Digestibility and Apparent Mineral Utilization by Arabian Geldings Fed Alfalfa, Tall Fescue, and Caucasian Bluestem

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(ABSTRACT)

Three palatability and digestion trials were conducted with six Arabian geldings fed alfalfa (*Medicago sativa* L.), endophyte-free tall fescue (*Festuca arundinacea* Schreb.), and Caucasian bluestem (*Bothriochloa caucasica* (Trin.) C.E. Hubbard) as hay to determine nutritional value of the hays for horses at maintenance in a Latin Square designed experiment. Alfalfa had higher ($P < .01$) dry matter digestibility, and voluntary intake, compared to grasses. Tall fescue and Caucasian bluestem did not differ in dry matter digestibility and voluntary intake. Feeding alfalfa resulted in higher ($P < .05$) intake and digestibility of CP and higher ($P < .05$) apparent absorption of Ca, P, K and S, compared to the grass hays. Tall fescue was higher ($P < .01$) in CP concentration and digestibility, total nonstructural carbohydrate concentration, and apparent absorption of Mg and S, compared to Caucasian bluestem. Caucasian bluestem was higher ($P < .05$) in Zn compared to tall fescue. At the end of the palatability trials, horses fed alfalfa had higher serum concentration of blood urea nitrogen, vitamin A, and serum P, S, and Cu, compared to horses fed grasses. Serum Zn was higher ($P < .05$) and Se tended to be higher ($P < .06$) in horses fed Caucasian bluestem, compared to tall fescue. All forages were below the recommended dietary Cu and P concentration but only Caucasian bluestem resulted in negative apparent P absorption. Caucasian bluestem would meet most nutrient requirements for horses at maintenance. Alfalfa supplied more crude protein, Ca, Mg, and K than was required by horses at maintenance.

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INTRODUCTION

Many warm-season and cool-season grasses have been used successfully in systems for cattle and sheep. Little research has been conducted concerning the nutritive value of warm-season grasses for horses. The purpose for comparing warm-season and cool-season grasses is to improve forage availability at appropriate quantity and quality to meet nutritional needs for horses throughout the grazing season. Common forages for horses in Virginia include tall fescue (*Festuca arundinacea* Schreb.) and alfalfa (*Medicago sativa* L.) as well as others. There is a possibility that cool-season grasses could form the basis of a system in Virginia that uses a warm-season grass such as Caucasian bluestem (*Bothriochloa caucasica* (Trin.) C.E. Hubbard) to increase forage supply during summer when growth of cool-season species is limited.

Cool-season grasses typically produce about 60 percent of their growth during spring while warm-season grasses produce approximately 60 percent of their growth during summer, between June and August. The purpose of using a warm-season grass in Virginia is to supplement cool-season grasses in midsummer, when their quality and quantity decrease. However, the warm-season species must be acceptable in palatability and should meet the horse's dietary needs. Little is known about the palatability and nutritional value of warm-season grasses, particularly Caucasian bluestem, for meeting nutrient requirements of horses. The purpose of this study was to determine nutritive value and palatability of Caucasian bluestem, tall fescue, and alfalfa for mature horses at maintenance.

LITERATURE REVIEW

Forages in Equine Nutrition and Digestion

General Nutritional Requirements of the Horse. Forages are an important part of the equine diet. Forages commonly fed to horses include alfalfa and clovers (*Trifolium spp.*), which are legumes. Forage grasses used for horses include Kentucy bluegrass (*Poa pratensis* L.), big bluestem (*Andropogon gerardii* Vitman), smooth bromegrass (*Bromus inermis* L.), orchardgrass (*Dactylis glomerata* L.), wheatgrasses (*Agropyron*, *Elymus*, and *Elytrigia* spp.), bermudagrass (*Cynodon dactylon* L.), and timothy (*Phleum pratense* L.) (Templeton, 1979; Anderson, 1988). Often, these grasses are fed mixed with legumes (Anderson, 1988).

Burke (1987) defined a high quality forage for horses as low in acid detergent fiber (ADF) and having a suitable protein level. Good quality hays are leafy and free of mold, dust, and weeds. A good quality hay that is palatable may be fed to horses as the only source of roughage (Hintz, 1983).

The overall feed requirement on a 90% dry matter basis for a mature horse at maintenance can be met by feeding 100% hay (NRC,1989). Forages provide energy, minerals, and carbohydrates as well as some amino acids (Smith et al., 1986). Forages also stimulate cecal bacteria to synthesize water-soluble vitamins and vitamin K required by the horse (Smith et al., 1986). However, these nutrients are not readily absorbed in the large intestine and are available through cropophagy which horses do not practice often.

Forages are important in stimulating "normal motility and function" of the digestive tract (Smith et el., 1986). An adequate forage diet helps to prevent colic and enterotoxemia (Smith et al., 1986). There is also less chance of colic due to impaction when forage is fed as long-stemmed hay at a minimum of 1% body weight (Burke, 1987).

On an all-forage diet, horses consumed 18% more DM than those on an all-concentrate diet to compensate for lower dietary energy in forage diets (Cymbaluk and Christison, 1989). Cymbaluk and Christison (1989) showed forage diets to be lower in digestible energy (DE) than grain or grain by-product concentrate, but horses ate more to compensate. According to Burke (1987), when compared to a pelleted feed, hay decreased the rate of passage of ingesta through the intestinal tract. The lower rate of passage allowed more time of exposure to enzymes and bacteria which increased total digestibility (Burke, 1987).

Equine nutrient requirements on a 90% dry matter basis are shown in Tables 1 and 2. Fiber is important in the diet but horses do not have an actual requirement (NRC, 1989). For a mature horse at maintenance, energy requirements are low and can be met by feeding a good-quality forage. The diet should contain .5 to 1% salt. The requirements for Fe and K are easily met in most forage diets. Burke (1987) suggested that young horses require a Ca:P ratio between 1:1 and 2:1. Phosphorus may need to be supplemented with forages high in Ca such as alfalfa (Table 2) to prevent an imbalance in the Ca:P ratio (Burke, 1987). Alfalfa is a cool-season legume and legumes are usually higher in Ca than grasses (Norton, 1981). Calcium uptake by plants is also greater in cooler temperatures (Norton, 1981). Knight et al. (1985) suggested that feeding alfalfa hay diets may result in inadequate utilization of trace minerals. The high Ca content in alfalfa may reduce the absorption of Cu, Zn, and Mn. Salt and mineral mixtures with Ca, P and trace minerals should be fed free choice when horses are grazing most grass pastures (Cunha, 1980). Smith et al. (1986) suggested a possible mineral supplement, depending on the chemical

Table 1. Digestible energy and crude protein requirements of a mature horse at maintenance and average digestible energy, crude protein and fiber composition of alfalfa, tall fescue and Caucasian bluestem

Item	Digestible energy	Crude protein	Crude fiber	Acid detergent fiber	Cell wall	Lignin
	Mcal/kg	---	---	%	---	---
Equine requirements (90% DM)[a]	1.8	7.2	-[b]	-	-	-
Alfalfa suncured hay, early bloom[a] (90% DM)	2.2	18.0	20.8	28.9	42.0	8.0
Tall fescue suncured early vegetative hay[c] (91% DM)	2.7	12.4	26.0	32.0	57.0	3.0
Caucasian bluestem (dry basis)[d]	-	8.0	-	39.9	-	6.1

[a]NRC (1989).
[b]Indicates data not available or not applicable.
[c]NRC (1985).
[d]Reid et al. (1988).

Table 2. Mineral and vitamin A requirements of a mature horse at maintenance and average mineral and vitamin A composition of alfalfa, tall fescue and Caucasian bluestem

Item	Ca	P	Mg	K	S	Cu	Fe	Mn	Zn	Se	Vit. A
	%					ppm					IU/g
Equine requirements (90% DM)[a]	.2	.6	.1	.3	.2	10.0	40.0	-[b]	50.0	.1	1650.0
Alfalfa, suncured hay, early bloom (90% DM)[a]	1.3	.2	.3	2.3	.3	11.4	205.0	33.0	16.2	.5	56.1[e]
Tall fescue, suncured early vegetative hay (91% DM)[c]	.5	.4	.2	2.3	-	-	-	-	-	-	-
Caucasian bluestem (dry basis)[d]	.3	.2	.1	1.4	.1	3.8	89.0	75.0	23.4	-	-

[a]NRC (1989).
[b]Indicates data not available.
[c]NRC (1985).
[d]Reid et al. (1988).
[e]Vitamin A equivalent.

composition of the forage, should include I, Fe, Cu, Zn, and Mn because they are essential for the horse and may not be supplied in adequate amounts in the diet. Vitamin A is sometimes supplemented because increased activity of the horse often increases the need for vitamin A to a greater level than provided the forages (Cunha, 1980; Smith et al., 1986).

Digestion. The stomach of the horse is eight percent of the total digestive tract volume (Burke, 1987). The stomach serves as a storage area and passes the ingesta to the small intestine where soluble carbohydrates, lipids, and proteins are digested and the end-products are absorbed (Burke, 1987). Soluble carbohydrates are digested by enzymes (∂-glycosidases) secreted in the horse's small intestine (Fonnesbeck, 1968). Minerals such as Ca, Zn, Cu, Mg, and Mn are absorbed from the small intestine (Burke, 1987). The large intestine has a large cecum that contains bacteria "similar to the rumen [bacteria] of cattle and sheep" (Burke, 1987). Horses digest the fibrous content of forages by the ß-glycosidase enzymes produced by bacteria in the cecum (Fonnesbeck, 1968). Bacteria also metabolize nitrogen in the large intestine (Burke, 1987). This process is less efficient than nitrogen metabolism in ruminants. Ruminant bacteria metabolize non-protein nitrogen in the rumen for use in building bacterial protein. In the horse, microbial protein is broken down by proteolytic enzymes into amino acids and absorbed from the large intestine (Vander Noot and Gilbreath, 1970; Burke, 1987). This takes place primarily in the cecum although the details are still unclear (Vander Noot and Gilbreath, 1970; Burke, 1987). Smith et al. (1986) suggested that little digestion and utilization of microbial protein take place in the lower digestive tract of the horse. Microbial protein in the ruminant is more likely to be utilized because it is digested and absorbed in the small intestine (Burke, 1987).

