SEASONAL DIFFERENCES IN APPARENT DIGESTIBILITIES OF FESCUE AND ORCHARDGRASS/CLOVER PASTURES BY HORSES

by

Deborah L. Moffitt

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
Master of Science
(Equine Nutrition)
in
Animal Science

APPROVED:

T. N. Meacham, Chairman

J. P. Fontenot

V. G. Allen

A. N. Huff

August, 1987

Blacksburg, Virginia

SEASONAL DIFFERENCES IN APPARENT DIGESTIBILITIES OF FESCUE AND ORCHARDGRASS/CLOVER PASTURES BY HORSES

by

Deborah L. Moffitt

T. N. Meacham, Chairman

Animal Science

(ABSTRACT)

An experiment was conducted to determine intake and apparent digestibilities of Kentucky 31 tall fescue (Festuca arundinacea schreb.) and orchardgrass/clover (Dactylus glomerata L./Trifolium pratense L.) pastures in different seasons of the year. Three digestion trials were conducted in December, 1985 (winter), May, 1986 (spring) and August, 1986 (summer). Five horses grazed each pasture type. A double marker procedure was used with indigestible neutral detergent fiber (INDF) and Yb as internal and external markers, respectively. Apparent digestibility of dry matter (DM), crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined. Digestibility of orchardgrass/clover components were not different between winter and spring, but were higher ($P<.05$) in DM, ADF and NDF digestibilities in the summer. Fescue DM and ADF digestibilities were higher ($P<.05$) in the winter while apparent digestibility of CP was higher ($P<.05$) in the spring. In summer orchardgrass/clover DM, ADF and NDF digestibilities

were higher ($P<.05$) than fescue. Dry matter intake was not significantly different between forages. Orchardgrass/clover intake was lowest ($P<.05$) in the winter. Fescue dry matter intake was highest ($P<.05$) in the summer.

ACKNOWLEDGEMENTS

My first thanks go to my parents, , for instilling in me the desire and ambition to learn. Their love and support gave me the courage to try and the will to continue.

Next, of course, is my major professor, Dr. Tom Meacham. Without his recognition of my abilities and acceptance of my shortcomings my graduate career would have been impossible. Thanks, also, to Dr. Ginger Rich, at Colorado State University, for the inspiration to continue my education and to Dr. Huff for giving me responsibility and education outside the classroom.

I am grateful to Dr. J.P. Fontenot and Dr. V.G. Allen for allowing me to use their laboratories and equipment. I am also grateful to and for their assistance and instruction in my lab work and statistical analysis.

Appreciation is also extended to those fellow graduate students who gave me not only guidance, assistance and support, but friendship.

Special appreciation goes to the family, , . Thanks especially to , whose understanding and care will never be forgotten.

But above all, I owe the most to , for always being there, no matter what, and , for being the closest friend I'll ever have.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Maintaining a horse becomes more expensive for owners every year. As the horse is a nonruminant herbivore and relies primarily on the ingestion of roughages for nutrients, feeding systems maximizing forage utilization need to be examined. Little work has been done regarding the efficiency of grazing pastures with horses. Tall fescue and orchardgrass are two of the most prevalent, high quality pasture species grown in the southeastern United States. Fescue alone covers more than 800,000 acres in Virginia. Although these grass species are used extensively for grazing cattle and sheep, their utilization by horses has received only limited study.

Practical methods of estimating forage intake and fecal output by grazing animals have only recently been developed. The use of marker procedures in ruminant grazing studies has been researched in depth in recent years. However, only limited application of these techniques in equine experiments has been reported. Ytterbium has been used extensively in ruminant pasture digestibility studies as an external marker (Teeter et al., 1979, 1984). The pulse dose procedure involves a single administration of external marker to estimate fecal output and subsequently dry matter intake. This procedure has been used successfully in ruminants and recently in horses (Meacham, 1987).

The objective of this study was to determine the DM, CP, ADF and NDF digestibility of orchardgrass/clover and Ky31 tall fescue pasture, by horses,in different seasons of the year, using Yb as an external marker to determine dry matter intake.

REVIEW OF LITERATURE

Tall Fescue as a Pasture Grass

Tall fescue grows on an estimated 12 to 14 million ha in the United States (Buckner et al., 1985) and is considered to be one of the predominant cool season perennial grasses. The primary use of tall fescue is forage production for livestock. It is the major cool season grass species in the transition zone of the United States, which spans latitudinally from IN to GA and longitudinally from Eastern KS to the eastern edge of the Piedmont area. Tall fescue grows best on soils that are heavy to medium in texture with considerable humus. However, it has been shown to grow on soils that vary from strongly acidic (pH 4.7) to strongly alkaline (pH 9.5). It will also thrive on droughty slopes and will form a dense thick sod on poorly drained soils. It has gained wide acceptance in the transition zone due to its ability to persist on a variety of soil types. Although tall fescue is a tufted bunchgrass, it possesses a massive root system and when mowed or grazed forms a dense sod. These qualities make it a desirable pasture for horses.

Extensive research with food-producing animals has been conducted to study the performance of the plant itself and its effects on the animals that consume it. Fescue dry mat-

ter production varies from 3 to 10.1 t/ha (Matches, 1979) depending on the management practices employed. According to NRC (1978) tall fescue in the fresh vegetative stage has 67% TDN, 14.5 % CP and 24.6% CF. Burns and Chamblee (1979) state that generally tall fescue is well adapted to the humid temperate areas of the world. Its presence in the more northern latitudes is restricted by cold winter temperatures. The ability of the plant to withstand warmer temperatures has been shown to be related to soil moisture. When soil moisture is adequate, tall fescue stays green and continues to grow; whereas, when moisture is limiting stand thinning occurs.

Wilkinson and Gross (1964) suggested that high temperatures and soil moisture deficits may result in little growth of tall fescue in midsummer. Allinson (1971) showed that both high temperatures and long photoperiods significantly decreased in vitro dry matter digestibility of tall fescue and alternately increased cell wall components. Temperature has been shown to greatly influence the accumulation of non-structural carbohydrates in temperate origin grasses. Investigators have found a higher concentration of total water-soluble carbohydrates in plants grown in low temperatures than in high temperatures (Smith, 1977). It is logical then that quality of fescue is lowest during the summer, intermediate in the spring and highest during the fall.

Crude protein contents of 24% in March and April, 9% in May and 13% in December have been reported by Stritzke and McMurphy (1982). Research results indicate that tall fescue is probably the best cool-season grass available for stockpiling (Buckner, 1985). In Maryland experiments (Archer and Decker, 1977a) tall fescue was considered better adapted than orchardgrass for use as a stockpiled forage, due to its superior fall growth. By allowing the forage to accumulate in the field during autumn, fescue pastures can be and are grazed all year round.

Several studies have been done to evaluate grazing animal performance on tall fescue (Blaser et al., 1956; Gross et al., 1966; Mott et al., 1971; McClaren et al., 1983; Fribourg et al., 1984). Generally, pure stands of tall fescue supported a longer grazing period, a higher stocking rate and a higher gain per ha than did pure stands of orchardgrass and grass-legume mixtures (Buckner, 1985). Gross et al. (1966) and Mott et al. (1971) showed that N fertilization slightly depressed average daily gains but nearly doubled carrying capacities of fescue.

Although fescue has admirable agronomic characteristics and is a heavy producer of forage, several studies have indicated that grazing tall fescue pastures can have undesirable effects. Tall fescue has frequently produced toxic symptoms and/or reduced animal performance in cattle and

horses. The presence of an endophytic fungus Epichloe typhina, or Acremonium coenophialum, has been related to these disorders in recent studies. Specific syndromes include fescue foot, summer syndrome and fat necrosis in cattle. Fescue foot is usually accompanied by reduced weight gain or a loss of weight, rough hair coat, an arched back and lameness in one or both hind legs (Jacobsen et al., 1963; Garner and Cornell, 1978). Hyperemia and swelling of the coronary band may also occur. The hooves may begin to slough off if the animal is not removed from the toxin. In severe cases the limb may be lost midway between the dewclaw and hoof and the tail may also slough at the switch. This syndrome occurs most often in fall and winter, but has also been reported at other times (Hemken et al., 1984).

