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Voluntary intake and digestibility of teff hay fed to horses[1]

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ABSTRACT: The objective of this study was to evaluate nutrient composition, voluntary DMI, and apparent DM digestibility of teff hay cut at 3 different stages of maturity to evaluate its potential as a preserved forage for horses. Six mature Quarter Horse mares (12 ± 3 yr; 553 ± 39 kg of BW) were used in a replicated balanced Latin square design with 3 periods and 3 maturities of teff hay. *Eragrostis tef* ('Tiffany' teff) was planted in May and harvested at the boot, early-heading, or late-heading stage of maturity through the summer. Horses were acclimated to a mixture of maturities of teff hay for 8 d before the beginning of the study. After this acclimation period, each period consisted of a 9-d voluntary DMI phase, followed by a 3-d DM digestibility phase. The percentages of nonstructural carbohydrates (NSC) increased from 5.4% in the boot stage to 8.4% in the late-heading stage, whereas concentrations of CP, K, Fe, and Mn decreased. The Ca:P ratio was 2.0 ± 0.3 for all maturities. Horses had less DMI of late-heading teff hay (1.5% BW) than teff hay of other maturities (1.8% BW; $P < 0.05$), indicating a preference for the earlier maturities. The intake and nutrient composition of the boot and early-heading maturities was sufficient to meet 90 to 97% of the average DE of the horses and most other nutrient requirements. Digestibility decreased from boot to late-heading teff hay for DM, CP, ADF, and NDF ($P < 0.05$). Digestibility increased from boot to early-heading to late-heading hay for nonfiber carbohydrates and water-soluble carbohydrates ($P < 0.05$). For all maturities of teff hay, the NSC intake was below 10% of the total intake. In conclusion, the low NSC and DE of teff hay grown in central Pennsylvania under the conditions in this study make it an appropriate forage source for obese horses and those at risk for laminitis or other metabolic disorders.

Key words: hay maturity, horse, indigestibility, teff, voluntary intake

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INTRODUCTION

Horse health disorders, including equine metabolic syndrome, laminitis, obesity, insulin resistance, and osteochondrosis have been associated with abnormalities in glucose metabolism and insulin signaling (Ralston, 1996; Treiber et al., 2005; Frank, 2009). This research has led to the recommendation to decrease dietary nonstructural carbohydrates (**NSC**) to reduce the risk of these associated health disorders (Kronfeld et al., 2004). We define NSC as the sum of water-soluble carbohydrates (**WSC**) and starch (Longland and Byrd, 2006). Although a reduction in grain intake is an obvious first choice for reducing dietary NSC, forages also contribute to dietary NSC. Researchers have investigated ways of reducing the amount of NSC intake from forage (McIntosh et al., 2007; Longland et al., 2009). One approach has been to use perennial warm-season grasses because of their generally decreased concentrations of NSC compared with perennial cool-season grasses (Watts and Chatterton, 2004). This is a consequence of warm-season grasses containing few or no fructans, whereas cool-season grasses contain 30 to 100 g/kg of DM (Moore and Hatfield, 1994).

Teff is a warm-season annual grass native to Ethiopia and is adapted to a range of climatic and geographic regions (NRC, 1996). Companies marketing teff as a preserved forage appropriate for horses claim a nutrient profile similar to timothy hay. In addition to its potential as hay for horses, teff is relatively disease and pest resistant and can be ready for cutting in 40 to 60 d when grown under good conditions (Target Seed, 2009). These characteristics make it an attractive crop for forage producers. The combined benefits to forage

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Table 1. Teff hay harvest sequence from 3 sections of the field to obtain hay of 3 different maturities[1]

	Field section		
Harvest	A	B	C
1	July 14, boot	July 28, early heading	August 11, late head
2	August 26,[2] late heading	September 2, early heading	September 15, early heading
3	September 22, boot	September 22, boot	

[1]Information is presented as date harvested and hay maturity. Boot = R0; early head = R2; late head = R4, where R is reproductive-floral development (Moore et al., 1991).

[2]Discarded because of rain damage.

and equine producers make teff a potentially beneficial crop in areas with large equine populations. The objective of this study was to evaluate nutrient composition, voluntary DMI, and apparent DM digestibility of teff hay cut at 3 different stages of maturity to evaluate its potential as preserved forage for horses.

MATERIALS AND METHODS

Animal protocols for this study were approved by The Pennsylvania State University Institutional Animal Care and Use Committee.