Horses digest crude protein (CP) in alfalfa as well as ruminants, but ruminants digest dry matter and organic matter of grass hays more efficiently than horses (Vander Noot and Gilbreath, 1970; Harbers et al., 1981). Vander Noot and Gilbreath (1970) suggested that CP digestion is inversely related to the amount of crude fiber (CF) in the forage. Koller et al. (1978) found that bacteria in the cecum of the horse do not digest dry matter and cell wall fractions of forages as well as ruminant bacteria in *in vitro* studies. This is due to the difference between cecal and rumen bacteria. In addition, Koller et al. (1978) suggested this is due to the slower rate of passage in the ruminant exposing the fiber to the ruminant bacteria for a longer period of time. The rate of passage of ingesta is about 96 hr in horses (Vander Noot et al., 1967) and 7 d (168 hr) in steers

(Balch, 1961). Harbers et al. (1981) found the digestibility of a grass by horses is related to mesophyll and cellular constituents in mesophyll-type tissues. Forage found in the cecum has passed through the stomach and small intestine and is not the same form found in the rumen which may affect the amount of fiber available and fiber digestion by the cecal bacteria (Koller et al., 1978).

Forage Legumes

General Characteristics. In general, cool-season legumes are native to the northern Eurasian region and the Mediterranean region (Norton, 1981). Most warm-season legumes are native to east and central Africa, Central America, and South America (Norton, 1981).

Legumes are high in protein, vitamins, and minerals compared with grasses (NRC, 1985). Norton (1981) suggested that high protein content may be due to a "continuous supply of N available from Rhizobial fixation". Legumes experience a slower decline in protein content with maturity, compared to grasses. This decline in crude protein concentration occurs mostly in the older leaves. As legumes mature and flower, there is less decline in quality compared to grasses (Norton, 1981).

Warm-season and cool-season legumes use the C_3 (Calvin-Benson Cycle) pathway for their photosynthetic processes which produces the 3-carbon compound 3-phosphoglyceric acid (Taiz and Zeiger, 1991). Warm-season legumes produce most of their growth in summer months while cool-season legumes produce the majority of their growth in the spring. Warm-season legumes have a lower P content than the cool-season legumes while legumes in general have higher contents of Ca, Cu, and Zn than grasses (Minson, 1990).

For improved animal nutrition and longer growing seasons, legumes are often mixed with grasses (Smith et al., 1986). The most common legume used in mixtures for grazing in the United States is white clover (*Trifolium repens* L.) (Smith et al., 1986). Legumes commonly used in the eastern United States are cool-season legumes such as alfalfa and red (*Trifolium pratense* L.) and white clovers mixed with cool-season perennial grasses. Cool-season legumes are higher in protein, minerals, and percent leaf during early spring growth (Blaser and Colleagues, 1986).

The common legumes used for hays or included in hay mixtures for horses in the United States include alfalfa, red clover, white clover, and birdsfoot trefoil (*Lotus corniculatus* L.) (Cunha, 1980). Alfalfa hay is considered high in quality compared to red clover and birdsfoot trefoil because alfalfa has a lower percentage of stems and higher protein and Ca compared to these legumes (Buxton and Hornstein, 1986; Cunha, 1980). The lower percentage stem generally results in lower percentage fiber since concentration of cell wall is higher in stems than leaves (Buxton and Hornstein, 1986). However, on a total plant basis, Buxton and Hornstein (1986) found alfalfa to have a higher cell wall concentration when compared to red clover, white clover, and birdsfoot trefoil with white clover having the lowest percentage cell wall concentration. They also concluded that if these legumes were harvested at proper maturity, concentrate supplements for ruminants would be unneccesary.

Digestibility. Legumes have high apparent digestibility. Buxton et al. (1985), using rumen fluid, found the *in vitro* digestible dry matter decreased in alfalfa and birdsfoot trefoil with maturity. Fonnesbeck (1968) found in horses, legume forages had more digestible organic matter and digestible energy than grass forages, but they also have more lignin content than grasses. Horses can digest about 60.8% of the dry matter in alfalfa hay harvested at the one-quarter bloom stage (Vander Noot and Gilbreath, 1970). Legumes have more soluble carbohydrates such as sucrose than grasses which account for their high organic matter digestibility (Fonnesbeck, 1968). Legumes store starch in the stems and leaves but at a lower content than warm-season grasses (Norton, 1981).

In *in vitro* and *in vivo* studies, warm-season legumes appear to have lower digestibility than the cool-season legumes as indicated by the differences in crude fiber content (Minson, 1980). Crude fiber (CF) approximates the amount of stuctural carbohydrates such as hemicellulose and cellulose and the phenolic polymer lignin (Norton, 1981). Cool-season legumes and cool-season grasses have similar amounts of CF, but in comparison, warm-season legumes contain higher amounts of CF (Norton, 1981). Cool-season legumes also contain less lignin than warm-season legumes which can further explain this higher dry matter digestibility (Bailey, 1973; Ulyatt and Egan, 1979; Norton, 1981).

Intake. Stems of alfalfa and birdsfoot trefoil limit intake of these two forage legumes (Buxton and Hornstein, 1986). Van Soest (1965) found alfalfa to have a higher intake as well as a higher lignin content than grass. Lignin is only a portion of the fiber content in the cell wall and although legumes are higher than grasses in percent lignin, their lower cell wall content allows intake to be higher compared to grasses. Furthermore, legumes are characterized by optimum intakes when compared with other classes of forages. Reid et al. (1959) found legume-grass hays consisting of alfalfa, red clover, timothy, ryegrass (*Lolium* spp.), quackgrass (*Elytrigia repens* (L.) Nevski), and orchardgrass, to have a slightly higher intake than all-grass hays.

Cool-Season, C_3 Grasses

General Characteristics. Common cool-season grasses in the northeastern United States include Kentucky bluegrass, timothy, orchardgrass, ryegrass, smooth bromegrass, and tall fescue (Hintz, 1983; Anderson, 1988). Common cool-season grass hays include timothy, orchardgrass, smooth bromegrass and tall fescue (Cunha, 1980).

Cool-season grasses use the Calvin-Benson cycle for photosynthetic processes and produce phosphoglyceric acid as an end-product (Taiz and Zeiger, 1991). The N concentration in the tissue of cool-season grasses is higher than N concentration in warm-season grasses (Bjorkmann et al., 1976, Norton, 1981). Brown (1978) hypothesized the difference to be a result of different photosynthetic pathways. The C_3 plants have about 50% of their soluble protein in mesophyll cells in the form of RuDP carboxylase as opposed to 20% in C_4 species (Bjorkmann, 1976). There is also more N in the leaves than stem and warm-season grasses tend to be higher in percentage stem than cool-season grasses (Wilson and Minson, 1980). The N decreases and becomes limiting for animal production with increasing maturity of the grasses (Norton, 1981).

The C_3 grasses contain less Mg than the C_4 grasses and are more likely to produce signs of Mg deficiency in livestock. This may be a result of differences in temperature during the growing season because Mg is more available to the plant with increasing temperature (Norton, 1981).

Digestibility. Cool-season grasses accumulate the carbohydrates, sucrose and fructosan, which are water soluble (Norton, 1981). The higher content of water soluble carbohydrates compared to warm-season grasses partially accounts for the higher digestibility of cool-season grasses. Cool-season grasses have lower amounts of crude fiber and less hemicellulose than warm-season grasses.

Intake. Grasses in general have a lower voluntary intake than legumes (Van Soest, 1965). Van Soest (1965) compiled data from West Virginia, Maryland, Michigan, and Utah. Forages included sudangrass (*Sorghum bicolor,* L. Moench), orchardgrass, bromegrass, timothy, bluegrass, tall fescue (endophyte status not known), reed canarygrass (*Phalaris arundinacea,* L.), alfalfa, and birdsfoot trefoil. Tall fescue had the lowest voluntary intake with all other grasses having a lower voluntary intake than the legumes (Van Soest, 1965). Van Soest (1965) suggested these results were a result of higher cell wall content in grasses compared to legumes.

Warm-Season, C_4 Grasses

General Characteristics. Common warm-season grasses in the southern United States include bermudagrass, bahiagrass (*Paspalum notatum* Flugge), digitgrass (*Digitaria* Stent), and bluestem (*Andropogon* spp.) (Templeton, 1979). Common warm-season grass hays include coastal bermudagrass, bahiagrass, and pangolagrass (*Digitaria decumbens* Stent.) (Cunha, 1980).

