SEASONAL DIFFERENCES IN APPARENT DIGESTIBILITY AND INTAKE OF TALL FESCUE BY HORSES

by

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INTRODUCTION

The horse, a nonruminant herbivore, relies primarily on the ingestion of roughages for nutrients. Of the many grass species grown in Virginia, tall fescue (Festuca arundinacea Schreb.) is the major species on over 800,000 hectares (Allen, personal communication). Many characteristics of fescue make it particularly well suited for the horse farm. It forms a dense, long lasting, durable sod, which enables it to withstand the heavy traffic associated with pastures and paddocks. It is drought resistant and adapted to a wide variety of both soil and climatic conditions. Work with cattle has shown that fescue is a nutritious forage in the early spring and late fall and is well suited for stockpiling as a winter forage. This could be particularly advantageous to horse producers, enabling them to extend the grazing season well beyond the fall months.

Over the last two decades little research has been conducted evaluating the utilization of forages by horses. However, during this time numerous technical advances have been made in the procedures employed in ruminant grazing studies. The pulse-dose procedure has become a convenient method of determining intake, requiring only a single dose of marker. The use of particulate bond markers such as metabolic isotopes and rare earth metals have also become a reliable and potentially more accurate alternative to the use of liquid-phase markers such as chromic oxide (Ellis et al., 1980).

Much concern has surrounded the use of fescue as a pasture species for grazing animals. Many health problems have been associated with fescue pastures infected with the fungus, Acremonium coenophialum Morgan-Jones and Gam (Hemkem et al., 1984). The fungus-infected fescue has been associated with various health problems in cattle. The most commonly occurring problems associated with horses grazing fescue are reproductive problems in pregnant mares. Frequently, other problems reported are agalactia, abortion of foals, thickened placentas and prolonged gestation. It is commonly advised that horse owners remove brood mares from fescue pasture during the last trimester of gestation to lessen the incidence of these problems.

Because of the adverse effects seen in pregnant mares grazing fescue pasture, the potential of fescue as a forage for horses other than broodmares has been overshadowed. Therefore, the main objective of this study was to determine digestibility and intake of fescue at different times of the year by grazing yearling and 2-yr-old horses.

LITERATURE REVIEW

Problems Associated with Grazing Fescue Pasture

Numerous authors have reported problems in animal production attributed to fescue pasture. Blaser et al. (1956) found that steers grazing fescue and fescue-ladino clover (Trifolium repens) pastures did not perform as well as steers grazing orchardgrass (Dactylis glomerata) or bluegrass (Poa pratensis) pastures. Weaning weights of calves on fescue pasture were lower, compared to those on other pasture systems (Blaser, 1977). Other symptoms seen in cattle grazing fescue include reduced milk production; rough hair coat; elevated rectal temperature; lameness and soreness in one of more feet; dry gangrene in the legs, tail and ears; and fat necrosis (Allen, 1983).

Garrett et al. (1980), in a survey conducted in Missouri, found that foaling rates were lower for mares grazing fescue pasture (85.7%), compared to mares grazing a mixed pasture containing some fescue (91.5%) or other forage species with no fescue (94.3%). In further research from Missouri it was found that mares supplemented with selenium had no reproductive abnormalities while grazing fescue pasture; however, 50% of unsupplemented mares showed problems at parturition (agalactia and suffocation of foals) (Heimann et al., 1981). In Virginia, conflicting results were found when selenium supplemented mares showed reproductive abnormalities and unsupplemented mares did not (Fontenot, Allen and Meacham, unpublished). It should be noted that results from both studies where inconclusive due to small numbers of animals.

Forage Utilization in Horses

Various trials have been conducted with horses to evaluate the utilization of forages by horses. In a trial by Fonnesbeck et al. (1967) the intakes and digestibilities of Pennscot red clover (Trifolium pretense), Atlantic alfalfa (Medicago sativa), timothy (Phleum pratense), Lincoln bromegrass (Bromus inermis), reed canarygrass (Phalaris arundinacea), orchardgrass , alta fescue, and midland bermudagrass (Cynodon dactylon) were compared. Horses preferred legume to grass hays. Crude protein (CP), nitrogen free extract (NFE) and dry matter (DM) digestibilities were higher for legume hays. The crude fiber (CF) of bromegrass was found to be the most digestible. The greatest difference among horses was in ability to digest CP. A positive correlation was observed between voluntary intake and percent total digestible nutrients (TDN) and CP of the forages. The results of this study demonstrated that the nutritive value of red clover and alfalfa hay was superior to that of the grass species. There were only small differences in nutritive value among the grasses. The forages were rated from highest to lowest nutritive value as follows: red clover, alfalfa, timothy, bromegrass, canarygrass, orchardgrass, bermudagrass and fescue.

Darlington and Hershberger (1968) studied the effect of forage maturity on digestibility and intake of timothy, orchardgrass and alfalfa by equine. Four ponies per treatment were used in a total collection trial utilizing collection harnesses. 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 date (mid-bloom) timothy was the most digestible, followed by alfalfa and orchardgrass. Throughout the experiment timothy had the highest CF digestibility and showed the slowest decline in nutritive value with increasing maturity. Alfalfa exhibited the most rapid decline in nutritive value. They found that generally, digestibility of DM, CP, CF, ether extract (EE) and NFE of all forages decreased with maturity. Digestibility of CP was directly proportional to CP content. Date of harvest (maturity) had no significant effect on the voluntary intake of timothy or orchardgrass, but increased maturity significantly reduced intake of alfalfa.