Animals and Diets

The study was conducted in January and February of 2009 in the middle of the winter season of the central Pennsylvania region (mean temperature, −3.1 ± 6.2°C; range, −20 to 19°C). Six nonpregnant Quarter Horse mares [12 ± 3 yr; 553 ± 39 kg of BW; 5.5 ± 0.9 BCS (1 to 9 scale, where 1 = poor and 9 = extremely fat)] were housed at the John O. Almquist Research Center in University Park, PA. All horses had routine veterinary medical care performed before the experiment, including deworming (Ivermectin, Bimeda-MTC Animal Health Inc., Cambridge, Ontario, Canada), teeth floating, and vaccinations if needed. Horses were housed at the Research Center for 8 d before the beginning of the study to allow for acclimation to the experimental conditions. Fresh, clean water and salt blocks containing only NaCl were available at all times. Horses were weighed using a livestock platform scale just before the beginning of the study and then before each DM digestibility phase. A replicated balanced Latin square design with 3 treatments, 3 periods, and 6 horses was used to allow estimation of any first-order carryover effects (Williams, 1949). Mares were paired by similar BW and the pairs were split and assigned to 1 of the 2 replicate squares so that the BW of mares in 1 square was similar to that of the other. For a period of 8 d before the beginning of the study, horses were acclimated to the teff hay by providing a mixture of equal parts of the 3 maturities of teff hay at each feeding. Each of the 3 experimental periods consisted of a 9-d voluntary DMI phase followed by a 3-d DM digestibility phase.

Eragrostis tef ('Tiffany' teff) was planted with a seeder (Brillion Farm Equipment, Brillion, WI) in a 1.2-ha conventionally tilled seedbed of a Hagerstown silt loam (fine-loamy, mixed, mesic Typic Hapludalfs) soil at the Russell E. Larson Agricultural Research Center near Rock Springs, PA, on May 28, 2008. Before planting, soils were limed and fertilized with P_2O_5 and K_2O according to soil test recommendations. Nitrogen was applied at 67 kg/ha 28 d after planting and 45 kg/ha after each harvest except the last. The teff area was divided into thirds (sections A, B, and C, consisting of 0.4 ha each), and each section was mowed with a disk mower equipped with an impeller conditioner when the grass reached either the boot, early-heading, or late-heading stage (Moore et al., 1991; Table 1). The teff was allowed to field dry until it reached 80% of DM, when it was baled into approximately 18-kg bales and stored in a barn. Hay exposed to precipitation during field drying was removed from the study to minimize quality variability within a hay maturity stage. Approximately 1,450 kg of hay of each maturity was prepared and stored for this study. A mixture of the 3 treatment hays was fed during the initial 8-d acclimation period to meet or slightly exceed the average daily DE requirements for maintenance for each horse (NRC, 2007). Throughout the study, hay was offered in concrete feeders incorporated into the corner of each stall.

Voluntary Intake

During the voluntary DMI phase, each horse was kept in a rubber-matted box stall (12.9 m^2) lightly bedded with pine shavings and allowed access to an individually fenced outdoor compacted stone enclosure (36 m^2). Each voluntary DMI phase lasted 9 d, during which mares were fed their experimental hay twice daily (0700 and 1900 h). Hay was initially offered at 2.2% of BW (as-fed basis), slightly over the daily elevated DE requirement of each horse, and it was adjusted as needed to ensure horses always had hay available (NRC, 2007). Stalls were cleaned three times daily (0730, 1200, and 1930 h). Orts were weighed, recorded, and subtracted from the daily amount of hay offered and the total, multiplied by the hay DM, to determine daily voluntary DMI.

Digestibility

During the DM digestibility phase, bedding was removed from stalls, and horses were allowed access to their outdoor enclosures for only 15 min each day at 1200 h while their stalls were cleaned. Each horse was offered the same experimental hay from the preceding voluntary DMI phase. Horses were fed an amount to meet their increased daily DE requirements for maintenance (NRC, 2007). The increased amount of maintenance DE was chosen over the average quantity because of the lower daily temperatures during the study possibly contributing to a greater DE requirement (Cymbaluk and Christison, 1989). Hay was fed in 2 meals (0700 and 1900 h). Orts were weighed, recorded, and subtracted from the daily amount of hay offered and the total, multiplied by the hay DM, to determine daily DMI. Manure was removed continuously on a 24-h basis for 3 d to allow for determination of total daily fecal output and to reduce any possible contamination with hay or urine. At 3 increments during the day (0700, 1200, and 1900 h), a subsample of the most recently excreted feces, approximately 0.2 kg, was obtained from each horse, placed in a collection bag, and weighed. The remaining feces were collected into 88-L plastic containers lined with plastic bags that were closed throughout the day to maintain the moisture content of the manure. Fecal output was calculated as the summed weight of the subsamples and the 88-L container for each 24-h period. The subsamples of feces for each horse for the 3-d digestibility phase were dried in a forced-air oven (55°C) for 48 h and ground through a 1-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) and mixed thoroughly, and a composite subsample was submitted in duplicate for nutrient analysis at a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY). Sample nutrient analysis was the same as that described for forages. Dry matter was determined by dividing the weight of the hay or feces after drying by the wet weight of the hay or feces as sampled. Apparent DM digestibility was calculated using the mean daily DMI and the mean daily fecal DM output using the following equation: DM digestibility = DMI – fecal output/DMI.