The C_4 grasses use the Hatch-Slack pathway for their photosynthetic processes which produce the 4-carbon compounds oxaloacetic acid, malic acid, and aspartic acid (Hatch and Slack, 1970). The C_4 grasses have a higher percentage vascular tissue and bundle sheath cells than cool-season grasses and a "radial arrangement" of bundle sheath around the vascular bundles (Laetsch, 1974). Warm-season grasses have a higher optimal temperature for growth than cool season grasses, use water and soil N, P, and K more efficiently, and tolerate soil Al^{3+} and atrazine to some extent, but are low in Na compared to cool-season grasses (Black, 1971; Brown, 1978; Norton, 1981; McKee et al., 1982; Martin et al., 1982; Morris et al., 1982). Although warm-season grasses utilize P and N more efficiently in low P situations, they have low P and N concentrations compared to cool-season grasses and supplementation to livestock may be required (Morris et al., 1982). Warm-season grasses mature and decline in quality quickly at warm temperatures as a result of high growth rates (Norton, 1981). However, the high growth rate at high temperatures produces lower N concentrations in the tissue of warm-season grasses compared to cool-season grasses (Bjorkmann, 1976; Norton, 1981). Jung et al. (1985) found warm-season grasses to be low in crude protein, especially at the heading stage of maturity. Anderson and Matches (1983) found IVDMD of switchgrass (*Pancium virgatum* L.) and Caucasian bluestem was low after head emergence and unable to meet the energy requirements for ruminants at maintenance. Jung et al. (1985) suggested, however, that laboratory results may be unreliable in accurately predicting dry matter digestibilities of warm-season grasses.

Digestibility. Warm-season grasses often have a lower nutritive value than cool-season grasses because of high concentrations of cell walls which result in lower digestibility and intake of warm-season grasses (Van Soest, 1965). Leaves of warm-season grasses store starch which consists of amylose and amylopectin, instead of fructosan which may also account for lower digestibility, compared to cool-season grasses (Norton, 1981). Amylopectin is not water soluble and is less easily digested than water soluble carbohydrates. Warm-season grasses have tightly packed cells in the mesophyll which contribute to lower digestibility when compared to cool-season grasses (Carolin et al., 1973;

Norton, 1981). Warm-season grasses have higher concentrations of lignin than legumes and cool-season grasses (Norton, 1981). The C_4 grasses experience a more "continuous decline in digestibility" compared to legumes and C_3 grasses.

Aiken et al. (1989) showed that if adequate forage is available, there is moderate growth in yearling horses selectively grazing bermudagrass. Vona et al. (1984) found warm-season grasses such as switchgrass and big bluestem to "provide a high intake of digestible energy by cattle", but lower intake of digestible energy by sheep. Stobbs (1973) suggested that lower animal performance on warm-season grasses, compared to animal performance on cool-season grasses, is a result of erect growth and more stem of the warm-season grasses leading to lower intake by the animal.

Forages in Virgnia

Virginia's livestock industry is based on cool-season forages such as tall fescue, orchardgrass, Kentucky bluegrass, red clover, white clover, and alfalfa. These forages experience a decline in both quantity and quality in summer. Caucasian bluestem, a warm-season grass, has the potential to supplement the feed supply during this time.

The horse industry in Virginia relies primarily on cool-season forages as the only feed source or to supplement a concentrate diet. Often, performance horses are fed forages in the form of hay rather than grazing. However, there is the potential to better utilize pasture by developing year-round grazing systems for the horse industry using cool-season forages integrated with warm-season forages.

Forages Used in this Study

Alfalfa. Alfalfa, known as lucerne in Europe, is thought to have originated in southwest Asia and was first cultivated in Iran (Barnes and Sheaffer, 1985; Smith et al. 1986). One of the earliest records of alfalfa is 700 B.C. in Babylon as Aspati (Smith et al., 1986). The Medes and Persians invaded Greece in 490 B.C. and introduced alfalfa, known as Medic, to feed their horses (Barnes and Sheaffer, 1985; Smith et al., 1986). Alfalfa was later introduced to European countries and eventually to Central and South America by Spanish explorers. It is thought to have been cultivated south of Mexico City as early as 1540 (Smith et al., 1986). In 1736, alfalfa was cultivated in Georgia, but had limited success until 1850 when introduced to the West Coast from Chile (Barnes and Sheaffer, 1985). From California, alfalfa was introduced to the rest of the United States (Barnes and Sheaffer, 1985).

Alfalfa is a cool-season legume with high levels of readily available carbohydrates, Ca, and carotene compared to grasses (Fonnesbeck and Symons, 1967; Fonnesbeck, 1969;). It is also known to be high in vitamins, minerals, and protein (Cunha, 1980). Alfalfa is often mixed with grasses but may be fed as the only hay source (Burke, 1987). Timothy used to be the "preferred hay" for horses and alfalfa was considered "too hot" in that it was thought to cause digestive disorders in horses (Burke, 1987). Freeman et al. (1987) found no digestive disorders when yearling horses grazed alfalfa and "results suggest that if managed correctly, moderate growth rates may be reached in yearling horses grazing alfalfa without additional supplementation". Alfalfa is considered "one of our best, most palatable forages" for livestock (Van Soest, 1965).

Sun cured alfalfa hay at early bloom (1/10 bloom) is approximately 90% dry matter when properly stored and cured and as an overall feed, exceeds most of the dietary requirements of the horse at maintenance (NRC,1989). It is an excellent source of roughage for performance and growing horses. Burke (1987) found that dry matter digestibility of alfalfa at early bud stage is approximately 65%. He also stated that alfalfa surpassed the NRC recommendations for horses in digestible energy, CP, Ca, P, and vitamin A. Koller et al. (1978) found alfalfa readily digestible by ruminal bacteria from cows and cecal bacteria from ponies in *in vitro* studies comparing alfalfa, orchardgrass, timothy, and wheat straw (*Triticum vulgare* L.). This is consistent with conclusions from metabolism studies using steers and geldings (Vander Noot and Gilbreath, 1970).

Some management recommendations for alfalfa include rotational stocking to minimize risk of stand loss (Barnes and Sheaffer, 1985). Barnes and Sheaffer (1985) suggested that alfalfa should be grazed 7-10 days with a 30-40 day recovery period. Alfalfa depends on stored carbohydrates for regrowth, thus, continuous defoliation could deplete the carbohydrate stores. Continuous stocking would cause the stand to thin and eventually result in stand loss. Alfalfa grazed by sheep for two consecutive years in summer using continuous stocking increased weed encroachment and decreased hay yields (Allen et al., 1986a). Allen et al. (1986a,b) suggested a 4-5 wk recovery before hay harvest when alfalfa was continuously grazed by sheep in summer. Alfalfa was continuously grazed by steers for two consecutive years beginning in early summer. Fall hay yields on grazed alfalfa were decreased when compared with ungrazed alfalfa hay yields (Wolf and Allen, 1990). Because steers and sheep selectively graze the leaves, grazed alfalfa may require mowing after grazing to remove ungrazed stems (Allen et al., 1986a). Wolf and Allen (1990) found that under continuous spring grazing with steers, green leaf area of alfalfa was maintained and alfalfa appeared to depend on photosynthesis for regrowth. These results are supported by spring grazing trials with sheep (Allen et al., 1986b). More leaf was maintained in spring grazed treatments than ungrazed (Allen et al., 1986b). Continuous grazing in summer by sheep resulted in more leafiness than non-grazed treatments (Allen et al., 1986a).

Tall Fescue. Tall fescue was first thought to be a variety of meadow fescue (*Festuca elatior,* L.) (Buckner, 1985; Smith et al., 1986). It received its species name *arundinacea* in 1771 from Schreber (Buckner, 1985). Native to Europe, settlers introduced meadow and tall fescue into the United States where tall fescue was first recorded in Cambden, New Jersey in 1879 (Buckner, 1985). Tall fescue has gained widespread use in the United States since the release of the cultivars 'Alta' in 1940 and 'Kentucky 31' in 1943 (Buckner, 1985; Smith et al., 1986). However, its drought resistance, cold tolerance, dense stand formation, and competitiveness on a variety of soils has been noted since the late 1800's in Utah and Kentucky (Barnes and Sheaffer, 1985; Smith et al., 1986).

Tall fescue is a cool-season grass and is generally lower in protein than alfalfa (Cunha, 1980). Tall fescue produces 60% of its growth before June 1, and can become a dormant, unproductive, low quality forage in summer (Anderson, 1988). As tall fescue matures, it increases in cell wall concentration and decreases in concentration of protein, palatability, and overall feed value (Cunha, 1980).

Tall fescue is often infected with an endophyte fungus (*Acremonia coenaphialum* Morgan-Jones and Gams) that can result in prolonged gestation, thick placentas, abortion and agalactia in mares (Garrett et al., 1980). Effects have not been noticed in geldings or nonpregnant mares but little information is available. There are endophyte-free tall fescue cultivars available. However, these cultivars may not be as widely adapted and tolerant to stress as the endophyte-infected tall fescue (Read and Camp, 1986).

Suncured, early vegetative, tall fescue hay is approximately 91% dry matter. As an overall feed, tall fescue meets or exceeds most of the dietary requirements of the horse at maintenance (NRC, 1985).

Tall fescue can be managed using continuous stocking as a result of its ability to tolerate close grazing. Management practices also include harvesting tall fescue as hay in the spring or as hay and grazed forage in the spring and summer. Tall fescue is often stockpiled in Virginia as a result of its physiology. Animals are removed from tall fescue pastures in early August and 67-90 kg N/ha fertilizer is applied. This practice allows the accumulation of growth of tall fescue that is high in percentage of total non-structural carbohydrates (TNC) (Brown and Blaser, 1965). An increase in concentration of TNC occurs when the rate of photosynthesis exceeds the rate of respiration. Around November 1, the stockpiled fescue may be grazed (Buckner, 1985).

Caucasian Bluestem. Also known as Old World bluestem, Caucasian bluestem originated in Russia. It has been introduced into the central and southern Great Plains of the United States (Schwendiman and Hawk, 1976).