Summer syndrome shares some of the same symptoms, but is associated with high ambient temperatures and has other distinct characteristics (Jacobsen et al., 1970; Bond et al., 1977; Bush et al., 1979; Hemken et al., 1979; Steen et al., 1979; Hurley et al., 1981). The high temperatures either increase the sensitivity of the animal to the toxin or increase the level of toxin in the forage. This is the most consistent syndrome seen with tall fescue. Symptoms include reduced growth or milk production; decreased feed intake; rough hair coat; elevated body temperature; increased respiration rate; lower serum prolactin levels; excessive

salivation and reduced reproductive performance. Also the animal will seek wet spots or shade (Hemken et al., 1984).

Fat necrosis is characterized by hard fat masses located in the adipose tissue of the abdominal cavity (Stuedemann et al., 1975). Other symptoms include elevated body temperature, rough hair coat, and lameness. The cattle seek to stand in shade or water and lie in mud. This disorder is associated with high levels of N application or poultry litter.

Another disorder that has not been frequently associated with the others is agalactia. This problem seems to be associated with horses more than cattle. Although the problem has never been produced in a controlled experimental study, (Heimann et al., 1981; Barnett et al., 1985) mares grazing tall fescue have been reported to display reproductive abnormalities. Garrett et al. (1980), Taylor (1983) and Heimann et al. (1981) described reproductive problems in mares grazing highly infected stands of tall fescue. The abnormalities commonly reported include agalactia, prolonged gestation, abortions, stillbirths, and thick, tough placentas that may cause perinatal mortality (Barnett et al., 1985). If mares are removed from the infected fescue at least 90 d before foaling or if the pasture is supplemented with a legume hay, or overseeded with clover, the problems can be reduced or avoided. Pastures with high endophyte levels can

be grazed by non-reproducing mares or males. Meacham (1987) observed no visible toxicity problems in yearlings and 2-yr-old horses grazing tall fescue.

Orchardgrass as a Pasture Grass

Orchardgrass is a cool season perennial that is found from Maine to the Gulf States and from the Atlantic Coast to the Eastern Great Plains. It is common throughout the Appalachian Mountains and is especially well adapted to MD, PA, WV, VA, KY and TN (Jung and Baker, 1985). Orchardgrass grows in clumps and produces an open sod. Like tall fescue, orchardgrass produces a fibrous root system. However, unlike fescue it cannot withstand continuous grazing as animals tend to regraze the same areas and weaken the plant. Therefore, orchardgrass performs best under a rotational grazing system. With high rates of N fertilization, orchardgrass is among the most productive of the cool season grasses. Hay yields of 13.5 t/ha can be expected when orchardgrass is properly fertilized and favorable weather prevails (Washko et al., 1967). However, researchers have shown excess N to be detrimental to plant growth (Donahue et al., 1981). When N is used other nutrients must be maintained in balance to keep production levels high. Optimum temperature for growth has been shown to be 21 C (Brown, 1939; Davidson and Milthorpe, 1965). When

a wide range of day-night temperatureswere examined the optimum combination was 22/12 C (Baker and Jung, 1968a).

Orchardgrass is less heat tolerant than tall fescue, and temperatures above 28 C greatly reduce growth and tillering (Baker and Jung, 1968b). Orchardgrass is only moderately winter-hardy and will usually not survive northern winter climates without snow cover. It is, however, shade tolerant and is found growing in many areas of reduced light (Singh et al., 1974). Also, orchardgrass withstands high light intensities and is found growing in areas of full sunlight as well as shade (Pearce et al., 1965). Orchardgrass is also drought tolerant, which may be attributed to its extensive root system. Additionally, it persists and grows on soils that have moderately poor drainage. Orchardgrass will grow on shallow rather infertile soil and be moderately productive. Yet it becomes very competitive and will become the dominant species when an abundance of nutrients are available. Competitiveness of orchardgrass depends on light, nutrients and moisture (Wilkinson and Gross, 1964).

According to NRC (1978), orchardgrass pasture contains 19% dry matter, 18.4% crude protein, and 55% TDN. Stratton et al. (1979) examined 415 orchardgrass clones and found a range of in vitro dry matter digestibility (IVDMD) from 49% to 68%. Orchardgrass has also been stockpiled for use as a winter forage. When compared to tall fescue as an autumn saved

forage, fescue excelled due to its superior growth (Archer and Decker, 1977a). However, differences in quality were not consistently found between the species. In vitro dry matter digestibility of accumulated orchardgrass was shown to be 73% over a 2-yr study by Archer and Decker (1977a). Blaser et al. (1956) showed orchardgrass to be a more highly palatable and higher quality pasture grass for steers than fescue. However, better gains/ha were seen on the fescue pasture due to its higher carrying capacity. Fribourg et al. (1979) showed orchardgrass pastures to result in more gains per steer over an entire grazing season than any of the bermudagrass (Cynodon dactylon L.) pastures compared to them. When the grazing period extended into July, more steers could be maintained on the bermudagrass. The authors suggested that orchardgrass may be more susceptible to drought stress than bermudagrass in less favorable years. Brown and Blaser (1970) showed that moisture stress resulted in an increase of soluble carbohydrates in orchardgrass. Although growth was reduced with higher temperatures, soluble carbohydrate in stem bases was increased. This is attributed to a greater reduction in utilization than in synthesis of photosynthetic products.

Forage Utilization by the Horse

Little work has been done regarding the utilization of pastures by grazing horses. A study conducted by Jordan and Marten (1975) compared the growth of yearling ponies grazing smooth bromegrass (Bromus inermis Leyss.), orchardgrass and reed canarygrass (Phalaris arundinacea L.). Ponies grazing the orchardgrass had the highest average daily gain (ADG). Thus, the authors concluded that orchardgrass excelled, when compared to the other two grasses as pasture for horses. Simons and Marten (1971) found that ewes grazing orchardgrass also had higher ADG than ewes on reed canarygrass. Several studies have been conducted recently to determine whether growing horses can be raised exclusively on a pasture diet. Rouquette et al. (1985) showed no difference in wither height or ADG for yearlings on either pasture only or pasture plus a 14% CP supplement. They concluded that an exclusive forage ration was a feasible method for development of yearling horses.

Hansen et al. (1987) reported similar results when they compared yearlings raised on 1) pasture alone, 2) pasture plus a daily grain supplement containing 25% and 30% of NRC (1978) requirements for energy and protein, respectively, or 3) pasture plus a daily grain supplement containing 50% and 60% of NRC (1978) requirements for energy and protein, re-

spectively. The authors indicated that high quality, improved pastures can support yearling horses with weight gains consistent with NRC projections and equal to the supplemented yearlings.

Aiken et al. (1985) postulated that horses need to be stocked on pastures at different rates than cattle. Bermudagrass pastures were stocked at the rates of 6.7, 7.9, 9.4 and 12.4 yearling horses/ha. There were no differences in mean wither height gain among the four treatment groups. The ADG for the yearlings on the heavy stocking rate (12.4 animals/ha) was significantly lower than that on the light and medium stocking rates. Selective grazing was evident on those pastures with the lightest stocking rates. The authors postulated that a rotational grazing system would enhance pasture utilization for horses, as the amount of available forage has a significant effect on weight gains. A subsequent study of stocking rates and grazing schemes was then conducted by Webb et al. (1987). Eighteen yearlings were assigned to three stocking rates, 3.8, 4.3, and 5.4 500 kg animal units/ha. Within each stocking rate, three yearlings grazed under a rotational system and three under a continuous grazing system. A positive control group was also maintained consisting of four animals on a continuous grazing scheme at a stocking rate of 3.4 500 kg animal units/ha. These animals were also fed a 13% protein concentrate at 1%

of their body weight. Results of this study indicated that at the stocking rates used there may not be any advantage of rotational over continuous grazing systems. Further, because increases in growth corresponded with increases in forage availability, the increase in forage quality seen in the rotationally grazed paddocks may have been offset by a lack of forage-on-offer. This may have prevented the yearlings from practicing selectivity and/or consuming enough forage to maximize growth.

