et al. (1982) believe that esophageal fistula samples represent the best estimate of the intake of grazing animals.

Data on the precision of esophageal fistula sampling are generally lacking. Lesperance et al. (1960a) presented data which indicated that the technique may not be extremely precise, but variation was much greater between animals than between samples from a given animal. Multiple collections may provide more representative sampling. Theurer (1970) listed factors which may limit the precision with which fistula forage samples represent the chemical composition of the diet. These include losses of diet sample material during fistula sample collection, chemical changes during mastication and salivation, and chemical changes during sample preparation for laboratory analysis. Despite these problems, it is now well accepted that fistula samples represent the diet of grazing animals better than clipped samples (Holechek et al., 1982).

Use of Indicators

The indirect method of determining digestibility and/or voluntary intake, involves the use of an inert reference substance as an indicator. Ideally, the indicator should be indigestible and unabsorbable, physiologically inert in the digestive tract, pass through the digestive tract at a uniform rate, be easily assayed chemically, and preferably be a natural feed constituent (Maynard et al., 1979).

In grazing studies, voluntary intake is determined by use of an external indicator to determine dry matter intake, and an internal, naturally occurring indicator to measure digestibility. Dosed marker substances are used to estimate fecal output, which in conjunction with digestibility values are used to estimate forage intake.

Perhaps the most commonly used marker substance in the past has been chromium sesquioxide (Cr_2O_3), usually referred to as chromic oxide. More recently, the reliability of this substance as a fecal indicator has been questioned. MacRae (1974) indicated that Cr_2O_3 does not adhere sufficiently to the particulate phase of the digesta. Langlands (1975) observed diurnal variations in excretion of Cr_2O_3, which are due to incomplete mixing of the digesta and indicator in the gastrointestinal tract.

Ytterbium. Rare earth elements, such as ytterbium (Yb), have many of the qualities necessary for an effective indicator (Prigge et al., 1981). Rare earth elements adhere tenaciously to the particulate phase of the digesta (Ellis and Huston, 1968). At very low concentrations (below 10^{-11}M) rare earth elements exhibit radio-colloidal behavior, i.e. strong adsorptive properties (MacRae, 1974). Garner et al. (1960) observed that rare earth elements were indigestible and formed tight association with particulate matter during passage through the gastrointestinal tract of cattle. Further studies involving soluble rare earth salts applied to forage showed complete recovery of the metal in feces (Ellis, 1968; Bell, 1969).

The strong capability of rare earth elements to bind to the digesta could reduce diurnal variation in excretion, leading to a more precise measure. However, Prigge et al. (1981) found a large diurnal variation in fecal excretion of Yb. This may have occurred for a variety of reasons. Incomplete binding of Yb to the forage could have occured, allowing some Yb to travel with the liquid phase of the digesta. In support of this, Ellis et al. (1979) found that 3 to 9% of the rare earth marker does not bind to particulate matter. Alternatively, Yb may have bound differentially to feed particles that left the rumen at different rates from the rest of the digesta, or Yb may have formed insoluble hydroxides which possibly travel at different rates than digesta particles (Prigge et al., 1981).

Ytterbium has been the rare earth element most frequently used in recent years (Coleman, 1979; Teeter et al., 1979). It has advantages over the other elements in that it is relatively inexpensive and can be readily detected by atomic absorption spectrophotometry. Furthermore, Yb offers advantages in dose preparation. It is soluble in dilute acid and doses can therefore be prepared by volume instead of weighing. Thus, Yb seems well adapted to routine use in grazing studies (Prigge et al., 1981).

Factors Influencing Voluntary Intake

Many factors are involved in determining the voluntary intake of grazing cattle. Conrad (1966) described two mechanisms by which intake may be controlled: 1) a mechanism sensitive to distention of the rumen or gastrointestinal fill, and the turnover rate of rumen digesta caused by degradation and passage (distention theory), and 2) a mechanism sensitive to the digestible energy of metabolizable energy absorbed by the animal (chemostatic theory). For grazing animals, intake appears to be primarily controlled by rumen fill (Moore and Mott, 1973).

Blaxter et al. (1956) observed higher feed consumption when sheep were fed a highly digestible feed that passed rapidly through the gastrointestinal tract. Increasing digestibility of the feed by 10% under ad libitum feeding conditions, increased the body gain by 100% primarily due to more rapid rate of passage. It was estimated that the dry matter fill of the gastrointestinal tract was 100g/kg body weight despite the relative forage quality. Campling and Balch (1961) reported that the quantity of forage accumulated in the reticulo-rumen had a direct and immediate effect on the amount of forage consumed. In addition, the amount of digesta in the reticulo-rumen immediately post-feeding was similar for either low or high quality forage (Freer and Campling, 1963). Conrad et al. (1964) observed that voluntary intake varied to yield a constant fecal output of .94 kg fecal organic matter per 100 kg body weight. Ulyatt et al. (1967) proposed that voluntary intake, when regulated by reticulo-rumen fill, was inversely related to rumen retention time. This was supported by Thornton and Minson (1972) who observed high correlations between intake and rumen retention time when feeding grasses and legumes of different qualities to sheep. Therefore, forage intake appears to be primarily regulated by the rate of degradation in, and passage from, the rumen. In general, when digestibility increases, the rate of turnover of rumen digesta will increase, and intake will be higher.

Many investigators reported positive correlations between voluntary intake and digestibility (Blaxter et al., 1961; Conrad et al., 1964; Minson et al., 1964) while others have reported large differences in intake for forages of similar digestibility (Minson, 1971a; Laredo and Minson, 1975). Variation in voluntary intake has not been consistently related to in vitro rate of digestion (Minson, 1971a; Laredo and Minson, 1973) or extent of digestion (Minson, 1971b, 1972). Owen et al. (1969) found that when the distention mechanism was responsible for intake control, as with forage-fed animals, the relationship between digestibility and intake was altered by the particle size of the feed. Intake varied according to the physical structure of the roughage, even when two feeds had equal digestibility.

Ellis (1978) reviewed voluntary intake-digestibility relationships and concluded that in order to elucidate the determinants of grazed forage intake all component attributes of the forage-animal-grazing system complex must be considered, including both plant and animal factors.

The relationship between voluntary intake and the chemical composition of forages has been the focal point of much research. However, the variation in the voluntary intake of many different forages has not been well described by differences in plant chemical composition (Van Soest, 1965; Moore and Mott, 1973).