Caucasian bluestem is a warm-season grass that produces 60% of its growth between June 1 and August 31 in the southeastern United States (Anderson, 1988). As Caucasian bluestem matures its concentration of lignin increases (Reid et al., 1988). It is not a well known source of feed for horses.

Based on the results of Reid et al. (1988), Caucasian bluestem is low in protein, Ca, P, and Zn for nutrition of growing horses. Reid et al. (1988) suggested that as a result of low values for CP and P, more research was needed to determine the true feeding value of Caucasian bluestem. Dabo et al. (1988) found Caucasian bluestem to be low in crude protein and high in indigestible fiber component compared to other old world bluestems. Based on laboratory analysis by Reid et al. (1988), Caucasian bluestem appears to meet the dietary requirements of a horse at maintenance. Research with cattle and sheep fed Caucasian bluestem has indicated that forage quality is higher than is indicated by laboratory tests (Reid et al., 1988). Anderson (1988) states that Caucasian bluestem "produced daily and per hectare gains in steers similar to tall fescue and fescue hay". Also, steers experienced "summer weight loss when only tall fescue was grazed in summer" (Anderson, 1988). In research with cattle, Reid et al. (1988) found that tall fescue and Caucasian bluestem systems produced a "higher carrying capacity than fescue-switchgrass" systems. The average daily gain improved when warm-season grasses were integrated into forage systems based on cool-season grasses in general, compared to systems that did not integrate warm-season grasses (Matches et al., 1977; Reid et al., 1988). Summer gains of steers grazing Caucasian bluestem were higher, compared to steers grazing cool-season forages during July and August in Virginia (Fontenot et al., 1993). Daily gains of steers that grazed Caucasian bluestem from late June to late August averaged 1.1 to 1.4 kg/d.

Anderson and Matches (1983) suggested that Caucasian bluestem may withstand continuous stocking as a result of its indeterminate growth habit and abundant basal leaves. However, Anderson and Matches (1983) also suggested that unless an animal is at maintenance, Caucasian bluestem should not be grazed past the jointing stage without supplementation. There is little information available that would indicate the potential for use of Caucasian bluestem for horses.

OBJECTIVES

The overall objective of our research was to determine the nutritional value of tall fescue (a cool season grass), Caucasian bluestem (a warm season grass), and alfalfa (a cool season legume) harvested as hays for horses. The specific objectives were to:

1. Determine chemical composition of the three forages harvested as hays.
2. Determine digestibility of dry matter, fiber components and crude protein.
3. Compare apparent absorption of minerals by horses fed the three forages.
4. Compare palatability of the three forages.
5. Determine the comparative value of the three forage hays as sources of vitamins A and E.

METHODS AND MATERIALS

Procedures

Three forages, endophyte-free 'Kentucky-31' tall fescue, 'Pioneer 3142' alfalfa , and Caucasian bluestem were harvested as hay during the 1993 growing season. Tall fescue and Caucasian bluestem were established in replicated fields during 1987 and 1988, respectively, at the Southwest Virginia Agricultural Research and Extension Center, Glade Spring, VA. These areas were used in grazing studies with steers prior to our experiment. Tall fescue, grown on a Hagerstown Silt Loam, fine mixed, mesic Typic Hapludalfs, was harvested on June 7, 1993. Caucasian bluestem, grown on a Frederick Silt Loam, clayey, mesic Typic Paleudults, was harvested on July 7, 1993 at the early bloom stage. Alfalfa, grown at the Virginia Tech Beef Center, Blacksburg, VA on a Groseclose clayey, mixed, mesic Typic Hapludults complex, was harvested May 1993. Each forage was harvested with field equipment, sun dried and baled.

Soils in tall fescue and Caucasian bluestem paddocks were sampled on Jan. 28, 1993 at 7.5-cm depth. Soils were mixed and air dried overnight, oven dried at 55° C for 72 hrs, ground and submitted for analysis to the Virginia Tech Soil Testing Laboratory. Fertilizer was applied based on recommendations.

On Apr. 14, 1993, 1.89 L Simazine (6-chloro-N,N'-diethly-1,3,5-trizine-2,4-diamine) in 10 L H_2O/ha, .65 L paraquat (1,1'-dimethly-4,4'-bypridium ion)/ha, and .473 L Surfactant/378 L water were applied to Caucasian bluestem for weed control. Nitrogen was applied at 56 kg/ha on Apr. 14, 1993.

Fescue was fertilized Apr. 19, 1993 with N (90 kg/ha), P_2O_5 (45 kg/ha), and K_2O (45 kg/ha). Additionally, 2.3 L 2,4-D Amine (2,4-dichlorophenoxy-acetic acid)/ha and .23 kg dicamba (3,6-dichloro-2-methocybenzoic acid) /ha were applied on the same date for control of broadleaf weeds and white clover.

Botanical composition of tall fescue on May 7, 1993 and Caucasian bluestem on July 5, 1993 was determined using the DAFOR (Dominant, Abundant, Frequent, Occasional, Rare) scale (Brodie, 1985 as modified by Abaye, 1992). Additionally, six quadrats, .25 m^2, were randomly taken from each Caucasian bluestem paddock on June 29, 1993 and hand separated.

Botanical composition of endophyte-free tall fescue and alfalfa was further defined by randomly taking two grab samples of each hay during each trial for a total of six samples for each forage. These samples were subsampled and hand separated for botanical composition of the hays.

Palatability and digestibility of the three forage hays were determined in three trials with six Arabian geldings in two 3 x 3 x 3 Latin Squares. Geldings ranged in age from two to six years with an average initial weight of 449 kg. Geldings were blocked by weight and randomized within blocks to the three treatment hays. Geldings were individually housed in 3.6 m x 3.6 m stalls (unrestrained), fed and provided water ad lib. Feed and water were provided in plastic buckets. Iodized salt was provided ad lib. Stalls were wood sided and bedded with sand. The sand contained 17 ppm Ca, 1 ppm P, 6 ppm Mg, 7 ppm K, 22 ppm Fe, 1.5 ppm S, .5 ppm Zn, .9 ppm Cu, and .6 ppm Mn that was soluble in a 10:1 dilution with .1 N HCl after shaking for 6 h. Hays were ground for each trial in a hammer mill through a 3.254 cm screen.

Palatability trial. Three trials using two Arabian geldings fed each forage during each trial were conducted. Five days were allowed for the geldings to adjust to the forages. During the preliminary periods, geldings were fed ad lib to determine approximate maximum intake of the respective forage hays. The preliminary period was followed by a 5-d palatability trial during which forage hays were fed at about 10% excess of voluntary intake. Forages were fed at

0800 and 1800 hr and samples of feed and refusals were taken at each feeding. Grab samples of the feeds were taken. Refusals were collected at each feeding and were weighed. Feed and refusals were sampled at each feeding. Subsamples of feed and refusals were dried at 105^{o} C for 48 h to determine percentage dry matter.

Digestion trial. A digestion trial immediately followed each palatability trial. During the digestion trials, geldings were fed a constant quantity for all horses at 5% below ad libitum intake of the gelding that had the lowest voluntary intake during the preceeding palatability trial. Geldings were fed at 0800 and 1800 h and samples of feed and refusals were taken. Feed was sampled by taking grab samples of the ground feed beginning 1 d prior to the beginning of each palatability trial and collection trial and ending 1 d prior to the termination of the palatability and collection trial. Refusals were weighed at each feeding, composited, and subsampled for analysis.

Each gelding was equipped with a harness and bag (Wyoming Tent Co, Cheyenne, WY) for total collection of feces (Figure 1). Geldings were allowed 4 d to adjust to a reduced feed intake. On day 4, following the palatability trial, geldings were fitted with the bags and harness. Geldings were allowed 1 d to adjust to the harness and bag. This was followed by a 5-d collection period.

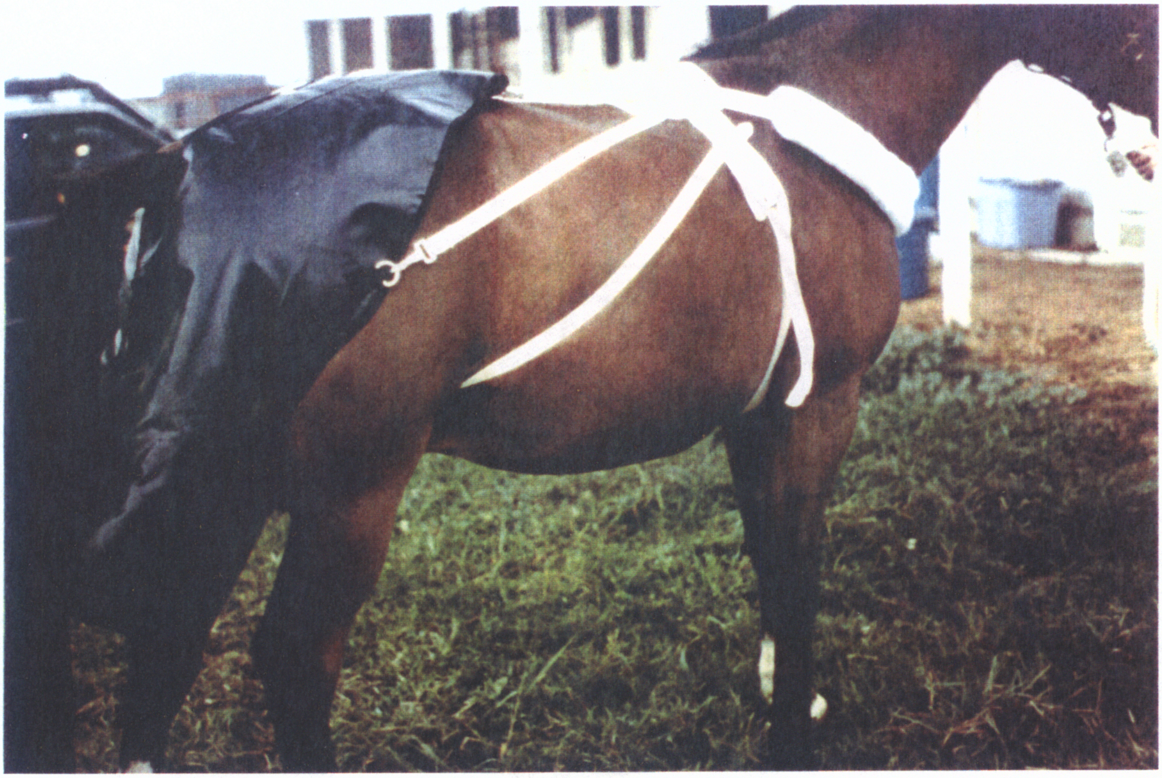

Figure 1. Gelding equipped with harness and bag for total collection of feces.