Digestiblity studies have also been conducted with horses. Fonnesbeck et al. (1967) compared the intakes and digestibilities of several hay varieties by horses. The varieties studied were Penscot red clover (Trifolium pretense L.), Atlantic alfalfa (Medicago sativa L.), timothy (Phleum pratense L.), Lincoln bromegrass, reed canarygrass, orchardgrass, alta fescue and Midland bermudagrass. When fed ad libitum, the horses consumed all of the hay varieties. However, there was a significant preference for legumes over grasses. The legume forages had more digestible crude protein (CP) and digestible nitrogen free extract (NFE), resulting in more digestible dry matter (DM) and total digestible nutrients (TDN). Alfalfa contained less digestible crude fiber (CF) and ether extract (EE) than all other forages and bromegrass had the most digestible CF. A positive correlation was seen between voluntary intake and per-

cent TDN and CP of the forages. Their results indicated that alfalfa and red clover hay are superior to all of the grass hays to which they were compared. There were no differences among the grass hays. The forages were ranked from highest to lowest in nutritive value as follows; red clover, alfalfa, timothy, bromegrass, canarygrass, orchardgrass, bermudagrass and fescue.

The effect of forage maturity on digestibility and nutritive value was studied by Darlington and Hershberger (1968). Four ponies were utilized in a total collection trial. The forages studied were alfalfa, timothy and orchardgrass. The apparent digestibility of DM, CP, CF, EE, NFE, TDN and energy decreased as the forages matured. When the forages were cut at the earliest maturity (pre-bloom) alfalfa was the most digestible, followed by timothy and orchardgrass. At the latest harvest (mid-bloom) timothy was the most highly digestible followed by alfalfa and orchardgrass. The crude fiber digestibility of timothy was higher than alfalfa and orchardgrass regardless of date of harvest. Additionally, date of harvest had no effect on the intake of timothy or orchardgrass. Maturity did, however, have an effect on the intake of alfalfa, as intake decreased with the later harvest dates.

Fonnesbeck (1968) studied the digestion of soluble and fibrous carbohydrate fraction of forages by horses.

Digestibility of the nutrients was shown to be dependant upon forage quality. Forage carbohydrate composition was shown to be the major cause of variation in digestible organic matter and digestible energy. Additionally, cell wall contents increased as the more digestible components decreased with forage maturity.

To determine the species preference of grazing horses, Archer (1973) conducted a palatability study with horses and ponies comparing 29 species of grasses, legumes and herbs. The most palatable was a "clover-rich" mixture. There was very little difference among the perennial ryegrasses (Lulium perenne L.) or between them and timothy or orchardgrass. White clover (Trifolium repens L.) was highly palatable while red clover was rejected. Tall fescue and crested dogs tail (Cynosurus cristatis L.) were also palatable grasses.

In an effort to determine the best method for assessing the nutritive value of forage and feedstuffs for horses, Fonnesbeck (1969) studied several chemical methods available. He compared various systems of partitioning the nutrients of forage to determine which fractions showed the highest nutritive uniformity and estimated the true digestibility of the components by horses. He also compared the true digestibility with apparent digestibility of the fractions. His results showed that the proximate scheme of analysis failed to partition the fibrous portions of the forage into

digestible and indigestible components. Lignin was found in both CF and NFE components. The Van Soest (Van Soest and Wine, 1967) method was more accurate in partitioning the soluble and fibrous components. The fibrous portion (NDF) of the forage was broken down into lignin and holocellulose (cellulose and hemicellulose). Holocellulose, they concluded, is a logical representation of the fibrous carbohydrate and should be used in future forage work with horses.

Although studies are limited in number, it is evident that the horse's ability to utilize forages is sufficient for normal growth and development. While the preferences for legumes are noted, the horse can perform acceptably on grass forages.

Associated Digestibility Studies with Horses

Studies have shown that altering the hay to grain ratio in the equine diet will affect digestibility. With an increase from 1:0 to 1:4 (hay:grain) ratio, DM digestibility increased from 55.5% to 79.7% and NDF digestibility increased from 41.2% to 53.3%, respectively (Hintz et al., 1971). The authors also showed that the major site of soluble carbohydrate digestion was pre-cecal, whereas the major sites of NDF digestion were the colon and cecum, regardless of the hay to grain ratio. Therefore, the importance of the lower gut

digestion increased with increased amounts of forage in the diet. Schurg and Holton (1979) also studied the effect of varying the hay to grain ratio in the diet. Completely pelleted diets consisting of either 1) 50% hay and 50% concentrate (control), 2) 50% ryegrass straw and 50% concentrate, or 3) 68% straw and 32% concentrate were fed to ponies. Body weight gains and feed intake did not differ among treatments. Gross energy and ADF digestibilities decreased as the level of straw in the diet increased.

Factors Affecting Intake

Intake and digestiblity have been shown to be positively correlated. Much research has been conducted to establish relationships between voluntary intake and chemical composition of forages (Van Soest, 1965). Factors affecting intake have been extensively researched in ruminants, especially dairy cows, as intake has been shown to be one of the major factors limiting milk production. Restrictions may arise due to chemical and physical characteristics of the feed or the anatomy and physiology of the animal. Conrad et al. (1964) concluded that physical and physiological factors regulating feed intake change in importance with increasing digestibility. For feeds of low digestibility significant factors were body weight (reflecting roughage capacity), un-

digested residue per unit body weight (reflecting rate of passage), and dry matter digestibility. With diets of higher digestibility intake appeared to be dependant on metabolic size, production and digestibility. Minson (1982) stated that the quantity of herbage eaten by a grazing animal depends on three factors: 1) the availability of the forage, 2) the physical and chemical composition of the forage and 3) the nutrient requirements of the animal. A relationship exists between the bulk of a diet and the quantity that is eaten voluntarily by an animal. This relationship appears to be associated with the filling effect in the gut and is related to such factors as digestibility and rate of passage of a feedstuff. Conrad et al. (1964) proposed that voluntary intake was controlled by "gut fill" over a range of digestibilities. Physical bulk of less digestible forages and capacity of the grazing ruminants' gastrointestinal tract are the dominant factors limiting forage intake. Therefore, voluntary intake of less digestible forages would increase with increasing digestibility of the ration until digestibility and intake levels were achieved which supplied energy equal to the animals capacity to utilize it (Ellis, 1978).

Blaxter et al. (1961) showed that voluntary intake of long fodders by sheep was related to the apparent digestibility of fodder energy, increasing rapidly as digestibility in-

creased from 38% to 70% and more slowly thereafter. This is supported by Van Soest (1965) who concluded that fiber mass inhibits intake of those forages with a high cell-wall content. Fiber mass appeared to be limiting when cell-wall content was between 50% and 60% of the forage DM. Hodgson et al. (1977) supported this concept. A rotational grazing study with calves revealed that the nutrient intake was maximized when calves were offered herbage of the highest possible digestibility, even with some restriction in the weight of standing crop at each grazing. However, fiber content limits intake of forages only if all other chemical components such as protein, vitamins and minerals are present in sufficient amounts (Minson, 1982).

As the horse is a nonruminant herbivore the factors controlling intake in the ruminant cannot be assumed to be identical to those for the horse. It has also been shown that forage intake is not limited by the capacity of the small and large intestine (Grovum and Phillips, 1978). Additionally, the horse has been categorized as a selective grazer, which further complicates using the ruminant as a model for predicting intake in the horse.

The control of feeding in the horse reflects its evolutionary development in an environment which favored consumption of small, frequent meals of a variety of forages. Ralston (1984) determined the stimuli responsible for con-

trolling meal size and duration to be oropharyngeal and external. Meal frequency is regulated by metabolic cues and absorption of nutrients. The factors that regulate feed intake in the horse were grouped into pregastric, gastrointestinal and metabolic cues. Pregastric stimuli include the appearance, taste, smell and texture of the feed and oropharyngeal factors such as prehension, chewing, salivation and swallowing. The control of the size and duration of a meal are heavily dependant upon these stimuli. Taste preferences and olfaction also play an important role in feed intake. Horses may prefer or reject a certain smell or taste. Horses, however, lack the ability to rapidly discern the gross energy content of a feed on the basis of taste. Archer (1973) reported there was no correlation between the gross energy content of a given species of forage and the amount consumed voluntarily by horses. Meal size appears to be controlled primarily on the basis of oropharyngeal stimuli, the sensitivity of which may be regulated by gastrointestinal and metabolic cues at the onset of the meal. Studies suggest that nutrients in both the small and large intestines of ponies generate cues, either pre- or post absorption, which influence the initiation of a meal and possibly the size of subsequent meals. Stimuli are generated by nutrients available for absorption and utilization, which are influenced by the type of nutrient present and its rate

of passage through the intestine (Ralston and Baile, 1982). Distention and osmolarity of ingesta apparently alter intakes only under extreme conditions, setting the upper physiologic limit on the amount eaten in a meal (Ralston and Baile, 1983). Metabolic cues, although unidentified at present, appear to act in conjunction with gastrointestinal stimuli to determine when an individual will begin eating. Changes in available body energy have been shown to influence the onset of feeding and exert delayed effects on meal size and duration.