The nutritional status of the animal concerning dietary nitrogen has a role in the regulation of voluntary intake (Egan, 1965,1972; Weston, 1971). Although it is not clear whether the mechanism is distention or chemostatic, the fact remains that low dietary nitrogen levels will result in low forage intake and submaximal fill of the reticulo-rumen. Protein concentrate supplementation of low-protein forage diets has a more substantial effect on intake than on digestibility (Blaxter et al., 1971; Moore et al., 1969; Ventura et al., 1972). It has been established that the voluntary intake of forages is severely limited if the crude protein content of the forage is below 7% (Zemmelink et al., 1972).

Van Soest (1965) reported that the percentage of cell wall constituents was the only structural component of forages consistantly related to intake. Intake was not closely related to digestibility when the dry matter of the forage contained less than 50 to 60% cell walls. Above this level, both intake and digestibility were negatively correlated with cell walls. Among forages having equal digestibility, the forage having the highest ratio of cell contents to digestible cell walls should have the highest intake (Van Soest, 1965; Osbourn et al., 1966; Allinson and Osbourn, 1970).

Cellulose may also influence voluntary intake of grazing animals. Research indicates that the amount of digestible cellulose in the forage remains unchanged with advancing maturity, while the percent of indigestible cellulose increases (Tilley et al., 1969; Tergas et al., 1971). In accordance with this, Waldo et al. (1972) indicated that cellulose in forage is made up of a potentially digestible and potentially indigestible component. Gill et al. (1969) found that the rate of digestion of the digestible fraction of cellulose was correlated with forage intake.

Smith et al. (1972) indicated that the rate of in vitro cell wall digestion was closely correlated with the lignin: cellulose ratio and that cell wall digestibility was related to lignin. Allinson and Osbourn (1970), however, found that the lignin complex in plants varies widely among species. Although increased lignin is often highly correlated with decreased quality within a species as it matures, intake and digestibility differences among species are less closely associated with lignification.

JOURNAL MANUSCRIPT

DIGESTIBILITY, INTAKE AND SELECTIVITY OF THREE MIXED-FORAGE PASTURES BY CATTLE

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Summary

A grazing trial was conducted to determine the relative value of three mixed-forage pastures, alfalfa-orchardgrass, bluegrass-white clover, and fescue-red clover. Three steers, three heifers, and one esophageally cannulated steer were randomly assigned to each pasture treatment. Chemical composition, digestibility, voluntary intake, and selectivity of the forages were determined through use of esophageally cannulated steers and a rare earth marker (ytterbium). Forage intake appears to be most closely related to DM digestibility and content of the NDF and ADF fiber fractions. Some degree of forage selectivity was observed, although the specific species selected for and determinants of selectivity were not apparent. From the data obtained on levels of intake, digestibility and chemical composition, alfalfa-orchardgrass and bluegrass-white clover offer the highest quality forage of the three compared during the time of year studied. Fescue-red clover was consistently inferior in all respects. The digestible dry matter intake by cattle grazing alfalfa-

orchardgrass, bluegrass-white clover, and fescue-red clover, was 3.2, 2.9 and 2.2 kg/d, respectively. More work needs to be done on a wider variety of pastures during different times of the grazing season.

(Key words: Beef Cattle, Forage, Voluntary Intake, Digestibility, Chemical Composition, Selectivity).

Introduction

Worldwide trends indicate that livestock are in ever increasing competition for available grain. Thus, there is an increased need for research in the area of forage utilization in feeding ruminants. The need is especially critical concerning forage finishing of cattle. Among the primary concerns in forage research is the lack of accurate methods of determining voluntary intake. Uniform forage sampling techniques and adequate indicator methodology also need to be established.

Beneficial effects of grazing grass and legume in combination are well established (Blaser et al, 1969). There is need for information on intake, digestibility, selectivity and chemical composition of typical grass-legume pastures. Bluegrass has a lower grazing yield than orchardgrass (Blaser et al., 1969). Defining the average intake and digestibility of common pastures, and determining differences in chemical composition as well as patterns of selective consumption, would enable the producer to establish forage systems for maximum use of pasture land for livestock. With appropriate use of indicators, reliable estimates of digestibility and intake of grazed forage can be established (Ellis, 1979). An experiment was conducted to establish a technique of determining voluntary intake of grazing beef cattle, making use of esophageally cannulated animals and a rare-earth marker; to determine voluntary intake, digestibility, selectivity, and chemical composition of three mixed-forage pastures; and to relate chemical composition and digestibility to voluntary intake levels.

Experimental Procedure

In order to determine the relative value of three mixed-forage pastures, a 10-d trial was conducted beginning August 1, 1981. Prior to the grazing trial, three steers were surgically equipped with esophageal cannulas by the method of Van Dyne and Torell (1964). Mesh collection bags were used to allow saliva to drain from collected forage samples. Three groups of seven cattle were randomly assigned to the treatments according to sex and weight. Each treatment group included three intact steers and three intact heifers plus one esophageally cannulated steer. The average initial weight of the cattle was 313 kg.

Pastures compared were 1.01 hectare lots of alfalfa-orchardgrass, bluegrass-white clover, and fescue-red clover located at the Southwest Virginia Research Station, Glade Springs. Forage availability was not limiting at any time during the grazing trial. Pastures were not fertilized in 1982. In August of the previous year, the alfalfa-orchardgrass pasture received 45 kg K_2O, and the fescue-red clover pasture received 30 kg of N. In May, 1982 hay was cut from each pasture. The amount of hay removed was 1100, 4500 and 1500 kg from the alfalfa-orchardgrass, bluegrass-white clover and fescue-red clover pastures, respectively. At the beginning and end of the grazing trial, pastures were evaluated visually for percent grass. Percent broadleaf plants was determined by difference, and therefore included both legumes and broadleaf weeds.

Cattle were dosed daily throughout a 10-d grazing trial with 2 g hydrous ytterbium nitrate ($Yb(NO_3)_3 \cdot 6H_2O$) to serve as an external indicator. Dosing was intiated 5 d prior to the onset of the trial to adjust cattle to the treatment and to equalize the marker through the digestive tract. Two g doses of $Yb(NO_3)_3 \cdot 6H_2O$ were weighed into gelatin capsules and administered to cattle by bolus gun for 15 d.

Fecal grab samples were collected daily at dosing time (0800 h) throughout the 10-d trial. Forage samples were collected twice daily, morning and afternoon via esophageal cannula, for use as representative samples of the forage actually grazed by all animals in the treatment group. Care was taken to insure that cannulated steers grazed during the same time of day and in the same vicinity as other animals in the group, during the sampling procedure. Because the cannulated steers were tame, it was possible to install and remove mesh collection bags in the field. Cannulated steers were permitted to graze with collection bags until bags were full of forage, a period of time that ranged from 15 to 45 min. All forage and fecal samples were labelled and frozen immediately after collection.