Fecal bags were changed three times each day at 0600, 1400, and 2000 hr to prevent bags from becoming too heavy and stressing the geldings. Each day's fecal samples were stored during the 24 hr in plastic ®Rubbermaid containers. Each morning, the fecal collection from the previous 24 hr was weighed and mixed using a Hobart mixer (Hobart Manufacturing Co., Troy, OH). A 10% sample of the feces was taken for percentage dry matter determination at 105° C in a forced draft oven and a 5% sample was dried at 50° C and ground for analysis.

Blood samples were collected from the jugular vein at the beginning, end of the palatability trial, and end of collection period for determination of BUN, and serum minerals. Separate blood samples were obtained for determination of vitamin A and E in serum. Vitamin A and E samples were protected from light at all times by wrapping with aluminum foil. A separate blood sample was also obtained in a heparazined tube for determination of Se in whole blood.

Geldings were evaluated for body condition score and weighed at the beginning, end of palatability, and end of collection following sampling blood beginning at 0700 hr. The geldings were individually walked daily for about 10 min between 1500 and 1600 hr.

Analyses. Samples of feed and refusals were stored in plastic bags until compositing. Feed and refusal samples were composited by horse for digestion trials and by feed for palatability trials and subsampled. Subsamples were dried for 48 hr in a forced draft oven at 55° C and ground through a 1-mm screen with a model ED-S stainless steel Wiley Mill (Thomas Scientific, Boston, MA). Feed, refusals during the digestion trials, feces, and serum were analyzed for Ca, Mg, P, K, S, Cu, Zn, Fe and Mn using inductively coupled plasma optical emission spectrospy following digestion with nitric and perchloric acid (Muchovej et al., 1986). Samples of feed, refusals and feces were analyzed for crude protein (AOAC, 1980), NDF, ADF, cellulose, and lignin by the procedure of Van Soest (Van Soest, 1963; Goering and Van Soest, 1970). Hemicellulose was calculated as NDF - ADF. Organic matter was determined for feed, feces, and refusals by dry ashing for 6 hrs at 600° C (AOAC, 1980). Total nonstructural carbohydrates were determined on feed samples following procedures of Davis (1976) and Smith (1981). *In vitro* dry matter digestibility was conducted on the feed samples using the modified Tilley and Terry two-stage in vitro technique (Tilley and Terry, 1963).

Blood urea nitrogen was determined by the method of Chaney and Marbach (1962). Vitamin A, vitamin E, and Se were determined by the Virginia-Maryland Regional College of

Veterinary Medicine from blood samples collected initially and at the end of the palatability trials (Elrick and Horowitz, 1986; Xi et al., 1988; Catignani and Bieri, 1991; Forage Livestock Lab, 1994).

Statistical Analysis

Data were analyzed as a Latin Square design with two complete Latin Squares using a model statement that tested block, treatment, trial, and animal within block (SAS, 1990). Orthogonal contrasts were: 1) alfalfa vs. the mean of tall fescue and Caucasian bluestem, and 2) tall fescue versus Caucasian bluestem. A probability level of .05 was considered significant.

RESULTS

Botanical Composition

Visual observations of tall fescue using the modified DAFOR scale showed 100% ground cover with 100% grass on an estimated dry weight basis. Tall fescue was dominant, bluegrass and white clover abundant, sweet vernalgrass (*Anthoxanthum odoratum* L.) and orchardgrass occasional, and weeds were rare (less than 5% of the estimated dry weight). Of the weeds, buttercup (*Ranunculus arvensis* L.) occurred occasionally and dandelion (*Taraxacum officinale* Weber in Wiggers.) was rare.

Visual observations of Caucasian bluestem using the modified DAFOR scale indicated about 95% ground cover. On an estimated dry weight basis, the ground cover consisted of about 100% grass. Caucasian bluestem was dominant with orchardgrass occasional and tall fescue and white clover rare. Weeds were also rare. Of the weeds, dock (*Rumex crispus* L.) and onion (*Allium canadense* L.) were occasional.

Using hand separations, botanical composition of tall fescue hay was 92% tall fescue, 3% orchardgrass, and 5% Kentucky bluegrass with < 1% sweet vernalgrass. The botanical composition of the Caucasian bluestem was 97% Caucasian bluestem, 2% weed and < 1% tall fescue, sweet vernalgrass, and orchardgrass. The botanical composition of the alfalfa hay was 91% alfalfa and 9% weeds.

Palatability Trial

Chemical composition. Alfalfa was higher ($P < .01$) in percentage crude protein than the grasses (Table 3). Alfalfa was lower ($P < .01$) in percentage NDF, hemicellulose, and cellulose, but was higher ($P < .01$) in percentage ADF and lignin compared to the grasses. Alfalfa was lower ($P < .05$) in percentage TNC compared to the grasses.

Tall fescue was higher ($P < .05$) in percentage crude protein, compared to Caucasian bluestem. Tall fescue was slightly lower ($P < .05$) in NDF than Caucasian bluestem. There were no other differences between the grasses in fiber components that were measured. Tall fescue was higher ($P < .01$) in percentage TNC compared to Caucasian bluestem.

Table 3. Composition[a] of alfalfa, tall fescue, and Caucasian bluestem hay fed to Arabian geldings in palatability trials

Item	Alfalfa	Grasses: Tall fescue	Grasses: Caucasian bluestem	SE
	%			
CP[b,d]	18	11	7	0.1
NDF[b,d]	55	71	72	0.1
ADF[b]	43	39	39	0.6
Hemicellulose[b]	12	32	33	0.6
Cellulose[b]	29	33	32	0.4
Lignin[b]	12	6	6	0.3
TNC[b,c]	4.1	8.3	7.1	0.2

[a]Dry Matter Basis
[b]Alfalfa differs from the mean of the grasses ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .01$).
[d]Tall fescue differs from Caucasian bluestem ($P < .05$).

Alfalfa was higher ($P < .01$) in Ca, Mg, P, K, S, Cu, and Fe, compared to the grasses (Table 4). Alfalfa was lower ($P < .01$) in Zn, compared to the mean of the grasses. Tall fescue was higher ($P < .01$) in Mg, P, K, S, and Cu, compared to Caucasian bluestem. Caucasian bluestem was higher ($P < .01$) in Zn and compared to tall fescue.

Voluntary intake. Dry matter intake of alfalfa hay was higher ($P < .05$), compared to grass hays when expressed on a kg/d or percentage of body weight basis (Table 5). Based on metabolic body weight, alfalfa had a higher ($P < .01$) dry matter intake and digestible dry matter intake than the grasses. Intake of crude protein, NDF, ADF, and lignin was also higher ($P < .01$) by geldings fed alfalfa, but intake of hemicellulose was lower ($P < .01$) compared with the grasses. The grasses did not differ in dry matter intake. Crude protein and cellulose intake for tall fescue was higher ($P < .01$ and $P < .05$, respectively) than Caucasian bluestem but intake of the other fiber components did not differ. Total nonstructural carbohydrate intake was lower ($P < .01$) for horses fed alfalfa compared to horses fed grasses. Feeding tall fescue resulted in higher ($P < .01$) TNC intake, compared to Caucasian bluestem.

Blood components. Initially, geldings did not differ with respect to packed cell volume, hemoglobin, BUN, vitamin A, vitamin E, and selenium (Table 6). At the end of the

Table 4. Average mineral composition[a] of alfalfa, tall fescue and Caucasian bluestem hay fed to Arabian geldings during palatability trials

Item	Alfalfa	Grasses		SE
		Tall fescue	Caucasian bluestem	
Ca, %[b]	1.0	0.3	0.3	0.01
Mg, %[b,c]	0.26	0.27	0.19	0.005
P, %[b,c]	0.40	0.31	0.15	0.007
K, %[b,c]	3.8	2.5	2.0	0.08
S, %[b,c]	0.24	0.19	0.14	0.003
Cu, ppm[b,c]	8.6	5.5	4.0	0.1
Zn, ppm[b,c]	28.2	19.0	62.0	0.4
Fe, ppm[b]	375.5	151.6	143.8	22.1

[a]Dry Matter Basis
[b]Alfalfa differs from the mean of the grasses ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .01$).