Markers in Digestibility Studies

Digestion trials can be run by either a direct or indirect method. The direct, or total collection method, can be time consuming and labor extensive. Therefore, researchers over the years have strived to perfect the indirect method; the use of an inert reference substance as an indicator (Maynard et al., 1979). Ideally, this substance should be totally indigestible and unabsorbable, have no pharmacological action on the digestive tract, pass through the tract at a uniform rate, be readily determined chemically, and preferably be a natural constituent of the feed in question (Maynard et al., 1979). Markers are distinguished as either internal, present in the feed, or external, added to the feed. In digestion

trials where intake is known, only one marker is required to determine digestibility. In a grazing study where intake is unknown, a double indicator procedure must be employed if intake is to be estimated. That is, an external marker is used to determine fecal output and subsequent dry matter intake. The internal marker is used to determine nutrient digestibilities.

Several substances have been tested in the quest for the most desirable marker. Chromic sesquioxide was first proposed in 1918. Chromic oxide (Cr_2O_3) has been the most prevalent substance used as an indicator (Haenelin et al., 1966; Knapka et al., 1967; Vander Noot et al., 1967; Prigge et al., 1981). However, many other substances, such as other metal oxides, mineral salts, natural and synthetic dyes, polymers, and plant components have been investigated (Kotb and Luckey, 1972).

Chromic oxide was widely accepted as a marker for many years. However, recently its reliability has been questioned. MacRae (1974) and Langlands (1975) found that chromic oxide does not adhere satisfactorily to the particulate phase of the digesta. Additionally, they found diurnal variation in excretion due to incomplete mixing of the digesta and the chromic oxide. This was also found in burros by Knapka et al. (1967). Ellis et al. (1980) explained that water insoluble materials, such as chromic oxide and synthetic polymers,

are not suitable for markers as they do not associate with one specific phase, particulate or liquid, of the digesta.

Many plant components have been used as internal markers in digestion trials. Lignin was one of the first to be researched. It was widely used for many years, but is now known to be digested to varying degrees by animals. Also, analytical error is inherent in lignin analysis. Therefore, it appears to be of questionable value as a marker (Elam and Davis, 1961). The more commonly used marker today is acid insoluble ash (AIA). Schurg et al. (1977) compared AIA to the total collection method in horses and rabbits. There were no differences in digestiblities among the rabbits, but the EE digestibility of the horses differed. In a later study, Schurg (1981) compared the total collection method to chromic oxide, AIA and lignin marker methods. There were no differences in total collection, chromic oxide or AIA results. Lignin was considered unreliable as it underestimated digestibilities from 12 to 18%. It is suggested that lignin only be used to rank and not to determine specific digestibility values.

Rare earth metals have received much attention recently and have been widely used in ruminant studies. Ytterbium has been researched extensively and has been used effectively as an external marker (Coleman, 1979; Teeter et al., 1979, 1984; Prigge et al., 1981; Pond et al., 1986). It binds

tenaciously with the fiber portion of a feed and therefore remains with the particulate phase of the digesta (Ellis et al., 1980). Ytterbium is a popular rare earth metal as it is readily detected using atomic absorption spectrophotometry and is relatively inexpensive. Ytterbium has been used in horses with limited success (Ellis, unpublished data). However, Meacham (1987) dosed yearling horses in a grazing study with Yb stained feed and were able to estimate fecal output and dry matter intake.

The Pulse-Dose Procedure

Recently, rare earth metals have been used as indicators to determine digesta flow and intake (Ellis et al., 1979, 1980; Prigge et al., 1981; Teeter et al., 1984; Pond et al., 1986). The use of rare earths to determine ruminal turnover of undigested feeds was examined by Ellis et al. (1979). These rare earths were given as a pulse (single) dose. The rare earths were mordated to feed residues which enabled the authors to determine the in-vivo kinetics of the digestive processes. However, mathematical models were applied as the authors considered ingesta flow to be a time-dependent, multicompartmental process in the ruminant. Pond et al. (1986) used this technique in pigs to determine digesta flow rate. However, the compartment turnover rate was considered

to be a single time-dependant compartment model with a time delay. Their results indicate that Yb gives an acceptable estimate of the flow of undigested residues through the tract of non-ruminants also.

Teeter et al. (1984) showed that the method of Yb application is critical. Although Yb binds strongly to feedstuffs, especially those high in fiber and CP, all feedstuffs had both strong and weak binding sites. The Yb can be detached from the weaker binding sites by water dialysis. Also, some organic compounds found in the digestive tract may bind with Yb. Therefore, it is important to minimize the amount of marker release from the labeled feedstuff.

Meacham (1987) used a model similar to that of Pond et al. (1986) to determine the fecal output and dry matter intake in horses. The horse was considered to represent a single time-dependant compartment model with a time delay.

JOURNAL ARTICLE

Abstract

An experiment was conducted to determine the intake and apparent digestibilities of Kentucky 31 tall fescue (Festuca arundinacea Schreb.) and orchardgrass/clover (Dactylis glomerata L./Trifolium pratense L.) pastures in different seasons of the year. Three digestion trials were conducted in December, 1985 (winter), May, 1986 (spring) and August, 1986 (summer). Five horses grazed each pasture type. A double marker procedure was used with indigestible neutral detergent fiber (INDF) and Yb as internal and external markers, respectively. Apparent digestibilities of dry matter (DM), crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined. Digestibility of orchardgrass/clover components were not different between winter and spring, but were higher ($P<.05$) in DM, ADF and NDF digestibilities in the summer. Fescue DM and ADF digestibilities were higher ($P<.05$) in the winter while apparent digestibility of CP was higher ($P<.05$) in the spring. In summer orchardgrass/clover DM, ADF and NDF digestibilities were higher ($P<.05$) than fescue. Dry matter intake was not different between forages. Orchardgrass/clover intake was

lowest ($P<.05$) in the winter. Fescue dry matter intake was highest ($P<.05$) in the summer.

(Key words: Horses, Fescue, Orchardgrass/clover, Digestibilities, Yb Pulse-Dose)

Introduction

The horse is a nonruminant herbivore and relies primarily on the ingestion of roughages for nutrients. Tall fescue and orchardgrass are two of the most prevalent, high quality pasture species grown in the southeastern United States. Tall fescue alone covers more than 800,000 acres in Virginia. Although these grass species are used extensively for grazing cattle and sheep, their utilization by horses has received only limited study.

The use of marker procedures in ruminant grazing studies has been researched in depth in recent years. However, only limited application of these techniques in equine experiments has been reported. Ytterbium has been used in ruminant pasture digestibility studies as an external marker (Teeter et al., 1979, 1984). The pulse dose procedure involves a single administration of external marker to estimate fecal output and subsequently dry matter intake.

The objective of this study was to determine the DM, CP, ADF and NDF digestibility of orchardgrass/clover and Ky31 tall fescue pasture, in different seasons of the year, by horses using Yb as an external marker to determine dry matter intake.

Materials and Methods

Ten 2-yr-old horses of light breeding (six fillies and four geldings) were randomly assigned, within sex, to two pasture groups. One group grazed a 3.5 ha pasture of Ky31 tall fescue (30% endophyte infected) and the other a 3.5 ha pasture of orchardgrass/clover (60% orchardgrass and 40% white clover). The horses were allowed to graze the pastures for a minimum 10-d adjustment period before fecal sampling began. Trials were designated as: 1)Winter (December, 1985); 2)Spring (May, 1986); and 3)Summer (August, 1986). Horse weights averaged 380, 400 and 440 kg for trials 1, 2 and 3, respectively. Horses were removed from the pastures on September 1, 1985, to allow stockpiling of the winter forage.