Following the grazing trial, the cattle were reweighed. Fecal and esophageal samples were dried at 50 C in a forced-air oven and ground through a Wiley Mill fitted with a 1 mm screen. A representative portion of each esophageal sample was removed and refrozen prior to drying, to be used in botanical analysis by the microscope-point technique (Lesperance et al., 1960b). The two daily samples were thoroughly mixed. Random aliquots were removed from each and mixed together. Dried esophageal and fecal samples were composited for the first 5 and last 5 d of the trial for analysis.

Fecal concentration of Yb was determined by atomic absorption spectrophotometry using a nitrous oxide flame. A 1 g subsample of feces was ashed in a muffle furnace and digested in 20 ml of an acid solution (3 N HCl + 3 N HNO_3) for use in the Yb assay (Conner, 1977). In vivo digestibility of the forage samples was determined by using indigestible neutral detergent fiber (INDF) as the internal indicator, by a modification of the Goering and Van Soest (1970) procedure. After 6 d of incubation, the unfermented residues were transferred from incubation tubes to 600 ml berzelius beakers with 100 ml of neutral detergent solution, and .5 g Na_2SO_4. The mixture was then refluxed for 20 min, filtered into 30 ml course porosity sintered glass crucibles, rinsed once with hot water (90 C) and twice with acetone. The residue was dried in a drying oven at 60 C for 12 h and weighed. Indigestible neutral fiber as percent of dry matter was calculated by the following formula:

Percent INDF =

$$\frac{(\text{crucible wt} + \text{INDF wt}) - (\text{crucible wt})}{\text{initial sample wt}} \times 100$$

Percent digestibility was then calculated:

Percent digestibility =

$$100 - \frac{(\%\text{INDF in forage})}{(\%\text{INDF in feces})} \times 100$$

Fecal output was determined by the following formula:

Fecal output, kg/d =

$$\frac{\text{Yb dosed, mg/d}}{\text{Yb in feces, mg/kg}}$$

Fecal output values and digestibility values were used to determine forage dry matter intake:

Forage intake =

$$\frac{\text{Fecal output}}{100 - \%\text{ digestibility}} \times 100$$

Forage samples were further analyzed for dry matter, ash, crude protein (A. O. A. C., 1980), neutral detergent fiber, acid detergent fiber (Goering and Van Soest, 1970), lignin and cellulose (Van Soest and Wine, 1968).

The data were statistically analyzed using the general linear models procedure of SAS (1979). Duncan's (1955) multiple range test was used to determine differences between the treatment means. The statistical model included effects of treatment and day for selectivity and chemical composition. The effects were tested by the treatment x day interaction. Fecal output, voluntary intake and digestibility analyses included effects of treatment, period, block, treatment x block and treatment x period. Treatment and block effects were tested by the treatment x block interaction. All other effects were tested by the treatment x block x period interaction.

Results and Discussion

Chemical Composition

The chemical composition of the forage samples collected by esophageal cannula on a DM and OM basis is presented in tables 1 and 2, respectively. Differences ($P < .05$) in chemical composition were similar whether expressed on a DM or OM basis, with the following exceptions. Differences in CP and lignin ($P < .05$) content between alfalfa-orchardgrass and fescue-red clover on an OM basis were not apparent ($P > .05$) on a DM basis. The NDF content of alfalfa-orchardgrass and bluegrass-white clover did not differ ($P > .05$) on an OM basis, but differed ($P < .05$) on a DM basis, with the level in the bluegrass-white clover being highest. These apparent differences indicate the need to express esophageal cannula forage samples on a ash-free basis to account for salivary contamination. Therefore, chemical composition in relation to forage intake will be discussed on an OM basis.

Bluegrass-white clover was highest in CP content,

TABLE 1. CHEMICAL COMPOSITION OF FORAGE SAMPLES OBTAINED BY ESOPHAGEAL CANNULA

Forage	Dry matter	Composition of dry matter, %					
		Ash	Crude protein	NDF[a]	ADF[b]	Lignin	Cellulose
	%						
Alfalfa-orchardgrass	23.1	12.3[c]	14.1[c]	66.4[c]	36.3[c]	7.9[c]	26.2[c]
Bluegrass-white clover	23.8	10.4[d]	15.8[d]	69.7[d]	37.6[cd]	8.8[d]	28.6[d]
Fescue-red clover	24.6	12.2[c]	13.1[c]	70.4[d]	38.4[d]	8.6[cd]	28.8[d]
SEM	±1.5	±.4	±.3	±.9	±.5	±.3	±.4

[a]Neutral detergent fiber

[b]Acid detergent fiber

[c,d]Means with different superscripts in same column are different ($P < .05$).

TABLE 2. CHEMICAL COMPOSITION OF FORAGE SAMPLES OBTAINED BY ESOPHAGEAL CANNULA

Forage	Organic matter[a]	Composition of organic matter, %				
		Crude protein	NDF[b]	ADF[c]	Lignin	Cellulose
	%					
Alfalfa-orchardgrass	87.7[d]	16.0[d]	75.8[d]	41.4[d]	9.1	29.9[d]
Bluegrass-white clover	89.6[e]	17.7[e]	77.8[de]	42.0[de]	9.9	31.9[e]
Fescue-red clover	87.8[d]	14.9[f]	80.2[e]	43.7[e]	9.9	32.9[e]
SEM	±.4	±.3	±1.2	±.7	±.3	±.4

[a]Dry basis

[b]Neutral detergent fiber

[c]Acid detergent fiber

[d,e,f]Means with different superscripts in same column are different ($P < .05$).

followed in order by alfalfa-orchardgrass and fescue-red clover (table 2, $P<.05$). The NDF content was generally lowest for the alfalfa-orchardgrass and similar for the other two forages, but differences were not always significant. The ADF content followed a similar pattern, with alfalfa-orchardgrass being lowest. There was a trend for alfalfa-orchardgrass to contain a lower percentage of lignin than the other two forages. Bluegrass-white clover and fescue-red clover had similar contents of lignin. Alfalfa-orchardgrass had the lowest content of cellulose with no differences between the other two forages ($P > .05$).