The digestion of soluble and fibrous carbohydrate of forages by horses was determined in a trial by Fonnesbeck (1968). He found that the quality of forage must be taken into consideration when discussing digestibility of the nutrients. Carbohydrate composition of forage was shown to be the major cause of variation in digestible organic matter and digestible energy among forages. He also found that as cell wall constituents (CWC) increased with maturity the more digestible nutrients (CP, EE, NFE) decreased. Increasing CWC was inversely related to digestibility.

The utilization of the carbohydrate portion of forages by horses was studied by Fonnesbeck (1969). He found that proximate analysis failed to partition the fibrous portions of the forage into digestible and indigestible components. Lignin was found in both CF and NFE components. Lignin digestibility was variable, but generally close to zero. A more accurate partitioning of the soluble and fibrous components was accomplished with the Van Soest scheme of analysis. The fibrous portion of the forage (NDF) was broken down into lignin and holocellulose (cellulose and hemicellulose). Cellulose and hemicellulose digestibilities were nearly identical, and these components were recommended for future forage work with horses.

<u>Associated Digestibility Studies with Horses</u>

Varying the proportions of hay to grain in the diet affects the digestibility of the diet. Hintz et al. (1971)

found that when the hay:grain ratio was increased from 1:0 to 1:4, DM digestion increased from 55.5% to 79.7%. Neutral detergent fiber digestion increased from 41.2% for the 1:0 diet to 53.3% for the 1:4 diet. Chromic oxide was used as an external marker for calculating apparent digestibilities. The author also found that the major site of digestibility of available carbohydrate and protein digestion was pre-cecal; whereas the colon and cecum were the primary sites of NDF digestion, regardless of the hay:grain ratio. Importance of lower gut digestion increased with increased levels of forage in the diet.

The effect of altering the roughage to concentrate ratio was studied by Schurg and Holton (1979). Ponies were fed completely pelleted diets containing various levels of ryegrass straw. Twenty-one mature pony mares were used to determine the maintenance potential and digestibility of the pelleted diets. Two separate trials were performed to compare the acid-insoluble ash versus the total collection method of determining digestibility. Three diets were fed, a control diet containing 50% hay and 50% concentrate, a diet consisting of 50% straw and 50% concentrate and a diet consisting of 68% straw and 32% concentrate. There were no statistically significant differences in feed intake or body weight gain between treatments. Results between the two methods were not different. Dry matter and CP digestibilities were not different between treatments; however, gross energy and ADF digestibilities decreased as the level of ryegrass straw increased in the diets. The authors suggested that while body weight will not be adversely affected using diets of 68% ryegrass straw, energy and fiber digestibilities may be decreased at the higher straw levels.

<u>Use of Markers and Indicators</u>

Digestion trials conducted with horses in the past have relied primarily upon two methods of determining apparent digestibility; the total collection of feces, or the use of indicators. Generally, the most commonly used indicator has been chromic oxide (Cr_2O_3) (Haenlein et al., 1966; Knapka et al.,1967; Vander Noot et al.,1967; Prigge et al., 1981). However, other materials such as plastic beads, (Albert et al., 1979), ^{144}Ce and polyethylene glycol (Knapka et al., 1967) have also been used as external markers. Ideally, the indicator or marker should be indigestible, unabsorbable and physiologically inert, should pass through the digestive tract at a uniform rate, be chemically quantifiable, and would ideally be a natural constituent of the feed (Maynard et al.,1979).

In digestion studies where intake is measured, only one indicator is required to determine digestibility. In grazing studies, intake cannot be easily monitored, therefore two separate indicators are required to determine both intake and apparent digestibility. An external marker, such as chromic oxide, is used to determine fecal output. Forage intake can then be calculated using digestibilities of the forage. Apparent digestibility is determined by using an internal indicator (present in the forage) by comparing the amount in the forage to the amount in the feces.

However, in ruminant studies, the reliability of chromic oxide has been questioned. MacRae (1974) and Langlands (1975) found chromic oxide does not adhere satisfactorily to the particulate phase of the digesta. They also noted diurnal variation in excretion due to incomplete mixing of the digesta and indicator. Knapka et al. (1967) found variation in the rate of excretion of chromic oxide in burros. Ellis et al. (1980) reported water insoluble materials such as chromic oxide and synthetic polymers (rubber and plastic beads) are not suitable as flow markers because they do not associate with either particulate or water soluble fractions of the digesta. This lack of association can result in sedimentation and sporadic transfer throughout the gastrointestinal tract.

Several forage components have been used as internal markers in digestion trials. Two of the most common are AIA and lignin. A comparison between total collection and use of AIA was reported by Schurg et al. (1977). Whole corn plant pellets were fed as the total diet to both horses and rabbits. Digestibilities calculated from the two techniques were not different for CP, ADF, and CWC, but differed for EE in horses. Rabbits were found to have higher digestibilities for CP, but lower ADF and CWC digestibilities compared to horses. Results from the two techniques were not different in rabbits (P>.05).

In a subsequent study, Schurg (1981) compared data obtained by total collection and using chromic oxide, permanganate lignin and AIA as indicators to determine apparent digestibility of a complete diet in horses. No difference was detected between the results obtained by total collection, chromic oxide and AIA. Permanganate lignin was considered unreliable because it underestimated digestibilities from 12 to 18 percentage units, compared to other methods.