Grass was clipped from each pasture, the day prior to fecal sampling, with hand shears in an effort to mimick the grazing pattern of the horses. This was then dried and ground in a Wiley mill through a 1 mm screen for chemical analysis.

For each trial a 1200 g sample of the dried forage was soaked for 20 h in 24 liters of a Yb solution containing 50 mg $YbNO_3$/g of forage. The material was then rinsed in an acetic acid solution (1.04 g/ml) for 4 h to remove any loosely bound Yb. Next, it was dried and ground in a hammer mill through a 5 mm screen. Following the adjustment period,

each horse was given a pulse dose of the Yb-stained forage. The pulse dose consisted of 160 g of dried, stained grass, mixed with .5 kg of ground corn grain and anise flavoring to enhance palatability. The animals were dosed by placing the mixture in canvas nose bags. Refusals were kept for subsequent weighing and Yb analysis. In order to minimize the interruption of the normal grazing pattern of the horses, they were not removed from the pasture prior to dosing or during fecal sampling. Horses were dosed and fecal samples were taken in small catch pens located in the pastures. Fecal grab samples were taken at 6, 12, 18, 24, 30, 36, 48, 60, and 72 h post dosing.

Feed and fecal samples were analyzed for Yb content by atomic absorption spectrophotometry using a nitrous oxide flame. One g of dried sample was ashed in a 50 ml pyrex beaker at 500 C in a muffle furnace and then digested in 20 ml of a 50% 3N HCl, 50% 3N HNO_3 solution for 8 h on an oscillating surface. All standards and blanks used for Yb analysis were prepared by digesting Yb-free feces with identical acid solutions to compensate for background interference in the analyses (Ellis et al., 1980; Meacham, 1987).

Fecal output was determined by predicting the excretion pattern of Yb, using the model:

Fecal stained particles = Co $((TP\text{-}TD)TO^{2}Xe^{-TO(TP\text{-}TD)})$;

where TP refers to the hour post dose the sample was taken, Co refers to the initial concentration of marker in the tract, TO represents the time dependant turnover rate and TD refers to the time delay to the first appearance of the marker (Ellis et al., 1979; Meacham, 1987). The model is a modification of a gamma curve which predicts Yb excretion by fitting Yb concentration of the fecal grab samples to the curve by using 50 iterations (Meacham, 1987). Fecal output was then determined by using the equation: Fecal Output = MD/Co; where MD refers to the amount of Yb in the pulse-dose.

Apparent digestibility of the DM, CP, ADF and NDF in the forage was calculated using INDF as an internal marker. The INDF was defined as the residue in NDF solvent following a 48 h in-vitro fermentation by a modification of the Goering and Van Soest (1970) procedure for determination of in-vitro digestible dry matter. A .5 g sample was digested for 48 hours in 10 ml of rumen fluid and 25 ml of artificial saliva (McDougall's buffer) in a 39 C water bath with a constant flow of CO_2. The sample was then transferred into 50 ml of neutral detergent solution and the procedure of Goering and Van Soest (1970) was used to determine the final value (INDF). Percent apparent digestibility was calculated using the formula; $\text{Percent digestibility} = 100 - 100\frac{(\text{INDF in forage}/\text{INDF in feces})}{(\text{nutrient in feces}/\text{nutrient in forage})}$.

Due to problems in preparing the winter and summer forage samples, abnormally high INDF values were obtained. The

grasses were not dried nor frozen immediately after clipping and were allowed to continue respiration. It is postulated that this caused the formation of a Maillard product, which increased the level of indigestible fiber in the grass. Therefore it was necessary to use calculated INDF values to estimate nutrient apparent digestibilities. Previous work with fescue (Meacham, 1987) indicated that INDF content averaged 30% of forage NDF. Fescue INDF in trial 2 of the present study was 29.8% of the NDF. The fescue INDF values for trial 1 and 3 were calculated to be 30% of their respective NDF content. The INDF content of the orchardgrass/clover in trial 2 was 28% of the NDF. Therefore, the calculated value for INDF of orchardgrass/clover forage in trials 1 and 3 was 28% of their respective NDF contents.

Acid insoluable ash (AIA) content of the feed and feces was also determined for use as an alternate marker. The procedure reported by Van Keulen and Young (1977) was used. Quantities of AIA in the forages (winter and summer) were minute. Therefore, digestibility values determined from this marker were outside of an acceptable range.

All forage and fecal samples were analyzed for DM and CP (A.O.A.C., 1980) and ADF and NDF (Goering and Van Soest, 1970).

In the winter the grasses were in a vegetative-dormant stage typical of stockpiled forage (Bagley et al., 1983). In the spring and summer trial the grasses ranged from the vegetative to head stages, depending upon the selective grazing of the horses. Some areas of mature grass were found in the areas where the horses defecated.

Forage dry matter intake was estimated using the formula;

$$\text{Forage intake} = \frac{(\text{fecal output})}{(100 - \text{digestibility})} X 100.$$

The data were analyzed statistically using the general linear models procedure (SAS, 1982). Tukeys pairwise comparisons were used to test for differences between treatment means. The model included effects of trial, treatment and horse.

Results and Discussion

Forage Sample Composition. Chemical composition of the two forages for each trial is shown in table 1. Fescue DM tended to be higher than that of Orchardgrass/clover in the winter trial. Crude protein content of the orchardgrass/clover was higher than fescue in the winter trial. Archer and Decker (1977a,b) also indicated that fall saved orchardgrass had higher CP levels than fall saved fescue. No differences in ADF and NDF content of the two grasses in the winter trial were seen.

Past research (Hobbs et al., 1956; Jung et al., 1974; Archer and Decker, 1977a) has suggested that fescue is more suitable for a fall saved forage as it produced higher live weight gains in cattle, produced more total non-structural carbohydrates and more total DM than orchardgrass/clover. However, Archer and Decker (1977a) showed no consistent differences in quality between the two grass species. In the present study, there were no advantages seen for either forage type. Horses grazing the orchardgrass/clover and the fescue showed no differences in mean weight gains either between or across all trials. This may have been due to the fact that the quantity of forage was not limited in either pasture.

TABLE 1. CHEMICAL COMPOSITION OF FORAGE (dry basis)

Item	Trial 1 Dec		Trial 2 May		Trial 3 August	
	OG[a]	F[b]	OG	F	OG	F
	----------%					
Dry matter	19.00	36.00	34.33	39.63	28.88	25.77
Crude protein	15.83	12.23	19.50	23.17	17.54	21.84
Acid detergent fiber	38.52	38.90	31.53	22.81	44.07	36.14
Neutral detergent fiber	72.27	72.52	64.39	68.98	80.26	80.58

[a]OG = Orchardgrass/clover.
[b]F = Fescue.

In the spring trial the difference in DM was less apparent. However, the fescue tended to have higher CP content than the orchardgrass/clover. The dramatic increase in the CP content of the fescue, as compared to the December trial may have been due to the continuous grazing of the stand prior to the trial. Fribourg and Loveland (1978b) found that stockpiled fescue had lower total N content than fescue which had been short clipped or continuously grazed prior to sampling. They also reported higher total N content in early summer regrowth following harvest. Fertilization may also have affected the CP content. Fribourg and Loveland (1978a) found that percent N in the forage reflected N application during the season of application. The orchardgrass showed slightly higher ADF than fescue in the spring.

In the summer trial the grasses were very similar in chemical composition. Archer and Decker (1977a) found that during summer growing conditions production from both species is similar. Dry matter of both grasses was lower than in the spring trial. Studies have shown that a drought situation may actually increase the quality of forage. While forage production of cool season grasses decrease under summer conditions (Brown and Blaser 1970; Fribourg et al., 1979; McClaren et al., 1983) it has been postulated that several factors which retard growth of grasses also cause an increase in soluble carbohydrates. Moisture stress is thought to be

one of these factors. Crude protein was somewhat lower than in the spring trial. The fescue showed higher CP content than the orchardgrass/clover.

In the summer orchardgrass/clover was somewhat higher than fescue in ADF content. However, NDF values were not different. It has been suggested by Probasco and Bjvstad (1980) that the main response of tall fescue to N fertilization was an increase in fiber production. This may also be true of the orchardgrass/clover pasture.