Apparent Digestibility

Apparent digestibility values for the various forage components are presented in table 3. Dry matter digestibility was higher for the alfalfa-orchardgrass and bluegrass-white clover, than for fescue-red clover ($P < .05$). Organic matter digestibility was consistently higher ($P < .05$) for alfalfa-orchardgrass than bluegrass-white clover. The OM digestibility of fescue-red clover was lower than for the other two forages. Crude protein digestibility was consistently higher for bluegrass-white clover, followed in order by alfalfa-orchardgrass and fescue-red clover ($P < .05$). Similar patterns in digestibility were observed for all fiber components. However, values between alfalfa-orchardgrass and fescue-red clover were not significantly different for NDF and lignin.

Relationship to Chemical Composition. The forage with

TABLE 3. APPARENT DIGESTIBILITY OF FORAGE COMPONENTS

Forage	Dry matter	Organic matter	Crude protein	NDF[a]	ADF[b]	Lignin	Cellulose
	%	%	%	%	%	%	%
Alfalfa-orchardgrass	52.7[c]	58.9[c]	56.6[c]	57.6[c]	43.0[c]	4.7[c]	72.7[c]
Bluegrass-white clover	52.0[c]	54.7[d]	59.7[d]	61.1[d]	45.1[d]	7.7[d]	73.8[d]
Fescue-red clover	48.7[d]	52.1[e]	55.0[e]	55.8[c]	39.8[e]	3.9[c]	68.4[e]
SEM	±.3	±.3	±.4	±.8	±.5	±.4	±.3

[a]Neutral detergent fiber

[b]Acid detergent fiber

[c,d,e]Means with different superscripts in same column are different ($P < .05$).

the highest DM and OM digestibilities, alfalfa-orchardgrass, consistently had the lowest content of the fiber components ie., NDF, ADF, lignin and cellulose. The content of the various fiber fractions in alfalfa-orchardgrass was lower ($P < .05$) than for fescue-red clover. There was also a trend for bluegrass-white clover to be intermediate in content of the fiber components, although these differences were not always significant.

The relationship between dry matter and organic matter digestibility and CP content was less consistent than the relationship concerning the fiber components. During the grazing trial, fescue-red clover contained the lowest CP and also had the lowest DM and OM digestibilities. However, the opposite relationship was observed with the other two forages. Alfalfa-orchardgrass had higher DM and OM digestibilities, while bluegrass-white clover had the highest CP content.

The relationship between the chemical components and their respective digestibilities was unclear, except for CP which exhibited a directly proportional relationship. The digestibilities of NDF, ADF, lignin and cellulose were generally highest for bluegrass-white clover, but the digestibility of OM and DM was generally highest for alfalfa-orchardgrass. The only consistent trend was that of fescue-red clover, which had the lowest digestibility for all the chemical components measured. Therefore, it was likely that the fiber components played an important role in determining forage digestibility.

Dry Matter Intake

The data for fecal output and forage intake are presented in table 4. Voluntary intake is expressed as kg/d, kg • 100 kg body weight^{-1} • d^{-1} and kg digestible DM/d. Throughout the grazing trial, no differences ($P > .05$) in voluntary intake were observed between cattle grazing alfalfa-orchardgrass and bluegrass-white clover treatments. However, there was a trend toward higher intake by cattle grazing alfalfa-orchardgrass. Intake was consistently higher for alfalfa-orchardgrass than fescue-red clover throughout the trial. The values were 6.0 and 4.4 kg/d for alfalfa-orchardgrass and fescue-red clover, respectively. Throughout the trial, there was a distinct trend toward higher intake by cattle grazing alfalfa-orchardgrass, followed in order by bluegrass-white clover and fescue-red clover.

Relationship to Chemical Composition. The relationship between voluntary intake and chemical composition was very similar to the relationship of chemical composition to digestibility. Bluegrass-white clover contained the highest percentage of CP, but was intermediate in voluntary intake. There was a trend for fescue-red clover to be lowest in both CP content and voluntary intake.

The relationship between CP and voluntary intake of forage is a complex issue. Weston (1971) related intake to grams of CP digested per gram of OM digested. Egan (1965) found that supplemental nitrogen increased intake of

TABLE 4. FECAL OUTPUT[a] AND VOLUNTARY INTAKE[a] OF CATTLE GRAZING ALFALFA-ORCHARDGRASS, BLUEGRASS-WHITE CLOVER, AND FESCUE-RED CLOVER

Forage	Fecal output, kg/d	Dry matter intake: Kg/d	Dry matter intake: $Kg \cdot 100$ kg body $weight^{-1} \cdot d^{-1}$	Digestible dry matter intake, kg/d
Alfalfa-orchardgrass	2.3	6.0[b]	1.9[b]	3.2[b]
Bluegrass-white clover	2.1	5.5[bc]	1.8[b]	2.9[bc]
Fescue-red clover	1.9	4.4[c]	1.4[c]	2.2[c]
SEM	±.2	±.4	±.1	±.2

[a]Dry basis

[b,c]Means with different superscripts in same column are different ($P < .05$).

low-protein hay, presumably by enhancing energy utilization. Egan (1972) later proposed that nitrogen status affected the level of ruminal distention at which intake is controlled. Minson and Milford (1966) found that when CP varies to a broad extent, it will alter the energy value of digestible OM. However, most researchers agree that CP will not limit intake unless it is below 7% of the dry matter. Table 1 shows that the percent CP on a dry basis does not approach this level. In this study, the low CP value associated with the low intake of fescue-red clover may be a consequence of a proportionately higher fiber fraction. In forage-fed animals, if nitrogen is not limiting, the distention theory of intake control is considered operative (Moore and Mott, 1973). In this case, the fiber fraction of the diet would be most influential in determining forage intake.

Of the forages compared, the fescue-red clover, consumed in the smallest amounts, consistently had the highest percentage NDF. The NDF content of fescue-red clover was 80.2% while NDF content of the higher intake alfalfa-orchardgrass was 75.8%. The NDF content of bluegrass-white clover was intermediate to the other two forages, but did not differ significantly from either one. The same observation was true in terms of the voluntary intake of bluegrass-white clover.

Van Soest (1965) reported that the percentage of cell wall constituents (CWC), analyzed as fiber insoluble in neutral detergent solution, or neutral detergent fiber (NDF), is the only chemical factor consistantly related to intake. The present study agrees with these findings, as there was a consistent inverse relationship between NDF content and level of forage intake.

Similar trends were observed for the relationship between voluntary intake and ADF between treatments. Although differences between the ADF content of alfalfa-orchardgrass and bluegrass-white clover were only slight, the ADF content of fescue-red clover was higher ($P < .05$) than the other two forages.