Table 5. Voluntary intake of dry matter, crude protein, and fiber components by Arabian geldings fed alfalfa, tall fescue and Caucasian bluestem hay

Item	Alfalfa	Grasses: Tall fescue	Grasses: Caucasian bluestem	SE
Dry matter				
kg/d[a]	11.6	10.6	9.8	0.3
DMI/% BW[b]	2.8	2.5	2.3	0.1
g DMI/kg $BW^{.75}$[a]	122.4	111.3	102.3	3.4
g DDMI/kg $BW^{.75}$[a]	71.2	54.8	45.0	3.6
Crude protein, kg/d[a,c]	2.1	1.2	0.7	0.3
NDF, kg/d[a]	6.4	7.6	7.1	0.2
ADF, kg/d[a]	5.0	4.2	3.9	0.1
Cellulose, kg/d[d]	3.4	3.5	3.1	0.1
Hemicellulose, kg/d[a]	1.4	3.4	3.2	0.1
Lignin, kg/d[a]	1.4	0.6	0.6	0.03
TNC, g/d[a,c]	476.9	882.0	691.5	23.8

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Alfalfa differs from the mean of the grasses ($P < .05$).
[c]Tall fescue differs from Caucasian bluestem ($P < .01$).
[d]Tall fescue differs from Caucasian bluestem ($P < .05$).

Table 6. Effect of forage species on blood components of Arabian geldings at the end of the palatability trials

Item	Time	Alfalfa	Grasses: Tall fescue	Grasses: Caucasian bluestem	SE
Packed cell volume, %	Initial	31.3	32.9	30.8	0.9
	Final	35.3	33.1	30.9	1.5
Hemoglobin, g/dl	Initial	11.5	12.3	11.9	0.4
	Final	12.3	12.2	12.4	0.4
Blood urea nitrogen, mg/dl	Initial	16.7	16.1	16.4	1.1
	Final[a,b]	22.7	19.9	14.1	0.7
Vitamin A, ppm	Initial	154.7	152.2	154.5	7.6
	Final[a]	180.0	125.8	126.7	7.7
Vitamin E, ppb	Initial	2.8	2.7	2.7	0.1
	Final	2.7	2.5	2.8	0.1
Se, ppb	Initial	238.5	239.8	227.8	5.5
	Final[c]	215.2	211.3	217.8	2.0

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Tall fescue differs from Caucasian bluestem ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .06$).

palatability trials there were no differences between treatments in packed cell volume or hemoglobin. Geldings fed alfalfa had higher ($P < .01$) BUN than geldings fed grasses by the end of the palatability trials. Feeding tall fescue resulted in higher ($P < .01$) BUN than Caucasian bluestem. Serum vitamin A was higher ($P < .01$) in geldings fed alfalfa compared to geldings fed the grasses.

There were no significant differences among treatments in serum vitamin E, but there was a trend ($P < .2$) for geldings fed tall fescue to have lower values than geldings fed Caucasian bluestem. By the end of the palatability trials, feeding Caucasian bluestem resulted in higher ($P < .06$) serum Se, compared to tall fescue.

There were no significant differences among treatments at the end of the palatability trials in serum Ca, Mg, K, and Fe (Table 7). Feeding alfalfa resulted in higher ($P < .01$) serum P, S, and Cu, compared to the grasses. Feeding Caucasian bluestem resulted in higher ($P < .05$) serum Zn, compared to tall fescue.

Digestion Trials

Forage composition. Hays fed during the digestion trials were similar in composition to those fed during palatability trials (Tables 3 and 8). Alfalfa was higher (P

Table 7. Effect of forage species on mineral components of blood of Arabian geldings at the end of the palatability trials

Item	Time	Alfalfa	Grasses		SE
			Tall fescue	Caucasian bluestem	
Ca, mg/dl	Initial	10.8	11.3	10.9	0.3
	Final	11.7	11.5	11.7	0.3
Mg, mg/dl	Initial	1.6	1.6	1.6	0.1
	Final	1.9	1.7	1.9	0.1
P, mg/dl	Initial	8.7	8.8	8.6	0.4
	Final[a]	9.7	8.6	8.6	0.2
K, mg/dl	Initial	15.7	15.8	15.3	0.6
	Final	16.3	16.3	16.1	0.5
S, mg/dl	Initial	77.6	81.4	78.7	1.0
	Final[a]	80.7	75.8	77.5	0.8
Cu, ppm	Initial	1.5	1.6	1.7	0.04
	Final[a]	1.6	1.4	1.3	0.1
Zn, ppm	Initial	0.7	0.7	0.6	0.03
	Final[b]	0.5	0.6	0.9	0.1
Fe, ppm	Initial	3.4	1.8	2.0	0.6
	Final	3.1	2.5	2.3	0.5

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Tall fescue differs from Caucasian bluestem ($P < .05$).

Table 8. Composition[a] of alfalfa, tall fescue and Caucasian bluestem hay fed to Arabian geldings during digestion trials

		Grasses		
Item	Alfalfa	Tall fescue	Caucasian bluestem	SE
	---------- % ----------			
CP[b,c]	19	11	7	0.3
NDF[b]	55	72	73	0.4
ADF[b]	43	40	39	0.6
Hemicellulose[b,c]	11	31	34	0.3
Cellulose[b]	29	33	33	0.4
Lignin[b]	12	6	5	0.4
TNC[b,c]	3.9	7.9	7.1	0.1

[a]Dry Matter Basis
[b]Alfalfa differs from the mean of the grasses ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .01$).

< .01) in CP concentration than the grasses, while tall fescue had a greater (P < .01) CP concentration than Caucasian bluestem. Alfalfa was lower (P < .01) in percentage NDF, cellulose, hemicellulose, and TNC, and was higher (P < .01) in percentage lignin than the grasses. The only differences between the grasses were higher (P < .01) percentage CP and TNC for tall fescue, and higher (P < .01) percentage hemicellulose for Caucasian bluestem.

Hays fed during the digestion trials were similar in mineral concentration to hays fed during the palatability trials (Tables 4 and 9). Alfalfa was higher (P < .01) in Ca, Mg, P, K, S, Cu, and Fe, and lower (P < .01) in Zn, compared to the grasses. Tall fescue was higher (P < .01) in Mg, P, K, S, and Cu, and lower (P < .01) in Zn, compared to Caucasian bluestem.

Apparent digestibility of forage. Alfalfa was higher (P < .01) in apparent dry matter digestibility and organic matter digestibility (OMD) than the grasses (Table 10). Alfalfa was higher (P < .01) in apparent digestibility of CP, ADF, cellulose and lignin than the grasses. Tall fescue was higher (P < .01) in apparent digestibility of crude protein than Caucasian bluestem. Caucasian bluestem had a negative apparent lignin digestibility. The forages did not differ in apparent digestibility of NDF or hemicellulose.

Table 9. Average mineral composition[a] of alfalfa, tall fescue and Caucasian bluestem hay fed to Arabian geldings during digestion trials

Item	Alfalfa	Grasses: Tall fescue	Grasses: Caucasian bluestem	SE
Ca, %[b]	0.87	0.22	0.23	0.01
Mg, %[b,c]	0.24	0.23	0.17	0.005
P, %[b,c]	0.36	0.25	0.13	0.004
K, %[b,c]	3.3	2.1	1.6	0.07
S, %[b,c]	0.24	0.18	0.12	0.005
Cu, ppm[b,c]	7.5	4.4	3.7	0.1
Zn, ppm[b,c]	25.6	15.1	50.8	0.8
Fe, ppm[b]	334	92	135	23.3

[a]Dry Matter Basis
[b]Alfalfa differs from the mean of the grasses ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .01$).

Table 10. Apparent digestibility of alfalfa, tall fescue and Caucasian bluestem hays fed Arabian geldings

Item	Alfalfa	Grasses: Tall fescue	Grasses: Caucasian bluestem	SE
	%			
DMD[b]	58	48	44	1.6
OMD[b]	59	48	44	1.6
CP[a,b,c]	72	67	44	1.3
NDF[a]	47	43	42	2.1
ADF[a,b]	45	36	33	2.2
Cellulose[a,b]	56	43	44	1.9
Hemicellulose[a]	55	52	52	2.8
Lignin[a,b]	31	11	-19	5.8
IVDMD[a,b]	62	59	58	0.5

[a]Dry Matter Basis
[b]Alfalfa differs from the mean of the grasses ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .01$).

In vitro dry matter digestibility of alfalfa was greater ($P < .01$) than the grasses (Table 10) with no differences between the grasses.

Feeding alfalfa resulted in higher ($P < .01$) Ca and Mg intake and higher ($P < .01$) fecal excretion compared to grasses (Table 11). Geldings fed alfalfa had higher ($P < .01$) apparent absorption of Ca on a g/d basis, compared to geldings fed grasses. There were no differences in apparent absorption of Ca as percent of intake. Intake and apparent absorption of Ca was similar in geldings fed the two grass hays.

Feeding tall fescue resulted in higher ($P < .01$) Mg intake and fecal excretion, compared to Caucasian bluestem. Geldings fed tall fescue had higher ($P < .01$) apparent absorption of Mg on a g/d basis, compared to geldings fed Caucasian bluestem, but there were no differences in apparent absorption of Mg as percent of intake.

Feeding alfalfa resulted in higher ($P < .01$) P intake and fecal excretion compared to grasses (Table 12). Feeding tall fescue resulted in higher ($P < .01$) intake of P, compared to Caucasian bluestem. Geldings fed tall fescue excreted more ($P < .01$) P, compared to geldings fed Caucasian bluestem. There were no significant differences in apparent absorption of P as a percent of intake among the three forages.