The comparative intakes and growth of yearling fillies in drylots and on pasture were evaluated by Heusner and Albert (1977). Chromic oxide was used as an external marker for both drylot and pastured horses. Lignin was used as an internal marker for the horses on pasture. The average percent recovery of chromic oxide from the drylot fillies was 100%. Average dry matter consumption and average daily gains for drylot fillies were 5.55 and .49 kg respectively, and 6.53 and .52, respectively, for fillies on pasture. Feed efficiency, calculated as feed intake divided by gain, was 13.1 for pastured fillies and 13.0 for fillies in the drylot. Digestibilities of feedstuffs were not given.

Rare earth metals, such as Yb, have strong adsorptive properties, which make them suitable for use as particulate markers (Kyker, 1962). Ytterbium binds tenaciously with the fibrous portion of a feedstuff, thereby remaining with the particulate phase of the digesta (Ellis, 1980). Complete recovery of water soluble rare earth salts in the feces was reported if they were applied to a forage (Ellis, 1968). Ytterbium has been the most commonly used rare earth marker in recent digestion studies (Coleman, 1979; Teeter et al., 1979; Tetter et al., 1984). It has many advantages over other rare earth metals. It is relatively inexpensive and can be easily detected using atomic absorption spectrophotometry. No studies were found in the literature which utilized Yb as an indicator in horses but it has been used in digestibility studies with horses with limited success (Ellis, personal communication).

<u>The Pulse-Dose Procedure</u> Rare earth metals have recently been utilized as indicators in pulse-dose procedures for determining ingesta flow characteristics and/or intake in animals (Ellis et al., 1979; Ellis et al., 1980; Prigge et al.,1981; Teeter et al.,1984; Pond et al.,1986). Ellis et al. (1979) reviewed the use of rare earths, given as a single dose (pulse dose), to determine ruminal turnover of undigested feed residues. They found that in-vivo kinetics of the digestive processes could be determined

by mordating the rare earths to feed residues. However, for accurate determinations, appropriate mathematical methods must be applied to consider ingesta flow as a time-dependent, multicompartment process in the ruminant.

Pond et al. (1986) used a pulse-dose technique to estimate digesta flow in pigs. Ytterbium and other rare earth markers were compared to a Cr-mordated diet to determine flow characteristics. Ytterbium was bound to a corn-soybean meal diet and the compartment turnover rate was determined using a single time-dependent compartment model with a time delay. Their results suggested that the Yb pulse-dose provided a reasonable estimate of the flow of undigested residues through the gastrointestinal tracts of nonruminant animals. They also found that the high specific gravity of the Cr-mordated feed slowed flow due to mixing.

Teeter et al. (1984) evaluated the binding strengths of various feedstuffs for Yb, the potential for release of Yb from the binding sites and the subsequent migration to particulate and soluble fractions, and the effect of Yb on the digestibility of the feedstuffs. They found that feedstuffs with higher fiber and CP contents bound more Yb. Each feedstuff had both weak and strong binding sites. Water dialysis of the Yb-labeled feedstuffs detached the Yb from the weaker binding sites. Some organic compounds commonly found in the gastrointestinal tract (lactate, acetate, lysine, glucose, glysine and sucrose) can form complexes with Yb. Therefore, the need to minimize marker release from labeled feedstuffs or residues is necessary. The potential for reduced feedstuff digestibility and Yb migration makes the method of application critical for valid results.

Control of Intake Because the horse is a nonruminant which relies primarily on roughage for its energy needs, the factors controlling its intake cannot be directly extrapolated from either nonruminant or ruminant animals. Ralston (1984) partitioned the factors controlling intake into three areas:

1) Pregastric
2) Gastrointestinal
3) Metabolic

Each area exerts influences upon the size of a meal, the duration of that meal, the frequency of meals in a period of time and the total intake over a period of time.

The pregastric influence on intake is divided into sensory and oropharyngeal (Ralston, 1984). Sensory effects have been studied for many years and include the response to taste, smell and appearance (or form) of a feedstuff. Taste studies conducted by several researchers (Randall et al.,1978; Ott et al.,1979; Burton et al.,1981, Hawkes et al.,1985) have shown that the horse has decided preferences for certain flavors. Randall and associates (1978) found the horse preferred water sweetened with sucrose, compared to ordinary tap water. Indifference to salty (NaCl), sour (acetic acid), and bitter (quinine) solutions was exhibited at low concentrations. At increasingly higher concentrations of these substances the intake diminished up to a point of total refusal. Similar responses were shown by sheep in a study conducted by Goatcher and Church (1970). Burton et al. (1981) found that feeding flavorings such as anize-molasses, caramel, apple and alfalfa aid in masking the undesirable taste of anthelmintic drugs in horse feeds. Cereal grain preferences were ranked in a study by Hawkes et al. (1985). Oats were the preferred grain, followed by corn, barley, wheat, and rye. In the same study, it was shown that oats sweetened with sucrose were preferred over plain oats. They also noted that one individual consistently ate from the feeder on the right side. It was suggested that the preferences shown may result from tastes developed from consistently consuming the same type of grain over long periods of time. Horses in geographic areas where certain grain types may be grown and fed could be expected to show certain preferences.

Forage preferences were quantified by Archer (1973) in a grazing study conducted in Newmark, Suffolk, England. Palatability studies were conducted using 29 species of grasses, legumes, herbs and two-seed mixtures. Clover-rich mixtures were found to be the most palatable. Perennial ryegrass, timothy and orchardgrass were the next most palatable species. Tall fescue-alta was only slightly less palatable than timothy.