Apparent Digestibility. Apparent digestibilities of the forages for the three trials are shown in table 2. There were no significant differences among horses. In the winter fescue DM digestibility was higher ($P<.05$) than that of orchardgrass/clover. The higher ($P<.05$) CP digestibility for fescue was the only difference between forages in the spring trial. In the summer trial orchardgrass/clover DM, ADF and NDF digestibilities were higher ($P<.05$).

Dry matter, ADF and NDF digestibilities were highest ($P<.05$) for orchardgrass/clover in the summer, compared to fall and spring, while CP digestibility remained unchanged across trials. Fescue was higher in DM and ADF digestibilities in the winter. Digestibility of fescue NDF was not different across trials.

Seasonal trends in fescue CP digestibility followed previously reported patterns (Darlington and Hershberger, 1968;

TABLE 2. MEAN APPARENT DIGESTIBILITY OF ORCHARDGRASS/CLOVER AND FESCUE FORAGE

	Trial 1 Dec		Trial 2 May		Trial 3 August		
Item	OG[a]	F[b]	OG	F	OG	F	±SE
	----------%----------						
Dry matter	59.71[c]	63.96[e]*	59.91[c]	59.63[f]	65.98[d]	62.04*[ef]	1.1
Crude protein	72.25[c]	72.41[e]	71.39[c]	79.00*[f]	75.79[c]	77.64[ef]	1.4
Acid detergent fiber	54.61[c]	57.24[e]	49.23[c]	50.22[f]	65.02[d]	51.74**[f]	1.6
Neutral detergent fiber	61.61[c]	63.33[e]	63.54[c]	64.71[e]	71.51[d]	65.29**[e]	1.2

[a]OG = Orchardgrass/clover.
[b]F = Fescue.
[cd]Values for orchardgrass/clover in the same line with unlike superscripts differ ($P<.05$) between trials.
[ef]Values for fescue in the same line with unlike superscripts differ ($P<.05$) between trials.
*Values differ ($P<.05$) between forages within trials.
**Values differ ($P<.01$) between forages within trials.

Meacham, 1987) by being lowest in the winter when the CP content was the lowest and highest in the spring when the CP content was the highest. Darlington and Hershberger (1968) and Meacham (1987) noted that CP digestibility is directly proportional to the CP content in the forage. Also, they showed that CP digestibility tended to decline with maturity of the forage. Results of the present study were similar as the lowest CP digestibilities for fescue were in the winter trial, when the forage was most mature. Although orchardgrass/clover tended to show its lowest CP content and digestibility in the winter, there was no significant difference in CP content or digestibility across trials for this forage.

In this study, the digestibility of the fibrous portions of the forages was directly related to the their fiber content. The digestibilty of NDF especially showed a strong trend to increase as the concentration in the forage increased. Digestibilities were highest in the summer when ADF and NDF content were greatest.

Fecal Output and Voluntary Intake. Fecal output and dry matter intake are shown in table 3. No differences were seen among animals for fecal output or DM intake. Fecal output was lower ($P<.05$) in the winter than the spring or summer trials for both forages. Dry matter intake was lowest ($P<.05$) for the orchardgrass/clover in the winter and tended

to be lowest in the winter for fescue. Intake has been shown to be inversely related to the content of the fibrous portions of the forage. Neutral detergent fiber content is considered to be the most reliable predictor of voluntary intake in ruminants (Van Soest, 1965). In this study, the highest intakes were seen in the summer trial when NDF values were also highest. However, it has been shown (Conrad et al., 1964) that this relationship is dependant upon digestibility of the fiber. In the summer trial, digestibility of NDF was highest ($P<.05$) for the orchardgrass and tended to be the highest for the fescue. This suggests that the fiber digestibilities of both pastures were high enough to prevent the fibrous portion of the plant from limiting intake.

Contrary to the findings of Meacham (1987) in which intake was lowest when CP content was highest in fescue pasture, intake was lowest ($P<.05$) for orchardgrass/clover when CP content was lowest (winter) and the intake of fescue also tended to be lowest when the CP content was the lowest (winter).

These results support the conclusions of Meacham (1987) in suggesting that fiber digestibility may not be a reliable indicator of voluntary intake in the horse.

The Predicion of Intake. Lewis (1982) estimates that the average yearling will consume 2.25% of its body weight in DM

TABLE 3. MEAN FECAL OUTPUT AND DRY MATTER INTAKE BY TRIAL (kg/d)

	Trial 1 Dec		Trial 2 May		Trial 3 August	
Item	OG[a]	F[b]	OG	F	OG	F
Fecal output	2.93[c]	2.97[e]	4.33[d]	3.50[f]	3.48[d]	4.96[f]
Dry matter intake	6.79[c]	8.24[e]	10.90[d]	8.67[e]	10.31[d]	12.77[f]

[a]OG = Orchardgrass/clover.
[b]F = Fescue.
[cd]Values for orchardgrass/clover in the same line with unlike superscripts differ ($P<.05$) between trials.
[ef]Values for fescue in the same line with unlike superscripts differ ($P<.05$) between trials.

per day. The average DM intake on a body weight basis in the present study for the winter, spring and summer trials was 2.14, 2.45 and 2.62%, respectively. The average DM intake over all trials was 9.6 kg/d. The horses on this trial were 2-yr-olds at the end of the study in August 1986.

The Pulse-Dose. Research is limited in evaluating the use of a pulse-dose indicator in the equine. Rare earth metals have also been used in only limited numbers. Ytterbium has attained popularity in recent years for ruminant digestion studies. It has been used to a limited degree in the horse (Ellis, unpublished data; Meacham, 1987).

Ellis described the digestive system of the horse as a single, steady-state compartment model. This concept is used to predict the passage rate of particles through the equine digestive tract and associated excretion patterns. The model used to predict the excretion pattern of the marker assumes a time-dependent loss from the compartment and incorporates a time delay between oral dosing of the marker and the first detectable appearance in the feces (Meacham, 1987). This time dependancy is based on the assumption that residence time in the gastrointestinal tract of the horse is based upon particle size, as in the ruminant (Ellis, 1979). Whether this is an accurate assumption is not fully known. Harbers et al. (1981) showed that the horse digests forage leaves in a similar manner as ruminants. However, whether or not they

can digest other forage components as completely is not known. The ruminant is adapted to the time dependant model as there is an efflux of smaller particles from the rumen. The horse does not need to reduce particle size for passage through the digestive tract (Janis, 1975). This presents an argument for the time dependent model. Ellis (unpublished data) found that this model fits the actual excretion curve better than other models based on exponential loss. Additionally, the slow and incomplete mixing in the cecum and colon favor the use of this model (Meacham, 1987).

The results of this study indicate that orchardgrass/clover and fescue are both suitable pastures types for horses. Fescue may be a more desirable forage for winter grazing as stockpiled fescue produces more total dry matter and is of higher quality. Orchardgrass/clover appears to be a more desirable summer pasture as it has been shown previously to be more palatable and (in this study) of higher digestibility. Both grasses were suitable for spring grazing.

Ytterbium appeared to be an effective external marker to determine fecal output for the grazing horse. Estimation of fecal output and DM intake are consistent with those previously reported for yearling and 2-yr-old horses. Also, the dosing of the horses and the analysis of feedstuffs and feces for Yb were relatively simple and inexpensive.

LITERATURE CITED

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

Aiken, G.E., G.D. Potter, B.E. Conrad and G.W. Webb. 1985. Growth performance of yearling horses grazed at different stocking rates on Bermudagrass pastures. Proc. 9th Equine Nutr. Physiol. Symp., East Lansing, MI. p 20.

Allinson, D.W. 1971. Influence of photoperiod and thermoperiod on the IVDMD and cell wall components of tall fescue. Crop Sci. 11:456.

Archer, K.A. and A.M. Decker. 1977a. Autumn accumulated tall fescue and orchardgrass. I. Growth and quality as influenced by N and soil temperature. Agron. J. 69:601.

Archer, K.A. and A.M. Decker. 1977b. Autumn accumulated tall fescue and orchardgrass. II. Effects of leaf death on fiber components and quality parameters. Agron. J. 69:605.

Archer, M. 1973. The species preference of grazing horses. J. Brit. Grassland Soc. 28:123.