When the ADF fraction was broken down into its component fractions of lignin and cellulose, a similar trend was apparent. The alfalfa-orchardgrass was lower in both lignin and cellulose content than the fescue-red clover. However, bluegrass-white clover had an intermediate level of intake, but did not differ signicantly from fescue-red clover, in content of lignin and cellulose.

Lignin is generally thought to be a structural factor which limits intake. Van Soest (1965) states that positive relations between voluntary intake and lignin can occur in at least two ways: rejection of immature forage because of palatability, taste or toxic factors, or because of species interactions in mixed forage systems, ie. selectivity. Smith et al. (1972) reported that the rate of in vitro cell wall digestion was closely related to the lignin: cellulose ratio. Increased digestion would influence intake by increasing digesta passage rate. Therefore, factors other than the absolute quantity of these two fiber components, seem to influence voluntary intake of forage.

Relationship to Digestibility. The DM digestibility values of the three forages closely reflect the respective voluntary intake values. Determination of digestibility on an OM basis revealed a difference ($P < .05$) between the alfalfa-orchardgrass and bluegrass-white clover treatments which was also evident in the voluntary intake trends. Higher digestibilities were generally associated with higher intake levels. Blaxter et al. (1956) observed that sheep consumed greater amounts of feed when it was highly digestible and passed through the digestive tract quickly. Researchers generally agree that the higher the rate of turnover from the rumen, the higher the intake.

The relationship between voluntary intake and the digestibilities of CP, NDF, ADF, lignin and cellulose, differed somewhat from the above mentioned relationship. The digestibilities of these components were consistently lowest in fescue-red clover, when compared with the other two forages. Fescue-red clover also had the highest content of the fiber fractions. Accordingly, the voluntary intake of fescue-red clover was lowest. The voluntary intake of alfalfa-orchardgrass and bluegrass-white clover was higher, as were the digestibilities of these components. However, the digestibilities of these components were generally higher in bluegrass-white clover than alfalfa-orchardgrass, while the trend was for higher voluntary intake of alfalfa-orchardgrass. The trend for lower digestibility of the fiber components in the alfalfa-orchardgrass, was accompanied by a trend towards a lower content of these fractions, which may be responsible for the higher intake of alfalfa-orchardgrass than bluegrass-white clover, despite lower digestibilities of the fiber components.

The voluntary intake of digestible DM was highest by cattle grazing alfalfa-orchardgrass (table 4). Although the intake of alfalfa-orchardgrass was not significantly ($P > .05$) higher than that of bluegrass-white clover, there was a clear trend toward higher intake of alfalfa-orchardgrass. Intake of digestible DM was consistently lower by cattle grazing fescue-red clover although not significantly lower than intake of bluegrass-white clover.

Forage Selectivity

The species composition of the three forage systems at the beginning and end of the grazing trial is presented in table 5. Although these figures do not give an exact representation of forage selectivity, they do indicate that a general pattern of selectivity was taking place. In the case of the alfalfa-orchardgrass pasture, grass percentage decreased, whereas the percentage of grass in the bluegrass-white clover and fescue-red clover pastures increased. However, the changes were relatively small and may have been a consequence of error in estimation. If the estimates were accurate, changes of this magnitude may be meaningful in terms of the 10-d duration of the trial. Since the

TABLE 5. ESTIMATES OF SPECIES COMPOSITION OF PASTURES[a]

Forage	Beginning of trial		End of trial	
	Grass	Other	Grass	Other
	%	%	%	%
Alfalfa-orchardgrass	59	41	50	50
Bluegrass-white clover	91	9	97	3
Fescue-red clover	96	4	98	2

[a]Visual estimate.

grazing trial was relatively short, only small changes in pasture makeup would be expected.. These changes may therefore be indicative of some degree of selectivity. More specifically, the decrease in percent grass in the alfalfa-orchardgrass pasture may indicate preference for grass. The increase in percent grass in the other two forage systems may represent selection for components other than grass.

The pattern of forage selection, as indicated by visual estimation, was also apparent in species analysis of the esophageal forage samples by the microscope-point technique (Lesperance et al., 1960b) as shown in table 6. There was a significant sampling day effect. In the case of the alfalfa-orchardgrass treatment the percentage of grass consumed was considerably higher than the percentage broad-leaf plant. Since the relative proportion of grass to broad-leaf plant was almost equal in the pasture, it would appear that the cattle were selecting for grass. In the bluegrass-white clover treatment group, cattle were selecting all species in approximately equal proportion to what was available in the pasture. Finally, the cattle grazing the fescue-red clover selected a higher percentage of broad-leaf plant than was estimated to be present throughout the trial.

It is apparent that some degree of forage selectivity was taking place. However, with these data, it is impossible to describe exactly what species were being selected, or what factors were involved in determining selectivity.

TABLE 6. SPECIES COMPOSITION[a] OF FORAGE SAMPLES OBTAINED BY ESOPHAGEAL CANNULA

Forage	Kind of plant	
	Grass	Broad-leaf
	%	%
Alfalfa-orchardgrass	84.9[b]	15.1[b]
Bluegrass-white clover	94.7[c]	5.3[c]
Fescue-red clover	95.2[c]	4.8[c]
SEM	±.5	±.5

[a]By microscope-point technique (Lesperance et al., 1960b).

[b,c]Means with different superscripts in column are different ($P < .05$).

It is also important to note that the trends observed may be due to error in estimation or sampling via cannula. It is also possible that the visual pasture assessment differs markedly from what was available to the grazing animal.

Table 7 presents the average cattle weight gains for various treatment groups. Since these represent a period of only 10-d, they are of limited value, but they show interesting trends. The average weight gains for cattle grazing alfalfa-orchardgrass and bluegrass-white clover were higher ($P < .05$) than those for cattle grazing fescue-red clover. These gains follow the differences in forage quality. Furthermore, there was a trend toward greater weight gain by cattle grazing alfalfa-orchardgrass than cattle grazing bluegrass-white clover, which followed the trend toward higher intake of alfalfa-orchardgrass.