Ralston and Baile (1982) demonstrated the importance of oropharyngeal stimuli in the control of intake. Oropharyngeal factors include prehension, mastication, salivation and swallowing. They found that oropharyngeal stimuli alone are sufficient for control of meal size in ponies. This was demonstrated by sham feeding esophogeally-fistulated ponies and leaving the fistula open and preventing swallowed feed from reaching the stomach. No significant difference was observed in meal size or duration following a 4-h fast, compared to controls. The time between meals is primarily controlled by gastrointestinal factors (Ralston and Baile, 1982; 1983). Various nutrient solutions were infused intragastrically and the responses quantified to show the relative reaction times each solution imparted. Glucose and xylose solutions delayed the onset of the first meal in ponies following a 4-h fast. An isocaloric solution of corn oil had no effect on the onset of the first meal. The time between the first and second meal was increased, compared to controls (mineral oil). Direct infusion of cellulose, which must reach the cecum and colon and undergo microbial fermentation before being utilized, showed no effect on intake until 3 to 13 h after treatment, when total intake was reduced. These results suggest that nutrients in both the large and small intestine of equine generate cues, either pre- or post-absorption, which influence feeding activity.

It is well established (Campling, 1970; Grovum, 1979; Baile and Della-Fera, 1981) that in ruminants, distention of the rumen acts as a means of controlling intake. It is thought that this is a means to prevent distress. In the equine, this mechanism is not apparent. Stimuli such as distention and hyperosmolar solutions cause behavior responses related to abdominal malaise (colic) rather than normal satiety (Ralston,1984). Another aspect which differs between ruminants and nonruminants is oropharyngeal control of meal size. In the mature ruminant oropharyngeal factors are probably not important (Campling, 1970; Baile and Della-Fera, 1981). Campling (1970) found that exhaustion of the salivary glands or fatique of the jaw muscles were unlikely means of intake control. Also, there is no evidence that an ability to monitor volume of feed swallowed might influence feeding.

The metabolic cues which regulate feeding in the horse have not been identified (Ralston, 1984). Plasma glucose and insulin concentrations are correlated with cues related to body stores of energy. These blood parameters are associated with feed intake and eating rate over time, yet do not affect immediate feeding activities. The yet unknown metabolic cues act in conjunction with gastrointestinal factors to set the degree of hunger the animal experiences.

The oropharyngeal stimuli may then regulate the meal size and duration, based upon the preset degree of hunger by the metabolic cues.

JOURNAL ARTICLE

ABSTRACT

Three yearling and three 2-year-old Saddlebred horses were used to determine seasonal differences in apparent digestibility of Ky 31 tall fescue (Festuca arundinacea Schreb.) pasture by horses. Three trials were conducted with collection periods beginning August 27, 1984; January 8, 1985; and June 3, 1985. Each 72 h collection period followed a 2 wk preliminary grazing period. The horses were given a pulse-dose of Yb impregnated fescue forage at 0 h, and fecal grab samples were taken at 6, 12, 18, 24, 30, 36, 48, 60, and 72 h after dosing. Fecal output was estimated from Yb concentration in the feces. Apparent digestibilities of dry matter (DM), acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and cellulose were estimated using indigestible NDF as an internal marker. Forage DM intake was calculated using the formula (fecal output/(100- % forage DM digestibility) x 100). Estimated DM intake and fecal DM were 4.5 and 1.7 kg/d for August; 7.5 and 2.7 kg/d for January; and 6.4 and 2.8 kg/d for June, respectively. Percent ADF and NDF were highest ($P<.05$) and apparent digestibilities of these components were lowest ($P<.05$) for the spring forage.
(Key words: Horses, Fescue Pasture, Seasonal Digestibilities, Pulse-Dose)

Introduction

Of the many grass species grown in Virginia, fescue is the primary forage on over 800,000 ha of its pasturelands (Allen, personal communication). Fescue has many characteristics which make it one of the ideal pasture species. It forms a dense, durable sod that withstands the heavy traffic associated with horse paddocks. It is drought resistant and adapted to a wide variety of climates. Fescue is a nutritious forage in the early spring and late fall, and can be stockpiled for winter grazing.

Recently much concern has surrounded the utilization of fescue by grazing animals. Many health and performance problems have been linked to fescue pastures infected with the fungus Acremonium coenophialum Morgan-Jones and Gams. Problems in cattle include poor gains, reduced milk production, elevated rectal temperature, lameness, dry gangrene and fat necrosis (Blaser et al., 1956; Blaser et al., 1977; Allen, 1983). The most commonly reported problems in horses include agalactia, abortions, thickened placentas and prolonged gestation (Garrett et al., 1980).

Because of the problems associated with pregnant mares on fescue, its potential as a pasture species for other horses is often overlooked. A trial was conducted to determine the intake and digestibility of Ky 31 tall fescue pasture by yearling and 2-yr-old horses utilizing a Yb pulse-dose marker technique.

Experimental Procedure

Three trials were conducted to determine the changes in digestibility of fescue pasture by horses at different times in the year. The trial dates were: August 27, 1984; January 8, 1985; and June 3,1985. Each trial consisted of a 2 wk preliminary period followed by a 72 h collection period. Three saddlebred 2-year olds and 3 yearlings were used.