Bagley, C.P., J.P. Fontenot, R.E. Blazer and K.E. Webb, Jr., 1983. Nutritional value and voluntary intake of tall fescue (Festuca arundinacea Schreb.) fed to sheep. J. Anim. Sci. 57:1383.

Baker, B.S. and G.J. Jung. 1968a. Effect of environmental conditions on the growth of four perennial grasses. I. Response to controlled temperature. Agron. J. 60:155

Baker, B.S. and G.J. Jung. 1968b. Effect of environmental conditions on the growth of four perennial grasses. II. Response to fertility, water and temperature. Agron. J. 60:158.

Barnett, D.T., S.G. Jackson and J.P. Baker. 1985. Endophyte-infected tall fescue effects on gravid mares. Proc. 9th Equine Nutr. Physiol. Symp., East Lansing, MI.

Blaser, R.E., R.C. Hammes, Jr., H.T. Bryant, C.M. Kincaid, W.H. Skrdla, T.H. Taylor and W.L. Griffeth. 1956. The value of forage species and mixtures for fattening steers. Agron. J. 48:508.

Blaxter, K.L., F.W. Wainman and R.S. Wilson. 1961. The regulation of food intake by sheep. Anim. Prod. 3:51.

Bond, J., J.B.Powell., D.J. Undersall, L.I. Colbert and R.R. Oltjen. 1977. Steers grazing fescue with different perloline levels. J. Anim. Sci. 45(Suppl. 1):37.

Brown, R.H. and R.E. Blaser. 1970. Soil moisture and temperature effects on growth and soluble carbohydrates of orchardgrass. Crop Sci. 10:213.

Buckner, R.C. 1985. The fescues. In: M.E. Heath, R.F. Barnes and D.S. Metcalfe (Ed.) Forages The Science of Grassland Agriculture. Iowa State Univ. Press Ames, IA.

Burns, J.C. and D.S. Chamblee. 1979. Adaptation. In: R.C. Buckner and L.P. Bush (Ed.) Tall Fescue Monograph. Amer. Soc. Agron., Madison, WI.

Bush, L.P., J.A. Boling and S.G. Yates. 1979. Animal Disorders. In: R.C. Buckner and L.P. Bush (Ed.) Tall Fescue Monograph. Amer. Agron. Soc., Madison, WI.

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

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

Darlington, J.M. and T.V. Hershberger. 1968. Effect of forage maturity on digestibility, intake and nutritive value of alfalfa, timothy and orchardgrass by equine. J. Anim. Sci. 27:1572.

Davidson, J.L. and F.L. Milthorpe. 1965. The effect of temperature on the growth of cocksfoot (Dactylis glomerata L.). Ann. Bot. 29:407.

Donahue, S.J., R.J. Bula, D.A. Holt and C.L. Rhykerd. 1981. Morphological development, yield and chemical composition of orchardgrass at several soil nitrogen levels. Agron. J. 73:5.

Elam, C.J. and R.E. Davis. 1961. Lignin excretion by cattle fed a mixed ration. J. Anim Sci. 20:484.

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

Ellis, W.C., C. Lascano, R. Teeter and F.N. Owens. 1980. Solute and particluate flow markers. Protein Symp., Oklahoma State Univeristy, Stillwater, OK. p 37.

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

Fonnesbeck, P.V., R.K. Lydman, G.W. Vander Noot and L.D. Symans. 1967. Digestibility of the proximate nutrients of forage by horses. J. Anim. Sci. 26:1039.

Fonnesbeck, P.V. 1968. Digestion of soluble and fibrous carbohydrate of forage by horses. J. Anim. Sci. 27:1336.

Fonnesbeck, P.V. 1969. Partitioning the nutrients of forage by horses. J. Anim. Sci. 28:624.

Fribourg, H.A., J.B. McClaren, K.M. Barth, J.M. Bryan and J.T. Connell. 1979. Productivity and quality of bermudagrass and orchardgrass-ladino clover pastures for beef steers. Agron. J. 71:315.

Fribourg, H.A., R.J. Carlisle and J.B. McClaren. 1984. Bermudagrass, tall fescue, and orchardgrass pasture combinations with clover or N fertilization for grazing steers. II. The species composition index and variability in forage growth and consumption, and animal performance. Agron. J. 76:615.

Fribourg, H.A. and R.W. Loveland. 1978a. Seasonal production, perloline content, and quality of fescue after N fertilization. Agron. J. 70:741.

Fribourg, H.A. and R.W. Loveland. 1978b. Production, digestibility, and perloline content of fescue stockpiled and harvested at different seasons. Agron. J. 70:745.

Garner, G.B. and C.N. Cornell. 1978. Fescue foot in cattle. In: T.D. Wyllie and L.G. Morehouse (Ed.) Mycotoxic Fungi, Mycotoxins, Mycotoxicosis: An Encyclopedic Handbook, Vol.2. pp. 45-62. Marcel Dekker, New York.

Garrett, L.W., E.D. Heinmann, L.L. Wilson and W.H. Pfander. 1980. Reproduction problems of pregnant mares grazing fescue pastures. Annual Meeting American Society of Animal Science. 322. Abstr.

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

Gross, H.D., L. Goode, W.B. Gilbert and G.L. Ellis. 1966. Beef grazing systems in Piedmont, North Carolina. Agron. J. 58:307.

Grovum, W.L. and G.D. Phillips. 1978. Factors affecting the voluntary intake of food by sheep. I. The role of distension, flow rate of digesta and propulsive motility in the intestines. Brit. J. Nutr. 40:323.

Haenlein, C.F.W., R.D. Holdren and Y.M. Yoon. 1966. Comparative response of horses and sheep to different physical forms of alfalfa. J. Anim. Sci. 25:740.

Hansen, D.K., F.M. Rouquette, Jr., G.W. Webb, G.D. Potter and M.J. Florence. 1987. Performance of yearling horses on pasture and supplemental feed. Proc. 10th Equine Nutr. Physiol. Symp., Fort Collins, CO. p 25.

Harbers, L.H., L.K. McNally, and W.H. Smith. 1981. Digestibility of three grass hays by the horse and scanning electron microscopy of undigested leaf ruminants. J. Anim. Sci. 53:1671.

Heimann, E.D., L.W. Garrett, W.E. Loch, L.S. Morris and W.H. Pfander. 1981. Selenium and reproductive abnormalities in pregnant pony mares grazing fescue pastures. Proc. 7th Equine Nutr. Physiol. Symp. p 62.

Hemken, R.W., L.S. Bull, J.A. Boling, E. Kane, L.P. Bush and R.C. Buckner. 1979. Summer fescue toxicosis in lactating cows and sheep fed experimental strains of ryegrass-tall fescue hybrids. J. Anim. Sci. 49:641.

Hemken, R.W., J.A. Jackson, Jr., and J.A. Boling. 1984. Toxic factors in tall fescue. J. Anim. Sci. 58:1011.

Hintz, H.F., D.E. Hogue, E.F. Walker, Jr., J.E. Lowe and H.F. Schryver. 1971. Apparent digestion in the various segments of the digestive tract of ponies fed diets with varying roughage to grain ratios. J. Anim. Sci. 32:245.

Hobbs, C.S. T.W. High, Jr., and I. Dyer, Jr. 1956. Orchardgrass and fescue pastures for producing yearling slaughter steers. Tenn. Agric. Exp. Stn. Bull. 386.

Hodgson, J., J.M.Rodrigues Capriles, J.S. Fenlon. 1977. The influence of sward characteristics on the herbage intake of grazing calves. J. Agric. Sci. 89:743.

Hurley, W.L., E.M. Convey, K. Leung, L.A. Edgerton and R.W. Hemken. 1981. Bovine prolactin, TSH, T_4 and T_3 concentrations as affected by tall fescue summer toxicosis and temperature. J. Anim. Sci. 51:374.

Jacobson, D.R., W.M. Miller and D.M. Seath. 1963. Nature of fescue toxicity and progress towards identification of the toxic entity. J. Dairy Sci. 46:416.

Jacobson, D.R., S.B. Carr, R.H. Hatton, R.C. Buckner, A.P. Graden, D.R. Dowden, and W.M. Miller. 1970. Growth, physiological responses, and evidence of toxicity in yearling dairy cattle grazing different grasses. J. Diary Sci. 54:575.