The results of this study indicate that there is a relationship between voluntary forage intake and chemical composition and digestibility. Intake seems to be most closely related to DM digestibility and content of NDF and ADF. Determinants of grazed forage intake appear to be highly species oriented. In agreement with this, Van Soest (1965) found that in some forage species (ie., orchardgrass) there is a close relationship between intake and chemical composition, while in others (ie., alfalfa and bluegrass) there is no consistent relationship between intake and digestibility or chemical composition. The selectivity

TABLE 7. AVERAGE CATTLE WEIGHT GAINS

Forage	Weight gain
	kg/d
Alfalfa-orchardgrass	.9[a]
Bluegrass-white clover	.8[a]
Fescue-red clover	.2[b]

[a,b]Means in same column with different superscripts are different ($P < .05$).

observed in this study may have been partly responsible for the lack of consistency in terms of these relationships. Since relationships between species are not uniform, altered selectivity in mixed-forage pastures may confound these relationships. However, from the data obtained on levels of intake, digestibility, chemical components, and weight gains, alfalfa-orchardgrass and bluegrass-white clover offer the highest quality forage of the three compared, during the time of year studied. More work needs to be done on a wider variety of pastures during different times of the grazing season.

Literature Cited

Allinson, D. W. and D. F. Osbourne. 1970. The cellulose-lignin complex in forages and its relationship to forage nutritive value. J. Agr. Sci. 74:23.

A. O. A. C. 1980. Official Methods of Analysis (13th Ed.). Association of Official Analytical Chemists, Washington, D. C.

Arnold, G. W., W. R. McManus, I. G. Bush, and J. Bell. 1963. Studies in the diet of the grazing animal. I. The use of oesophageal fistulated sheep to measure diet quality. Australian J. Agr. Res.

Bailey, C. B. and C. C. Balch. 1961. Saliva secretion and its relation to feeding in cattle: II. The composition and rate of secretion of mixed saliva in the cow during rest. Brit. J. Nutr. 15:383.

Bath, D. L., W. C. Weir, and D. T. Torell. 1956. The use of the esophageal fistula for the determination of consumption and digestibility of pasture forage by sheep. J. Anim. Sci. 15:1166.

Bell, M. C. 1963. Effect of ^{144}Ce-^{144}Pr intestinal irradiation in sheep on ^{86}Sr and ^{45}Ca metabolism. Proc. 6th Inter. Cong. of Nutr. Edinburgh. p. 185.

Bland, B. F. and J. W. Dent. 1962. Animal preference in relation to chemical composition and digestibility with varieties of cockfoot. J. Brit. Grassl. Soc. 17:157.

Blaser, R. E., H. T. Bryant, R. C. Hammes, Jr., R. L. Boman, J. P. Fontenot and C. E. Polan. 1969. Managing forages for animal production. V. P. I. and S. U. Res. Bull. 45.

Blaxter, K. L., N. W. McGraham and F. W. Wainman. 1956. Some observations on the digestibilities of food by sheep and on related problems. Brit. J. Nutr. 10:69.

Blaxter, K. L., F. W. Wainman and R. S. Wilson. 1961. The regulation of food intake by sheep. Anim. Prod. 8:75.

Brown, R. H., R. E. Blaser and J. P. Fontenot. 1963. Digestibility of fall grown Kentucky 31 fescue. Agron. J. 55:321.

Bush, L., J. A. Boling, G. Allen, and R. C. Buckner. 1972. Inhibitory effects of perloline to rumen fermentation in vitro. Crop Sci. 12:277.

Butcher, J. E. and C. W. Cook. 1960. Esophageal fistula studies. Annual Progress Report, Western Regional Research Project W-34, Utah Agr. Exp. Sta. p. 1.

Campbell, C. M., K. S. Eng, A. B. Nelson and L. S. Pope. 1968. Use of esophageal fistual in diet sampling with beef cattle. J. Anim. Sci. 30:231.

Campling, R. C. and C. C. Balch. 1961. Factors affecting the voluntary intake of food by cows. I. Preliminary observation on the effect of changes in the amount of reticulo-ruminal contents on the voluntary intake of hay. Brit. J. Nutr. 15:523.

Coleman, S. W. 1979. The use of ytterbium as a rumen kinetic marker. J. Anim. Sci. 49(Suppl. 1):38.

Conner, M. C. 1977. Lanthanides as particulate flow markers in ruminants. M. S. Thesis, Texas A&M University.

Conrad, H. R. 1966. Symposium on factors influencing the voluntary intake of herbage by ruminants: Physiological and physical factors limiting feed intake. J. Anim. Sci. 25:227.

Conrad, H. R., A. D. Pratt, and J. W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47:54.

Cook, C. W. 1964. Symposium on nutrition of forages and pastures: Collecting forage samples representative of ingested material of grazing animals for nutritional studies. J. Anim. Sci. 23:265.

Cook, C. W., J. E. Mattox and L. E. Harris. 1961. Comparative daily consumption and digestibility of summer range forage by wet and dry ewes. J. Anim. Sci. 20:866.

Cook, C. W., K. Taylor and L. E. Harris. 1962. The effect of range condition and intensity of grazing upon daily intake and nutritive value of the diet on desert ranges. J. Range Mgt. 15:1.

Cook, C. W., J. L. Thorne, J. T. Blake, and J. Edlefsen. 1958. Use of an esophageal fistula cannula for collecting forage samples by grazing sheep. J. Anim. Sci. 17:189.

Cook, C. W., J. T. Blake and J. W. Call. 1963. Use of esophageal fistula cannulae for collecting forage samples from both sheep and cattle grazing in common. J. Anim. Sci. 22:579.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Edlefsen, J. L., C. W. Cook and J. T. Blake. 1960. Nutrient content of the diet as determined by hand plucked and esophageal fistula samples. J. Anim. Sci. 19:560.

Egan, A. R. 1965. Nutritional status and intake regulation in sheep. III. The relationship between improvement of nitrogen status and increase in voluntary intake of low-protein roughages by sheep. Australian J. Agr. Res. 16: 463.

Egan, A. R. 1972. Nutritional status and intake regulation in sheep. VII. Control of voluntary intake of three and the responses to intraruminal feeding. Australian J. Agr. Res. 23:347.

Ellis, W. C. 1968. Dysprosium as an indigestible marker and its determination by radioactive analysis. J. Agr. Food Chem. 16:220.

Ellis, W. C. 1978. Determinants of grazed forage intake digestibility. J. Dairy Sci. 61:1828.

Ellis, W. C. and J. E. Huston. 1968. ^{144}Ce-^{144}Pr as a particulate digesta flow marker in ruminants. J. Nutr. 95:67.

Ellis, W. C., J. H. Matis and C. Lascano. 1979. Quantitating ruminal turnover. Fed. Proc. 38:2702.