The same 5 ha Ky 31 tall fescue (endophyte-free) pasture was used in each trial. This pasture is located on the campus of Virginia Polytechnic Institute and State University, Blacksburg, VA. The pasture was fertilized prior to the August trial with 52 kg/ha of N. Horses were removed from the pasture following the August trial. The pasture was then clipped and fertilized with 52 kg/ha of N to enable stockpiling of the forage for the January trial. The pasture was not fertilized or clipped prior to the June trial, however, a separate group of horses was maintained on the pasture prior to the preliminary period for the June trial. Pasture samples were obtained for analyses in each trial by hand collection, attempting to mimick the grazing selection of the horses.

Prior to each trial, the horses were removed from the pasture and kept in drylot for 8 to 12 h before receiving the pulse-dose. The pulse-dose consisted of 150 g of

$YbNO_3$ impregnated forage, 75 to 100 g of wet molasses and a maximum of 500 g of ground corn. Mixing the stained forage with corn and molasses was required to obtain adequate intake of the Yb dose and aid in more rapid consumption. The dose was administered by feeding the mixture in polyethylene-lined feeding pans with the horses head movement restricted by cross-ties in front of the feeders. One h was allowed for each horse to consume the dose. During the January trial, one horse refused the dose and was not used in that trial. Refusals were kept for subsequent analysis for Yb concentration.

The Yb-stained forage was prepared by clipping 5 kg of the fresh fescue pasture and drying it in a forced draft oven to approximately 15% moisture. The dried forage was transferred to a 100 l plastic container and soaked in a solution of 20 ml distilled water and 50 mg of $Yb(NO_3)_3$ per g of dried forage for 20 h. The forage was then removed from the Yb solution, drained, and soaked in a .01 M acetic acid solution (20 ml/g of forage) for 4 h to dissociate any weakly bound Yb from the forage, which might otherwise dissociate in the gastrointestinal tract of the horse. The forage was removed from the solution, thoroughly rinsed with distilled water, dried and ground in a Wiley mill through a 5 mm screen.

Upon completion of the dosing procedure, (0 h), the horses were returned to pasture to continue grazing.

Fecal grab samples were taken at 6, 12, 18, 24, 36, 48, 60, and 72 h from each horse. Samples were obtained by confining the horses in a catch pen located in the pasture to minimize stress of excessive handling. Fecal samples were immediately weighed and frozen. Prior to analysis they were dried in a forced-draft oven at 60 C.

Ytterbium concentrations in fecal samples, stained forage, and dose refusals were determined 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 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 and forage with identical acid solutions to compensate for background interference in the analyses (Ellis et al., 1980; Ellis, personal communication).

In-vivo digestibility of the forage was calculated by using indigestible NDF (INDF) as the internal indicator. The INDF was analytically defined as the insoluble residue in neutral detergent fiber solvent following a 96 h in-vitro fermentation by a modification of the Tilley and Terry (1963) technique. Modifications were 1) using .5 g air-dried sample; 2) following a 48-h incubation the tubes were centrifuged at 10,000 x g for 15 min, decanted, and 25 ml acid-pepsin solution added to the tubes (2 g pepsin

+ 82.3 ml of HCl per l of solution). The undigested residue was then dried and weighed and NDF determined using the procedure of Goering and Van Soest (1970). A similar INDF technique was utilized by Ellis et al. (1984) using a modification of the Goering and Van Soest (1970) in-vitro fermentation procedure.

Fecal output was calculated by first predicting the excretion pattern of the marker using the model:

Fecal stained particles =

$$C_o\ [(TP-TD)\ TO^2 \times e^{-TO(TP-TD)}]$$

where TP refers to the hour post dose the sample was taken, C_o refers to the initial concentration of the marker in the GI tract, TO represents the time dependent turnover rate and TD refers to the time delay to the first appearence of the marker (Ellis, 1979; Ellis, personal communication). 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 using 50 iterations. Calculations for R^2 were made for each plot (horse by trial) using the formula:

$$R2 = \frac{(\text{corrected total sum of squares}) - (\text{residual sum of squares})}{(\text{corrected total sum of squares})}$$

where the appearance of fecal stained particles was the dependent variable. Fecal output was then predicted using the formula:

$$\text{Fecal Output} = \frac{MD}{C_o}$$

where MD refers to the amount of Yb in the pulse-dose.

Percent INDF was calculated using the formula:

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

Percent digestibility was calculated using the formula:

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

Forage intake was determined using fecal output and digestibility values:

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

All forage samples were analyzed for DM, ash, CP (A.O.A.C., 1980), NDF, ADF (Goering and Van Soest, 1970), lignin and cellulose (Van Soest and Wine, 1968).

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

Results and Discussion

Forage Sample Composition Stage of growth for the fescue varied within the pasture in August and June due to the selective grazing of the horses. Generally, the forage was in a range from vegetative to boot stage in the areas where the horses were observed grazing. Some mature fescue was found in the elimination areas of the pasture. During the January trial, the fescue was in a vegetative-dormant stage typical of stockpiled fescue (Bagley et al. 1983). Forage availability was not limited in any of the trials. The chemical composition of the pasture samples for each trial are shown in table 1. The DM did not differ (P>.05) between trials. Crude protein content differed (P<.05) between trials, with values being highest in August and lowest for January.