Janis, C. 1975. The evolutionary strategy of the equid and the origin of rumen and cecal digestion. Evolution 30:757.

Jordan, R.M. and G.C. Marten. 1975. Effect of three pasture grasses on yearling pony weight gains and pasture carrying capacity. J. Anim. Sci. 40:86.

Jung, G.A. and B.S. Baker. 1985. Orchardgrass. In: M.E. Heath, R.F. Barnes and D.S. Metcalfe (Ed.) Forages The Science of Grassland Agriculture. Iowa State Univ. Press Ames, IA.

Jung, G.A., R.F. Kocher, C.F. Gross, C.C. Burg and O.L. Bennett. 1974. Seasonal fluctuations of nonstructural carbohydrate concentration in the forage if cool-season grasses. Int. Grassl. Congr. Proc. 12th Moscow, USSR. 12:285.

Knapka, J.J., K.M. Barth, D.G. Brown and R.G. Cragle. 1967. Evaluation of polyethylene, chromic oxide, and cerium-144 as digestibility indicators in burros. J. Nutr. 92:79.

Kotb, A.R. and T.D. Luckey. 1972. Markers in nutrition. Nutr. Abstr. Rev. 42:28.

Langlands, J.P. 1975. Techniques for estimating nutrient intake and its utilization by the grazing ruminant. In: I.W. McDonald and A.C.I. Warner (Ed.).Digestion and Metabolism in the Ruminant. Univeristy of New England, Publishing Unit, Armdale, NSW, Australia.

Lewis, L.D. 1982. Minimum nutrient requirements. In: Feeding and Care of the Horse. p 226. Lea and Febiger. Philadelphia, PA.

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

Matches, A.G. 1979. Management. In: R.C. Buckner and L.P. Bush (Ed.). Tall Fescue Monograph. Amer. Soc. Agron., Madison, WI.

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 41.

McClaren, J.B., R.J. Carlisle, H.A. Fribourg and J.M. Bryan. 1983. Bermudagrass, tall fescue and orchardgrass pasture combinations with clover or N fertilization for grazing steers. I. Forage growth and consumption and animal performance. Agron. J. 75:587.

Meacham, V.B. 1987. Seasonal differences in apparent digestibility of fescue pasture by horses. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Minson, D.J. 1982. Effects of chemical and physical composition of herbage eaten upon intake. In: Nutritional Limits to Animal Production from Pastures. J.B. Hacker (Ed). Proc. Int. Symp. St. Lucia, Queensland, Aust. Commonwealth Agr. Bureaux, UK.

Mott, G.O., C.J. Kaiser, R.C. Peterson, R. Peterson, Jr., and C.L. Rhykerd. 1971. Supplemental feeding of steers on festuca arundinacea schreb. pastures fertilized at three levels of nitrogen. Agron. J. 63:751.

N.R.C. 1978. Requirements of Domestic Animals. Nutrient Requirements of Horses. Sixth Revised Ed. National Academy of Sciences-National Research Council. Washington, D.C.

Pearce, R.B., R.H. Brown and R.E. Blaser. 1965. Relationships between leaf area index, light interception and net photosynthesis in orchardgrass. Crop Sci. 5:553.

Pond, W.G., K.R. Pond, W.C. Ellis and J.H. Matis. 1986. Markers for estimating digesta flow in pigs and the effects of dietary fiber. J. Anim. Sci. 63:1140.

Probasco, G.E. and A.J. Bjugstad. 1980. Influence of fertilizer aspect, and harvest date on chemical constituents and in-vitro digestibility of tall fescue. J. Range Man. 33:244.

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

Ralston, S.L. 1984. Controls of feeding in the horse. J. Anim. Sci. 59:1354.

Ralston, S.L. and C.A. Baile. 1982. Gastrointestinal stimuli in the control of feed intake in ponies. J. Anim. Sci. 55:243.

Ralston, S.L. and C.A. Baile. 1983. Effects of intragastric loads of xylose, sodium chloride and corn oil on feeding behavior in ponies. J. Anim. Sci. 56:302.

Rouquette, F.M., Jr., G.W. Webb and G.D. Potter. 1985. Influence of pasture and feed on growth and development of yearling Quarter Horses. Proc. 9th Equine Nutr. Physiol. Symp., East Lansing, MI. p 14.

Schurg, W.A. 1981. Compilation of data evaluating various techniques for determining digestion of equine rations. Proc. 7th Equine Nutr. Physiol. Symp., Warrenton, VA. p 1.

Schurg, W.A., D.L. Frei, P.R. Cheeke and D.W. Holton. 1977. Utilization of whole corn plant pellets by horses and rabbits. J. Anim. Sci. 45:1317.

Schurg, W.A. and D.W. Holton. 1979. Digestibility in ponies fed completely pelleted diets containing various levels of ryegrass straw. Proc. 6th Equine Nutr. Physiol. Symp., College Station, TX. p 86.

Simons, A.B. and G.C. Marten. 1971. Relationship of indole alkaloids to palatability of Phalaris arundinacea, L. Agron. J. 63:915.

Singh, M., W.L. Ogren and J.M. Widholm. 1974. Photosynthetic characteristics of several C_3 and C_4 plant species when grown under different light intensities. Crop Sci. 14:563.

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

SAS. 1982. SAS Users Guide. Statistical Analysis System Institute Inc. Cary, N.C.

Steen, W.W., N. Gay, J.A. Boling, R.C. Buckner, L.P. Bush and G. Lacefield. 1979. Evaluation of Kentucky 31, G1-306, G1-307 and Kenhy tall fescue as a pasture for yearling steers. II. Growth, physical response and plasma constituents of yearling steers. J. Anim. Sci. 48:618.

Stratton, S.D., D.A. Sleper, A.G. Matches. 1979. Genetic variation and interrelationships of in vitro dry matter disappearance and fiber content in orchardgrass herbage. Crop Sci. 19:329.

Stritzke, J.F. and W.E. McMurphy. 1982. Shade and N effects on tall fescue production and quality. Agron. J. 74:5.

Stuedemann, J.A., S.R. Wilkinson, D.J. Williams, H. Ciordia, J.W. Ernst, W.A. Jackson and J.B. Jones, Jr. 1975. Long-term broiler litter fertilization of tall fescue pastures and health and performance of beef cows. Proc. 3rd Int. Symp. Livestock Wastes. p 264.

Taylor, M.C. 1983. Toxicity in pregnant mares on Kentucky-31 fescue. M.S. Thesis, Univeristy of Missouri, Columbia.

Teeter, R.G., F.N. Owens and G.W. Horn. 1979. Ytterbium as a ruminal marker. J. Anim. Sci. 49 (Suppl. 1):412 (Abst.).

Teeter, R.G., F.N. Owens and T.L. Mader. 1984. Ytterbium chloride as a marker for particulate matter in the rumen. J. Anim. Sci. 58:465.

Van Keulen, J. and B.A. Young. 1977. Evaluation of acid-insoluable ash as a natural marker in ruminant digestibility studies. J. Anim. Sci. 44:282.

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. 24:834.

Van Soest, P.J. and R.H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell wall constituents. J. Assoc Official Anal. Chem. 50:55.

Vander Noot, G.W., L.D. Symons, R.K. Lydman and P.V. Fonnesbeck. 1967. Rate of passage of various feedstuffs through the digestive tract of horses. J. Anim. Sci. 26:1309.

Washko, J.B. Jung, A.M. Decker, R.C. Wakefield, D.D. Wolf and M.J. Wright. 1967. W. Va. Agr. Exp. Sta. Bull. 557T.

Webb, G.W., B.E. Conrad, M.A. Hussey and G.D. Potter. 1987. Growth of yearling horses under continuous or rotational grazing systems at three levels of forage-on-offer. Proc. 10th Equine Nutr. Physiol. Symp., Fort Collins, CO. p 31.

Wedin, W.F., I.T. Carlson, and R.L. Netter. 1967. Fall-saved forages. Crops Soils. 19:17.

Wilkinson, S.R. and C.F. Gross. 1964. Competition for light, soil moisture and nutrients during Ladino clover establishment in orchardgrass sod. Agron. J. 56:389.

The vita has been removed from the scanned document