Freer, M. and R. C. Campling. 1963. Factors affecting voluntary intake by cows. V. The relationship between the voluntary intake of food, the amount of digesta in the reticulo-rumen and the rate of disappearance of digesta from the alimentary tract with diets of hay, dried grass or concentrates. Brit. J. Nutr. 17:79.

Gaillard, B. D. E. 1962. The relationship between the cell-wall constituents of roughages and the digestibility of the organic matter. J. Agr. Sci. 59:369.

Galt, H. D., B. Theurer, J. H. Ehrenreich, W. H. Hale and S. C. Martin. 1969. Botanical composition of diet of steers grazing a desert grassland range. J. Range Mgt. 22:14.

Garner, F. J., H. G. Jones and L. Ekman. 1960. Fission products and the dairy cow. The fate of orally administered cerium^{144}. J. Agr. Sci. 55:107.

Gill, S. S., H. R. Conrad and J. W. Hibbs. 1969. Relative rate of in vitro cellulose disappearance as a possible estimator of digestible dry matter intake. J. Dairy Sci. 52:1687.

Goering, G. H. and P. J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). U.S.D.A. Agricultural handbook No. 379.

Hardison, W. A., J. T. Reid, C. M. Martin and P. G. Woolfolk. 1954. Degree of herbage selection by grazing cattle. J. Dairy Sci. 37:89.

Heady, H. F. and D. T. Torell. 1959. Forage preferences exhibited by sheep with esophageal fistulas. J. Range Mgt. 12:28.

Holechek, J. L., M. Vavra and R. D. Pieper. 1982. Methods for determining the nutritive quality of range ruminant diets: a review. J. Anim. Sci. 54:363.

Johnson, W. L. and D. Pezo. 1975. Cell-wall fractions and in vitro digestibility of Peruvian feedstuffs. J. Anim. Sci. 41:185.

Lesperance, A. L. and V. R. Bohman. 1963. The use of fistulated cattle for predicting digestibility. Proc. West. Sect. Amer. Soc. Anim. Sci. 14:1.

Lesperance, A. L., V. R. Bohman and D. W. Marble. 1960a. Development of techniques for evaluating grazed forage. J. Dairy Sci. 43:682.

Lesperance, A. L., E. H. Jensen, V. R. Bohman and R. A. Madsen. 1960b. Measuring selective grazing with fistulated steers. J. Dairy Sci. 43:1615.

Lesperance, A. L., D. C. Clanton, A. B. Nelson and C. B. Theurer. 1974. Factors affecting the apparent chemical composition of fistula samples. Univ. of Nevada Agr. Exp. Sta. Bull. T18.

Lusk, W. C., M. B. Jones, D. T. Torell and C. M. McKell. 1961. Medusahead palatability. J. Range Mgt. 14:248.

MacDougall, D. and W. A. DeLong. 1942. Effect of intial drying temperature on the apparent lignin content of plant tissues. Can. J. Res. 20:40.

MacRae, J. C. 1974. The use of intestinal markers to measure digestive function in ruminants. Proc. Nutr. Soc. 33:147.

Mayland, H. F. and A. L. Lesperance. 1977. Mineral composition of rumen fistula samples compared to diet. J. Range Mgt. 28:448.

Maynard, L. A., J. K. Loosli, H. F. Hintz and R. G. Warner. 1979. Digestive processes in different species. In: J. R. Campbell (Ed.) Animal Nutrition. McGraw-Hill Book Co., New York. p. 21.

McDougall, E. I. 1948. Studies on ruminant saliva. I. The composition and output of sheeps' saliva. Biochem. J. 43:99.

McManus, W. R. 1961. Properties of roughage feedstuffs collected from oesophageal fistulas. Australian J. Exp. Agr. and An. Husb. 1:159.

Metcalfe, D. S. 1976. The Botany of Grasses and Legumes. In: M. E. Heath, D. S. Metcalfe, and R. F. Barnes (Ed.) Forages. Iowa State University Press, Ames.

Minson, D. J. 1971a. The digestibility and voluntary intake of six panicum varieties. Australian J. Exp. Agr. Anim. Husb. 11:18.

Minson, D. J. 1971b. The nutritive value of tropical pastures. J. Australian Inst. Agr. Sci. 37:325.

Minson, D. J. 1972. The digestibility and voluntary intake by sheep of six panicum varieties. Australian J. Exp. Agr. Anim. Husb. 12:21.

Minson, D. J., C. E. Harris, W. F. Raymond and R. Milsord. 1964. The digestibility and voluntary intake of S22 and H1 ryegrass, S170 tall fescue, 548 timothy, S215 meadow fescue and germinal cocksfoot. J. Brit. Grassland Soc. 19:298.

Minson, D. J. and R. Milford. 1966. The energy values and nutritive value indices of Digitaria decumbens, Sorghum almum and Phaseolus atropurpureus. Australian J. Agr. Res. 17:411.

Moore, J. E., G. L. Ellis, C. E. Rios and M. Koger. 1969. Estimates of the voluntary intake and nutrient digestibility of bahiagrass pasture by grazing steers. Soil Crop. Sci. Soc. Florida, Proc. 29:168.

Moore, J. E. and G. O. Mott. 1973. Structural inhibitors of quality in tropical grasses. In: A. G. Matches (Ed.) Anti-quality components in Forages. Crop Sci. Soc. of Amer., Madison, WI. pp. 53.

Nelson, A. B. 1969. Methods of sampling and measuring intake of grazed forages. Annual Progress Report, Southern Regional Research Project S-45. Okla. Agr.

Exp. Sta. p. 8.

Osbourn, D. F., D. J. Thomson and R. A. Terry. 1966. The relationship between voluntary intake and digestibility of forage crops, using sheep. Int. Grassland Congr., Proc. 10th (Helsinki, Finland). p. 363.

Owen, J. B., D. A. R. Davies and W. J. Ridgman. 1969. The control of voluntary food intake in ruminants. Anim. Prod. 11:511.

Prigge, E. C., G. A. Varge, J. L. Vicini and R. L. Reid. 1981. Comparison of ytterbium chloride and chromium sesquioxide as fecal indicators. J. Anim. Sci. 53: 1629.

SAS. 1979. Users Guide. SAS Institute Inc. Raleigh, North Carolina.

Smith, A. E. 1977. Influence of temperature on tall fescue forage quality and culm base carbohydrates. Agron. J. 69:745.

Smith, L. W., H. K. Goering and C. H. Gordon. 1972. Relationships of forage compositions with rates of cell wall digestion and indigestibility of cell walls. J. Dairy Sci. 55:1140.