Prior to the initiation of the August trial, the fescue pasture was fertilized with N. This may have affected the chemical composition of the fescue. Fribourg and Loveland (1978a) found that percent N in forage reflected N application during the season of application. This may explain the higher (P<.05) CP content in late August, during the period when CP content in fescue is expected to be low. The stand was also fertilized prior to the January trial; however, this application was made immediately following the August trial. The January trial was conducted approximately 3 mo after the first trial, utilizing the stockpiled forage. Little residual effects of the fertilization were seen in January.

The continual grazing of the stand prior to the June trial may also explain the higher CP content in the late

Table 1. CHEMICAL COMPOSITION OF FORAGES

Month	Dry matter	Dry Matter Composition, %					
		Crude protein	Neutral detergent fiber	Acid detergent fiber	Lignin	Cellulose	Ash
August	29.9[a]	19.0[a]	51.8[a]	29.7[a]	3.7[a]	26.0[a]	4.6[a]
January	30.2[a]	14.7[c]	49.8[a]	29.5[a]	4.5[a]	25.0[a]	3.4[a]
June	30.5[a]	15.4[b]	55.8[b]	33.8[b]	5.5[a]	28.3[a]	3.3[a]
SE[d]	.02	.03	.57	.91	.53	1.28	.9

[a,b,c]Means with different superscripts differ (P<.05).

[d]Standard error of means.

spring trial (June). Fribourg and Loveland (1978b) found that stockpiled fescue contained lower total N content than fescue which had been short clipped or continuously clipped prior to sampling. In the present study the stockpiled fescue in January was lower in CP content than the late spring regrowth. Fribourg and Loveland (1978b) reported higher total N content in early summer regrowth following harvest.

Neutral detergent fiber and ADF content did not differ ($P>.05$) between August and January, but in June, both ADF and NDF levels were higher ($P<.05$). No differences ($P>.05$) were detected between trials in lignin, cellulose and ash content. Acid detergent fiber and NDF may have also been affected by fertilization. Probasco and Bjvstad (1980) suggested that the main response of tall fescue to fertilization was an increase in fiber production. They also stated that additional fiber is produced during the time toward the end of the spring growing period. This was the period (June) in which the highest ($P<.05$) ADF and NDF percents were detected.

Apparent Digestibility The apparent digestibilities for the three trials are shown in tables 2 and 3. Digestibility values by trial are given in table 2 and values by horse are given in table 3. No significant differences were detected in the apparent digestibilities among horses. Dry matter digestibility was lowest ($P<.05$) in June,

Table 2. APPARENT DIGESTIBILITY OF FORAGE COMPONENTS BY TRIAL[a]

Month	Dry matter	Crude protein	Neutral detergent fiber	Acid detergent fiber	Lignin	Cellulose
August	61.7[b]	72.5[b]	53.4[b]	51.8[b]	10.0[b]	57.4[b]
January	63.8[b]	68.2[b]	53.2[b]	51.4[b]	32.9[c]	54.4[b]
June	55.8[c]	73.4[c]	48.5[c]	46.9[c]	54.6[d]	45.4[c]
SE[e]	.89	1.43	1.17	1.00	2.61	1.05

[a]Each observation represents a mean of six horses.

[b,c,d]Means in same column with different superscripts are different ($P<.01$).

[e]Standard error of means.

Table 3. APPARENT DIGESTIBILITY OF FORAGE COMPONENTS BY HORSE ACROSS TRIALS[a]

Horse	Dry matter	Crude protein	Neutral detergent fiber	Acid detergent fiber	Lignin	Cellulose
1	61.6	73.6	52.6	51.6	40.6	32.3
2	58.6	68.0	49.7	49.2	29.8	52.0
3	59.9	69.3	51.2	50.0	32.6	52.3
4	60.6	72.9	51.8	49.3	25.8	53.1
5	61.1	72.8	52.4	49.5	36.7	51.2
6	60.7	71.8	52.4	50.4	29.3	53.5
SE[b]	1.27	2.02	1.65	1.41	3.69	1.49

[a]Each observation represents a mean of three trials.

[b,d]Standard error of means.

with no difference between the August and January trials. Crude protein digestibility was not different between trials (P>.05). Lignin digestibility was lowest in August and highest in June (P<.05).

Apparent digestibility of crude protein tended to decline with the maturity. In the June trial CP digestibility was highest. This would have been the least mature forage of the three trials due both to the season and the continuously grazing prior to the trial. The lowest CP digestibility was seen in January, for the stockpiled forage. Similar results were reported by Darlington and Hershberger (1968) who found decreasing digestibility coefficients for CP by ponies as maturity increased in timothy, alfalfa and orchardgrass hays. They also noted that CP digestibility was directly proportional to the CP content in the forage. Similar patterns of CP digestibility of tall fescue were observed by Pendlum et al. (1980) in lambs. They found that CP digestibility decreased with maturity and increased with increasing CP content in the forage. While the relationship was not as strong, a similar pattern was seen in this study. The lowest CP content was seen in January, at which time the forage tended to be lowest in CP digestibility. Crude protein content was highest in August; however, digestibilities were not different between the August and June trials. The residual effect of N fertilization immediately prior to the August trial may have masked more definite trends in this study by increasing CP content in the forage.

The apparent digestibilities of the fibrous portions (excluding lignin) were generally inversely related to their content in the forage. Content of NDF and ADF was highest in June and their digestibilities lowest. Although not significant, the highest cellulose content was also detected in June which had the lowest cellulose digestibility.

Lignin digestibility was extremely variable showing significant differences ($P<.05$) between trials. Variation between horses was large, but not significant. In studies conducted by Fonnesbeck (1968,1969) the digestibility of the lignin fraction of forages by horses was generally near zero. Large variations were reported in these studies as well. The variation was attributed to analytical error inherent in lignin analysis.