Table 11. Intake and apparent absorption of calcium and magnesium by geldings fed alfalfa, tall fescue, and Caucasian bluestem

		Grasses		
Item	Alfalfa	Tall Fescue	Caucasian bluestem	SE
Calcium				
Intake, g/d[a]	77.8	19.5	19.8	1.3
Fecal excretion, g/d[a]	42.0	11.3	10.1	1.3
Apparent absorption				
g/d[a]	35.8	8.1	9.7	0.9
% of intake	46.3	40.7	49.6	4.0
Magnesium				
Intake, g/d[a,b]	21.6	20.2	14.3	0.5
Fecal excretion, g/d[a,b]	15.9	13.7	10.3	0.3
Apparent absorption				
g/d[b]	5.7	6.5	4.0	0.5
% of intake	27.3	32.4	28.5	2.7

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Tall fescue differs from Caucasian bluestem ($P < .01$).

Table 12. Intake and apparent absorption of phosphorus and potassium by geldings fed alfalfa, tall fescue, and Caucasian bluestem

Item	Alfalfa	Grasses: Tall Fescue	Grasses: Caucasian bluestem	SE
Phosphorus				
Intake, g/d[a,b]	31.9	21.8	10.9	0.6
Fecal excretion, g/d[a,b]	29.5	21.2	11.7	0.9
Apparent absorption g/d	2.4	0.6	-0.9	1.0
Potassium				
Intake, g/d[a,b]	292.9	185.6	142.7	6.9
Fecal excretion, g/d[a,c]	64.6	50.5	36.9	3.3
Apparent absorption g/d[a]	228.3	135.1	105.8	7.8
% of intake	77.8	72.8	74.2	1.8

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Tall fescue differs from Caucasian bluestem ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .05$).

Geldings fed alfalfa had higher ($P < .01$) intake and fecal excretion of K, compared to geldings fed grasses (Table 12). Feeding alfalfa resulted in higher ($P < .01$) apparent absorption of K on a g/d basis, compared to grasses. Feeding tall fescue resulted in more ($P < .05$) fecal excretion of K, compared to Caucasian bluestem. There were no differences among the forages in apparent absorption of K as a percent of intake.

Feeding alfalfa resulted in higher ($P < .01$) intake and apparent absorption of S, compared to grasses (Table 13). Geldings fed tall fescue had higher ($P < .01$) intake and apparent absorption of S than geldings fed Caucasian bluestem. Differences in apparent absorption were observed when expressed either on a g/d or percentage of intake basis.

Feeding alfalfa resulted in higher ($P < .01$) intake and fecal excretion of Cu, compared to grasses (Table 13). Feeding tall fescue resulted in higher ($P < .05$) intake and fecal excretion of Cu, compared to Caucasian bluestem. There were no differences in apparent absorption of Cu.

Feeding alfalfa resulted in lower ($P < .01$) intake and fecal excretion of Zn, compared to the mean of the grasses, but these differences were due to the high intake and excretion of Zn in geldings fed Caucasian bluestem (Table 14). Geldings fed tall fescue had lower ($P < .01$) intake, fecal excretion, and lower ($P < .05$) apparent absorption of

Table 13. Intake and apparent absorption of sulfur and copper by geldings fed alfalfa, tall fescue, and Caucasian bluestem

Item	Alfalfa	Grasses: Tall Fescue	Grasses: Caucasian bluestem	SE
Sulfur				
Intake, g/d[a,b]	21.6	15.6	10.0	0.5
Fecal excretion, g/d	7.4	7.1	7.1	0.2
Apparent absorption				
g/d[a,b]	14.2	8.5	2.9	0.6
% of intake[a,b]	65.9	54.4	28.3	2.6
Copper				
Intake, mg/d[a,c]	6.7	3.9	3.2	0.2
Fecal excretion, mg/d[a,c]	6.5	3.6	2.9	0.2
Apparent absorption				
mg/d	2.1	3.0	2.5	0.2
% of intake	3.4	7.8	7.0	5.6

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Tall fescue differs from Caucasian bluestem ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .05$).

Table 14. Intake and apparent absorption of zinc and iron by geldings fed alfalfa, tall fescue, and Caucasian bluestem

Item	Alfalfa	Grasses: Tall Fescue	Grasses: Caucasian bluestem	SE
Zinc				
Intake, g/d[a,b]	0.2	0.1	0.5	0.01
Fecal excretion, g/d[a,b]	0.3	0.2	0.5	0.01
Apparent absorption g/d	-0.02	-0.03	-0.004	0.01
Iron				
Intake, g/d[a]	3.1	0.7	1.1	2.2
Fecal excretion, g/d[a]	4.0	1.4	1.6	3.0
Apparent absorption g/d	-0.9	-0.6	-0.5	0.1

[a]Alfalfa differs from the mean of the grasses ($P < .01$).
[b]Tall fescue differs from Caucasian bluestem ($P < .01$).
[c]Tall fescue differs from Caucasian bluestem ($P < .05$).

Zn than geldings fed Caucasian bluestem. All forages resulted in net apparent secretion of Zn.

Feeding alfalfa resulted in higher ($P < .01$) intake and fecal excretion of Fe, compared to grasses (Table 14). There were no differences in apparent absorption of Fe. All forages resulted in net secretion of Fe.

Blood components. At the end of the digestion trials, there was no difference in packed cell volume (Table 15). Horses fed grass hays had higher ($P < .05$) hemoglobin at the end of the trials than the horses fed alfalfa hay ($P < .05$). Horses fed alfalfa hay had higher ($P < .05$) BUN than horses fed grass hays. There was a trend ($P < .1$) for horses fed tall fescue to have higher BUN values compared to horses fed Caucasian bluestem hay at the end of the digestion trials. Feeding alfalfa resulted in higher ($P < .05$) serum Cu, compared to grasses (Table 16). The geldings did not differ in serum mineral concentration of Ca, Mg, P, K, S, Zn, and Fe although differences existed in the forages.

Table 15. Effect of forage species on blood components of Arabian geldings at the end of digestibility trials

Item	Alfalfa	Grasses: Tall fescue	Grasses: Caucasian bluestem	SE
Packed cell volume, %	29.4	30.9	31.5	0.7
Hemoglobin, g/dl[a]	11.5	12.2	12.7	0.3
Blood urea nitrogen, mg/dl[a]	19.7	17.2	14.4	1.0

[a]Alfalfa differs from the mean of the grasses ($P < .05$).

Table 16. Effect of forage species on mineral components of blood of Arabian geldings at the end of digestibility trials

		Grasses		
Item	Alfalfa	Tall fescue	Caucasian bluestem	SE
Ca, mg/dl	11.3	12.0	11.2	0.5
Mg, mg/dl	1.5	1.6	1.7	0.1
P, mg/dl	8.7	8.6	8.6	0.2
K, mg/dl	14.7	15.3	15.0	0.4
S, mg/dl	78.5	77.6	80.7	1.7
Cu, ppm[a]	1.6	1.3	1.3	0.1
Zn, ppm	0.8	0.9	0.9	0.1
Fe, ppm	2.5	2.0	1.9	0.2

[a]Alfalfa differs from the mean of the grasses ($P < .05$).

DISCUSSION

The forages used in this experiment were relatively pure for the desired species. The modified DAFOR scale indicated that the hays were mostly free of weeds. Visual evaluation by the DAFOR scale appeared to over-emphasize the presence of other grasses in tall fescue paddocks. The DAFOR scale documented relative abundance and not percentage on a dry weight basis. The hand separations indicated that 92% of the dry weight was tall fescue. Thus, the DAFOR scale provided information on other plants present in the field but not included in the harvested hay. Data from the hand separations supported this. Observations of the Caucasian bluestem paddocks indicated that the weeds and cool-season grasses and legumes had largely been eliminated by herbicide applications.

Alfalfa is a standard hay used in the horse industry. It is often chosen for performance horses because it is higher in CP and some minerals and vitamins, compared to grasses. Tall fescue was used in this study because it is the most commonly found cool-season grass in Virginia pastures. Caucasian bluestem was chosen as a warm-season species because of its performance in studies using cattle (Fontenot et al., 1993), and its ability to survive in Virginia, and its protential to provide forage during midsummer.

The major difference in chemical composition of the forage hays was in CP. As expected, alfalfa, a cool-season legume, had the highest percentage CP. Legumes are generally higher in CP, compared to grasses (Cunha, 1980; Norton, 1981). Caucasian bluestem, a warm-season grass had the lowest percentage crude protein. These results are consistent with what is expected for cool-season forages vs. warm-season forages (Jung et al., 1985). Chemical composition of the grasses was similar in all other respects. Tall fescue was one percentage point lower in NDF, compared to Caucasian bluestem, but this may not have had practical importance and was only significant in hays fed during the palatability trials. The 7.1% TNC in Caucasian bluestem may account for the 1.1 to 1.4 kg/d weight gain of steers grazing Caucasian bluestem from late June to early August at the

Southwest Virginia Research Center, Glade Spring, VA prior to this study (Fontenot et al., 1993).

Alfalfa had a higher voluntary dry matter intake compared to the grasses. Legumes have generally been shown to have high dry matter intake compared with grasses (Reid et al., 1959; Van Soest, 1965). Van Soest (1965) suggested that total cell wall content affected intake, and legumes generally have lower total cell wall content compared to grasses. In our study, alfalfa had lower percentage NDF, compared to the grasses.

Voluntary intake on metabolic body size and percent of body weight was also higher for geldings fed alfalfa. This is consistent with the fact that alfalfa had lower percentage NDF, compared to the grasses. The grasses did not differ in dry matter intake. As percentage NDF increases, voluntary intake of ruminants decreases (Van Soest, 1965).

Alfalfa was higher in percentage lignin and lower in percentage ADF compared to the grasses. The cause of the negative apparent digestibility of lignin in Caucasian bluestem is not known. However, it is consistent across the data. A lower ADF indicates higher dry matter digestibility (Van Soest, 1965). This is consistent with the results found *in vivo* and *in vitro*. The DMD of alfalfa by geldings was 58%. Vander Noot and Gilbreath (1970) found that horses can digest 60.8% of the dry matter in alfalfa hay harvested at

1/10 bloom. The results of this study were very close to these results.