Somers, M. 1961. Factors influencing the secretion of nitrogen in sheep saliva: I. The distribution of nitrogen in the mixed and parotid saliva of sheep. Australian J. Exp. Biol. & Med. Sci. 39:111.

Teeter, R. G., F. N. Owens and G. W. Horn. 1979. Ytterbium as a ruminal marker. Abst. Amer. Soc. of Anim. Sci. p. 412.

Tergas, L. E., W. G. Blue and J. E. Moore. 1971. Nutritive value of fertilized Jaragua grass (Hyparrhenia rufa (Nees) Stapf.) in the wet-dry Pacific region of Costa Rica. Trop. Agr. Trinidad. 48:1.

Theurer, C. B. 1970. Determination of botanical and chemical composition of the grazing animals diet. In: Natl. Conf. Forage Quality Evaluation and Utilization. Nebraska Center for Continuing Education, Lincoln.

Thornton, R. F. and D. J. Minson. 1972. The relationship between voluntary intake and mean apparent retention time in the rumen. Australian J. Agr. Res. 23:87.

Tilley, J. M. A., R. A. Terry, R. E. Deriaz and G. E. Outen. 1969. The digestibility of structural carbohydrates of grasses by rumen microorganisms in vitro. J. Brit. Grassl. Soc. 24:238.

Torell, D. T. 1956. Development of a point system for plant composition analyses of hand-clipped and fistula-collected samples for nutrition studies. In: Annual Calif. Agr. Exp. Sta. p. 2.

Ulyatt, M. J., K. L. Blaxter and I. McDonald. 1967. The relations between the apparent digestibility of roughages in the rumen and lower gut of sheep, the volume of fluid in the rumen and voluntary reed intake. Anim. Prod. 9:463.

Van Dyne, G. M. 1960. Range investigations. In: Annual Progress Report, Western Regional Research Project W-34. Mont. Agr. Exp. Sta. p. 9.

Van Dyne, G. M. 1962. Micromethods for nutritive evaluation of range forages. J. Range Mgt. 15:303.

Van Dyne, G. M. 1963. Comparative chemical and botanical composition of fistula forage samples. Abst. Amer. Soc. range Mgt. p. 45.

Van Dyne, G. M., N. R. Brockington, Z. Szocs, J. Duek and C. A. Ribic. 1980. Large herbivore subsystem. In: A. I. Breymeyer and G. M. Van Dyne (Ed.) Grasslands, systems Analysis and Man. Cambridge Univ. Press, Cambridge, England.

Van Dyne, G. M. and D. T. Torell. 1964. Development and use of the esophageal fistula. J. Range Mgt. 18:78.

Van Dyne, G. M. and J. L. Van Horn. 1959. The hole in the throat technique. Montana Wool Grower. 33:52.

Van Soest, P. J. 1962. The estimation of forage protein digestibility and determination of the effects of Heat-drying upon forages by means of the nitrogen content of acid-detergent fiber. Ann. Meeting Amer. Dairy Sci. Assoc. p. 16.

Van Soest, P. J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci. 24:838.

Van Soest, P. J. and R. H. Wine. 1968. Determination of lignin and cellulose in acid-detergent fiber with permanganate. J. Assoc. Official Anal. Chem. 51:780.

Ventura, M., J. E. Moore, D. E. Franke and O. C. Ruelke. 1972. Nutritive evaluation of Pangola digitgrass hays. J. Anim. Sci. 35:234.

Waldo, D. R., L. W. Smith and E. L. Cox. 1972. Model of cellulose disappearance from the rumen. J. Dairy Sci. 55:125.

Weir, W. C. and D. T. Torell. 1959. Selective grazing by sheep as shown by a comparison of the chemical composition of the range and pasture forage obtained by hand-clipping and that collected by esophageal fistulated sheep. J. Anim. Sci. 18:641.

Weston, R. H. 1971. Factors limiting the intake of feed by sheep. V. Feed intake and the productive performance of the ruminant lamb in relation to the quantity of crude protein digested in the intestines. Australian J. Agr. Res. 22:307.

Zemmelink, G., R. J. Haggar and J. H. Davies. 1972. A note on the voluntary intake of Andropogon gayanus hay by cattle, as affected by level of feeding. Anim. Prod. 15:85.

APPENDIX

TABLE 1. EXAMPLE OF ANALYSIS OF VARIANCE, VOLUNTARY INTAKE (KILOGRAMS PER DAY)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Treatment	2	15.19	7.59	9.06**
Period	1	29.27	29.27	34.89***
Block	5	17.95	3.59	4.28*
Treatment x period	2	2.92	1.46	1.74
Treatment x block	10	21.76	2.18	2.59*
Error	15	12.58	.84	
Total	35	99.66		

*($P < .05$), **($P < .01$), ***($P < .001$).

TABLE 2. EXAMPLE OF ANALYSIS OF VARIANCE, PERCENT CRUDE PROTEIN, DRY BASIS

Source	Degrees of freedom	Sum of squares	Mean squares	F
Treatment	2	37.63	18.82	18.27***
Day	9	8.76	.97	.94
Error	18	18.52	1.03	
Total	29	64.91		

***($P < .001$).

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DIGESTIBILITY, INTAKE AND SELECTIVITY

OF THREE MIXED-FORAGE

PASTURES BY CATTLE

by

K. P. Thompson

(ABSTRACT)

A grazing trial was conducted to determine the relative value of three mixed-forage pastures, alfalfa-orchardgrass, bluegrass-white clover, and fescue-red clover. Three steers, three heifers and one esophageally cannulated steer were randomly assigned to each pasture treatment. Chemical composition, digestibility, voluntary intake, and selectivity of the forages were determined through use of esophageally cannulated steers and a rare earth marker (ytterbium). Forage intake appears to be most closely related to DM digestibility and content of the NDF and ADF fiber fractions. Some degree of forage selectivity was observed, although the specific species selected for and determinants of selectivity were not apparent. From the data obtained on levels of intake, digestibility and chemical composition, alfalfa-orchardgrass and bluegrass-white clover offer the highest quality forage of the three compared during the time of year studied. Fescue-red clover was consistently inferior in all respects. The digestible dry matter intake by cattle grazing alfalfa-orchardgrass, bluegrass-white clover and fescue-red clover

was 3.2, 2.9 and 2.2 kg/d, respectively. More work needs to be done on a wider variety of pastures during different times of the grazing season.
(Key words: Beef Cattle, Forage, Voluntary Intake, Digestibility, Chemical Composition, Selectivity).