Fecal Output and Voluntary Intake The fecal output and DM intake data are presented in tables 4 and 5. Fecal output was significantly lower ($P<.05$) in the late summer trial (August) and no difference was detected between the stockpiled (January) and late spring (June) fescue. Dry matter intake was lowest in August and highest in January. In June, DM intake was intermediate. The fecal output and voluntary intake by horse are given in table 5. No significant differences were seen.

Voluntary intake showed an inverse relationship to

Table 4. FECAL OUTPUT AND FORAGE DM INTAKE OF HORSES BY TRIAL[a]

Trial	Fecal output	DM intake
	kg/d	
August	1.8[b]	4.6[b]
January	2.7[c]	7.6[c]
June	2.8[c]	6.4[b,c]
SE[d]	.21	.55

[a] Each observation represents a mean of six horses

[b,c] Means within rows with different superscripts differ ($P<.05$)

[d] Standard error of means

Table 5. FECAL OUTPUT AND FORAGE DM INTAKE BY HORSE ACROSS TRIALS[a]

Horse	Fecal output	DM intake
	---------- kg/d	-----------
1	2.4	6.3
2	2.2	5.2
3	2.7	6.7
4	1.8	4.7
5	3.0	8.0
6	2.5	6.2
SE[b]	.26	.75

a Each observation represents a mean of three trials

b Standard error of means

the CP content of the forage. Intake was highest in January, where CP content was lowest. When CP content was highest (August) intake was lowest. This relationship is not easily explained, and may be confounded by other factors. The possible residual effects of fertilization prior to the August trial (raising the CP value) would alter a normal relationship. One possible explanation is that the stockpiled fescue in January may have been more palatable due to the lower fiber content. Conversely, the late August and June forage may have been less palatable due to higher fiber content.

Intake tended to be higher when the fibrous portions of the forage were lowest. Acid detergent fiber, NDF and cellulose were all lowest in the stockpiled fescue (January) when intake was highest. Dry matter intakes were lower in the August and June trials, when fibrous portions of the forage were higher. A similar response was found with sheep consuming freshly harvested tall fescue. A negative relationship was found between intake and NDF content (r=-0.357) (Bagley et al., 1983). Neutral detergent fiber is generally accepted as the most reliable predictor of voluntary intake in ruminants (Van Soest, 1965). Results in this study indicate a similar response by horses; however, the highest NDF content was observed for the late spring forage, in which the intake was intermediate between that for the stockpiled (January) and late summer (August) forages.

A trend was observed between intake and digestibility of the fibrous portions of the forage, excluding lignin. Apparent digestibility was highest in August, when voluntary intake was lowest. In the June trial intake was higher than in August and digestibility of ADF, NDF, and cellulose was lower. Fonnesbeck et al. (1967) reported a similar trend in their study comparing intakes and digestibilities of different species of grasses. Alfalfa had the highest intake and lowest digestibility of CF compared to grass species. This observation agrees with the theory given by Janis (1976) that the equine is in some ways more adept to exist on poor quality forage than the ruminant. The horse can maintain a high constant intake of higher fiber forage due to decreased retention time in the gut, compared to the ruminant. However, in a trial conducted by Darlington and Hershberger (1968) it was shown that CF, digestibility decreased as the forage matured, yet date of harvest had no significant effect on the voluntary intake of timothy or orchardgrass. These results, as well as those seen in the present study, suggest that in grass species such as fescue, fiber digestibility may not a reliable indicator of voluntary intake.

<u>The Pulse-Dose</u> Little has been done to evaluate the use of a pulse-dose indicator method with the horse. Nor has the suitability of rare earth metals with this

specie been elucidated. Chromic oxide has historically been used as the indicator for metabolism studies with horses. Many of the disadvantages found using chromic oxide in ruminant studies apply to the equine as well.

In using the pulse-dose the digestive system of the horse was described as a single, steady-state compartment (Ellis, personal communication). 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. The time dependency is based on the assumption that residence time in the gastrointestinal (GI) tract of the equine is based upon particle size as in the ruminant (Ellis, 1979). However the degree to which this is true in the horse must be more directly ascertained. Harbers et al. (1981), using electron microscopy of undigested leaf remnants, found that while the horse digests forage leaves in a similar pattern as ruminants, its ability to digest other structures (such as stems) as completely as ruminants is not evident. The efflux of smaller particles from the rumen adapt it to the time-dependent model. However the horse is not limited by the need to reduce the particle size of ingesta for passage through the digestive tract (Janis, 1976). While this is an argument against the time-dependant model, this model did result in a more consistent fit to the actual excretion curve than other models based on exponential loss (Ellis, unpublished data and Ellis, personal communication). Other factors which may be present in the cecum and colon such as slow and incomplete mixing may also favor use of the time-dependent model. The average R^2 value was .778, showing a strong fit of the predicted curve to the observed curve plotted from the grab samples FSP content. This is an indication that the single compartment, time-dependent model used to predict the excretion pattern of the FSP could be a reliable tool in predicting fecal output in horses.

<u>The Prediction Of Intake</u> The average dry matter intake for horses across three trials was 5.1 kg/d which is less than the 6.53 kg/d observed by Heusner and Albert (1977) for yearling fillies on pasture. It is estimated that the average yearling will consume 2.25% of its body weight of dry matter per day (Lewis, 1982). The estimated average body weight of the horses in this study was 400 kg, thus mean DM intake was approximately 1.52% of body weight. This indicates a possible underestimation of DM intake.