Although tall fescue is a cool-season grass and Caucasian bluestem is a warm-season grass, they did not differ as expected in dry matter digestibility. The DMD of tall fescue and Caucasian bluestem by geldings was 48% and 44%, respectively. This is not consistent with *in vitro* and *in vivo* data compiled by Reid et al. (1988) which showed warm-season grasses such as switchgrass, big bluestem, little bluestem, Indiangrass, Plains bluestem, and Caucasian bluestem had lower IVDMD and DMD by cattle and sheep compared to cool-season grasses. The difference may be a result of the hays in this study being harvested at optimum times. Reid et al. (1988) found most warm-season grasses to have IVDMD around 50%, compared to 60% for cool-season grasses such as orchardgrass, tall fescue, alfalfa, red clover, crownvetch, and birdsfoot trefoil. Our data showed tall fescue and Caucasian bluestem had IVDMD of 59% and 58%, respectively. Caucasian bluestem in this study had higher IVDMD than the warm-season grasses studied by Reid et al. (1988). Dry matter digestibility of warm-season grasses was 55% for sheep, compared with 66% for sheep fed cool-season forages. Dry matter digestibility of warm-season grasses fed to cattle was 60%, compared to 67% for the cool-season species. The data of Reid et al. (1988) are supported results reported by Vona et al. (1984). Horses had a lower DMD than ruminants. However, ruminants digest dry matter of grass hays more efficiently than horses (Harbers et al., 1981; Vander Noot and Gilbreath, 1970).

In our research, the IVDMD procedure consistently overestimated apparent digestibility observed *in vivo*. Alfalfa was overestimated by 4%, while tall fescue and Caucasian bluestem were overestimated by 11 and 16%, respectively. Thus, the IVDMD appeared to be a more accurate predictor of the legume than the grass hays. However, Jung et al. (1985) found the IVDMD procedure underestimated the dry matter digestibility of switchgrass when compared to metabolism trials with steers. The estimated difference between *in vivo* and *in vitro* may have been due to rumen fluid used in the *in vitro* studies as opposed to the *in vivo* studies with geldings which are nonruminants. *In vitro* DMD data using cecal fistulated ponies and rumen fistulated, dry cows indicated greater IVDMD when rumen fluid was used, compared to cecal fluid (Koller et al., 1978).

Digestible CP requirement for horses is .6 g/kg body weight or .3 g/d (NRC, 1989). We found digestible CP intake (1.5 kg/d) was higher for alfalfa compared to the grasses and higher for tall fescue (0.8 kg/d) compared to Caucasian bluestem (0.3 kg/d; data not shown). All forages met the digestible CP requirement on a g/kg body weight basis.

Digestible intake of NDF was higher for tall fescue compared (3.3 kg/d) to Caucasian bluestem (2.9 kg/d). Digestible hemicellulose intake was lower in alfalfa (0.8 kg/d) compared to tall fescue (1.8 kg/d) and Caucasian bluestem (1.7 kg/d). Digestible cellulose intake was higher for alfalfa (1.9 kg/d) compared to tall fescue (1.5 kg/d) and Caucasian bluestem (1.4 kg/d). This is consistent with the results of chemical composition and dry matter digestiblity of the forages.

According to NRC (1989) requirements, all forages appeared to meet the requirements for horses at maintenance for Ca, P, Mg, K, and Fe (Table 2). Alfalfa and tall fescue used in this study were low in Zn for all classes of horses. All forages were low in Cu and would not have met the Cu requirement for horses at maintenance. NRC (1985) indicates this may be due to a copper deficiency in soils and most forages in the Southeast United States (NRC, 1985). Caucasian bluestem was marginal in S for horses at maintenance. For growing or working horses, and pregnant or lactating mares, only alfalfa appeared to meet the requirement for Ca. Tall fescue and alfalfa appeared to meet the P requirement for working horses, but only alfalfa met the P requirement for growing horses and pregnant or lactating mares. Reid et al., (1988) suggested that low uptake of certain elements such as N and S by warm-season grasses, such as Caucasian bluestem may limit animal performance unless supplemented. Our results confirm this with respect to CP and S.

Alfalfa was higher in Ca, Mg, and vitamin A, compared to grasses. Legumes are generally higher in Ca and Mg and vitamin A, compared to grasses (Fonnesbeck and Symons, 1967; Fonnesbeck, 1969; Norton, 1981). Fonnesbeck and Symons (1967) found alfalfa to be higher in Ca and carotene, the precursor to vitamin A, than grasses. Thus, geldings fed alfalfa had higher Ca and Mg intake and fecal excretion, comapared to geldings fed grass hays. Alfalfa was higher in P and K compared to grasses. Burke (1987) found that alfalfa surpassed P requirement of horses. The Ca:P ratio of alfalfa used in this study is close to the suggested 2:1 ratio. Alfalfa was higher in S, Cu, and Fe, compared to the grasses which is supported by Cunha (1980). However, in this study, the alfalfa did not meet the Cu requirement and Cu would require supplementation. Horses fed alfalfa hay or grazing alfalfa comparable to that used in our study, would not need supplementation of Ca, Mg, P, K, or vitamin A.

Tall fescue was higher in Mg, P, K, S, and Cu, compared to Caucasian bluestem. These findings, with the exception of Mg are consistent with those reported by Norton (1981). He suggested that cool-season grasses are lower in percent Mg compared to warm-season grasses. Morris et al. (1982) found that although warm-season grasses utilize P better than cool-season grasses in low P situations, warm-season grasses are generally lower in P than cool-season grasses. Caucasian bluestem was higher in Zn and Fe, compared to tall fescue. The grasses were grown on different soils, but Reid et al. (1988) also found Caucasian bluestem to be higher in Zn compared to cool-season grasses. The net secretion of Zn and Fe by all geldings appeared to imply that these horses were at balance which is consistent with mature horses at maintenance. Net secretion of Zn and Fe were most likely not due to contamination because any feces that touched the ground was not included in the mixed sample.

Blood components measured were within the normal ranges for geldings at all times (Duncan and Prasse, 1986). No deficiencies were observed which supported the no change in body condition or weight (data not shown). The lack of differences in initial blood parameters was a result of being on the same diet before the start of the trials. Blood urea nitrogen was higher in geldings fed alfalfa hay which is consistent with the higher percentage crude protein in the alfalfa hay. When comparing the grasses, feeding tall fescue hay resulted in higher BUN which was consistent with the higher percentage CP, in tall fescue, compared to Caucasian bluestem.

Serum vitamin A was higher in geldings fed alfalfa hay. Legumes are higher in beta-carotene, the precursor to vitamin

A (Fonnesbeck and Symons, 1967). Vitamin A is required for vision and the prevention of night blindness (NRC, 1989). Serum Se was higher in geldings fed Caucasian bluestem, and there was a trend ($P < .2$) for serum vitamin E to be higher. Selenium and vitamin E act as antioxidants to prevent the buildup of lipid peroxides. Vitamin E prevents the formation of lipid peroxides from unsaturated lipids. Selenium is part of glutathione peroxidase that breaks down lipid peroxides (Rotruck et al., 1973). Selenium is marginal in the soils of the Southeast United States (NRC, 1985). This causes concern because Se supplementation is restricted for horses (NRC, 1989). The Se requirement for horses is .1 ppm and Se was undectectable in all forages (NRC, 1989). Serum vitamin A, E, and Se were not measured at the end of the digestion trials because the horses were on restricted intake during that time.

Although there were no differences in serum mineral components at the end of the digestion trials, there were significant differences in mineral composition of the forages as already stated. Only horses fed alfalfa had higher serum Cu. However, alfalfa did not meet the Cu requirement. There were differences in serum mineral components at the end of palatability. This may be a result of the horses being on unrestricted intake during palatability trials. Serum Ca and

Mg did not differ probably because homeostatic mechanisms maintain the range of serum Ca and Mg (NRC, 1989).

The results raise many questions with regard to the nutritional value of Caucasian bluestem for horses. The digestibility of lignin in Caucasian bluestem merits further research. Also, more mineral research is needed to further investigate the potential for Caucasian bluestem to meet the requirements of working and growing horses and pregnant or lactating mares. This research was conducted using Caucasian bluestem as harvested hay. The next step should be to conduct grazing studies with alfalfa, tall fescue, and Caucasian bluestem. Caucasian bluestem is a viable option in Virginia. The stands used for this research have been able to survive the winters in Virginia and have required minimal herbicide and fertilization applications.

CONCLUSIONS

All three forages appear to meet most nutritional requirements of horses at maintenance. All forages were low in Cu content. Caucasian bluestem hay was marginal in crude protein content. Feeding Caucasian bluestem resulted in lower crude protein intake and digestibility, compared to feeding alfalfa and tall fescue. Feeding Caucasian bluestem also appeared to result in net secretion of some minerals by some horses. However, this was not consistent. Caucasian bluestem was too low in percentage S to meet the S requirement for horses at maintenance. Caucasian bluestem was also low in some minerals and would require supplementation for growing and working horses as well as pregnant or lactating mares. However, dry matter digestibility of Caucasian bluestem did not differ from dry matter digestibility of tall fescue. Selective grazing of vegetative Caucasian bluestem may increase the percent crude protein and other minerals as well as dry matter digestibility. From the results of this study, more research concerning minerals and digestibility of Caucasian bluestem is needed. However, it does appear that Caucasian bluestem has the potential to be implemented into grazing systems for horses in Virginia.

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