Several factors could contribute to the possible underestimation of intake. Since intake was calculated from estimated fecal output using the apparent digestibility of the forage, an over estimation of digestibility would be reflected in lowered intake values. However, DM digestibilities were consistent between horses and were similar to those in other grazing studies (Shelle, 1979). Another factor which may have contributed to an underestimation of intake was the horses being held off pasture for 8-12 h prior to the initiation of each trial to aid in the consumption of the Yb marked forage. The pulse-dose technique is assuming steady-state conditions. By eliminating intake prior to dosing, gut fill was reduced. Less material will be present for the stained forage to mix with and the initial concentration (C_o) of the marker will be higher than if the horses had been grazing normally. The higher marker concentration will lead to an underestimation of fecal output for that trial, even if the horse grazes normally subsequent to dosing. Thus, it is apparent that to realize optimum results with this procedure, the dose should be administered as efficiently as possible, avoiding any significant alterations in the normal grazing schedule.

The results of this study suggest that fescue grass can be a suitable pasture species for the normal growth and maintenance of yearling and 2-yr-old horses. Generally, digestibility of the forage was inversely related to its ADF and NDF content. Intake of the fescue pasture seemed to reflect the fiber content, showing an inverse response as well. These results are commonly seen in both ruminants and nonruminants.

From results in this study, the use of a Yb pulse-dose procedure in equine grazing trials is promising. However, further studies must be conducted to refine the techniques and standardize the procedure to insure its validity for future use with horses.

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APPENDIX

Example of Analysis of Variance,
Digestibility of Dry Matter

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Horse	5	16.45	3.29	.69
Trial	2	208.04	104.02	21.67*
Error	10	48.01	4.80	
Corrected Total	17	272.50		

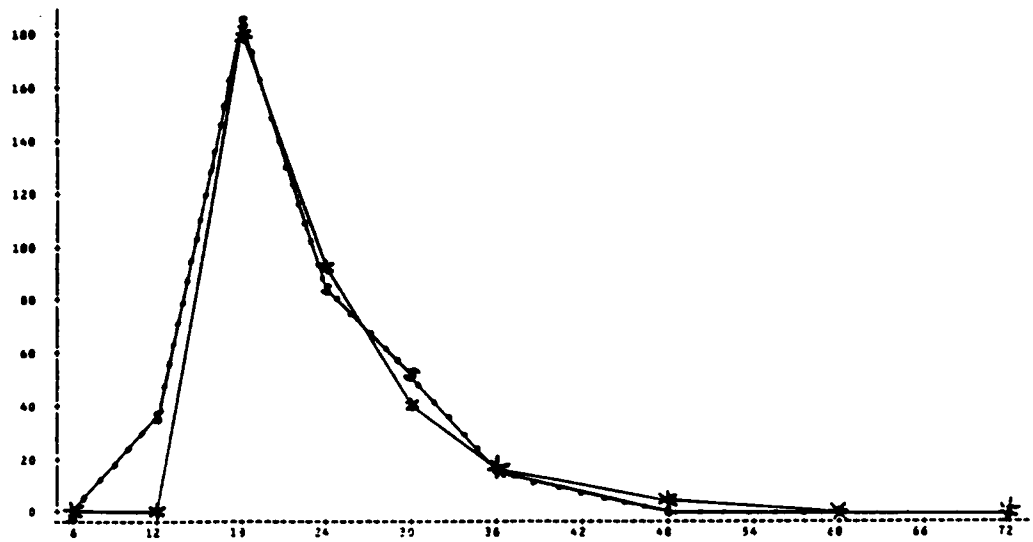
* (P<.05)

Example Plots of Predicted verses Actual
Output of Fecal Stained Particles

——*—— Predicted Output
——s—— Actual Output

Animal 5
Trial 3

Concentration
of FSP (ppm)



Hours After Dosing

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SEASONAL DIFFERENCES IN APPARENT DIGESTIBILITY AND INTAKE OF TALL FESCUE GRASS BY HORSES

by

Vernon B. Meacham

(ABSTRACT)

Three yearling and three 2-year-old Saddlebred horses were used to determine seasonal differences in apparent digestibility of Ky 31 tall fescue (Festuca arundinacea Schreb.) pasture by horses. Three trials were conducted with collection periods beginning August 27, 1984; January 8, 1985; and June 3, 1985. Each 72 h collection period followed a 2 wk preliminary grazing period. The horses were given a pulse-dose of Yb impregnated fescue forage at 0 h, and fecal grab samples were taken at 6, 12, 18, 24, 30, 36, 48, 60, and 72 h after dosing. Fecal output was estimated from Yb concentration in the feces. Apparent digestibilities of dry matter (DM), acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and cellulose were estimated using indigestible NDF as an internal marker. Forage DM intake was calculated using the formula (fecal output/(100- % forage DM digestibility) x 100). Estimated DM intake and fecal DM were 4.5 and 1.7 kg/d for August; 7.5 and 2.7 kg/d for January; and 6.4 and 2.8 kg/d for June, respectively. Percent ADF and NDF were highest ($P<.05$) and apparent digestibilities of these components were lowest ($P<.05$) for the spring forage.

(Key words: Horses, Fescue Pasture, Seasonal Digestibilities, Pulse-Dose)