Chemical Analyses

Nutrient analysis of hay and fecal samples was completed at a commercial laboratory (Dairy One Forage Laboratory). Analyses were conducted to measure N concentration (method 990.03; AOAC, 2010), with CP calculated as the percentage of N multiplied by 6.25. The NDF, ADF, and lignin concentrations were measured using filter bag techniques (Ankom Technology, 2005, 2006a,b). Starch, WSC, and ethanol-soluble carbohydrates (**ESC**) were measured using techniques described by Hall et al. (1999). Crude fat was determined by ether extraction (method 2003.05; AOAC 2010). Mineral concentrations were determined (Thermo Jarrell Ash IRIS Advantage HX Inductively Coupled Plasma Radial Spectrometer, Thermo Instrument Systems Inc., Waltham, MA) after microwave digestion (Microwave Accelerated Reaction System, CEM, Mathews, NC).

Statistical Analysis

The effect of hay maturity on nutrient composition was analyzed by 1-way ANOVA. If maturity was significant, the 3 maturities of hay were compared using a post hoc Tukey's test for pairwise comparisons, with SED in hay maturity estimated without any homogeneity of variance assumption using the Welch SE and Satterthwaite's degrees of freedom (Satterthwaite, 1946; Welch, 1947). Voluntary DMI was evaluated using a mixed ANOVA with repeated measures (PROC MIXED, SAS Inst. Inc., Cary, NC). Fixed effects were maturity of hay, period, day, and the maturity of hay × day interaction, with a random effect of horse within square. Dry matter digestibility values were evaluated using a mixed ANOVA, in which fixed effects were maturity of hay and period, with a random effect of horse within square. A Bonferroni correction was used to preserve the type I error rate for post hoc multiple comparisons. Nutrient composition and animal data are presented as means ± SD, unless specified otherwise. Voluntary DMI and DM digestibility data are reported as least squares means and SE. Differences were considered significant with $P < 0.05$.

RESULTS

Nutrient Composition

Nutrient compositions for the 3 maturities of teff hay are shown in Table 2. The percentages of starch, WSC, and ESC were greater ($P < 0.05$) in the late-heading teff hay compared with that cut at the boot stage. Alternatively, concentrations of CP, K, Fe, and Mn were greater in the boot stage than in the late-heading stage. In most cases, the early-heading hay was intermediate in nutrient concentrations, with the exception of crude fat, Zn, and Cu. The sum of starch and WSC, collectively termed NSC, remained below 9% for all maturities. The difference between WSC and ESC remained relatively constant across all maturities (1.7 ± 1.5). The Ca:P ratio was 2.0 ± 0.3 for all maturities.

Voluntary Intake

Horses voluntarily consumed less late-heading teff hay than the other experimental hays during the 9-d voluntary DMI phase when expressed on a DM basis as kilograms per day, percentage of BW, or grams per kilogram of $BW^{0.75}$ ($P < 0.001$; Table 3). For all measures of voluntary DMI, there was a main effect of day ($P < 0.001$; Figure 1), but no hay maturity × day interaction was detected. There were no detect-

Table 2. Nutrient composition[1] of early, boot, and late cuttings of teff hay fed to mature Quarter Horse mares

	Teff hay maturity		
Item	Boot (n = 7)	Early (n = 7)	Late (n = 6)
DM, %	92.0 ± 0.3	92.1 ± 0.4	92.5 ± 0.6
CP, %	16.4 ± 2.4[a]	10.8 ± 3.4[b]	7.5 ± 0.5[c]
ADF, %	35.7 ± 1.5[a]	40.2 ± 3.4[b]	41.5 ± 1.9[b]
NDF, %	68.1 ± 2.4[a]	71.1 ± 3.7[ab]	70.8 ± 2.0[b]
Lignin, %	3.6 ± 1.9	4.0 ± 0.7	4.0 ± 0.9
NFC,[2] %	11.5 ± 1.6[a]	14.0 ± 3.8[ab]	16.8 ± 2.1[b]
Starch, %	0.6 ± 0.4[a]	0.8 ± 0.4[ab]	1.5 ± 0.8[b]
WSC,[3] %	4.8 ± 0.8[a]	6.1 ± 2.0[ab]	6.9 ± 1.2[b]
ESC,[4] %	3.0 ± 1.0[a]	4.3 ± 1.2[ab]	5.4 ± 1.4[b]
Crude fat, %	2.4 ± 0.1[a]	1.7 ± 0.6[bc]	2.2 ± 0.8[ac]
Ca, %	0.44 ± 0.05	0.43 ± 0.07	0.44 ± 0.06
P, %	0.24 ± 0.01	0.23 ± 0.05	0.20 ± 0.02
Mg, %	0.16 ± 0.02	0.17 ± 0.03	0.17 ± 0.04
K, %	2.2 ± 0.1[a]	1.8 ± 0.3[b]	1.6 ± 0.3[b]
Fe, mg/kg	237 ± 93[a]	112 ± 54[b]	83 ± 28[b]
Zn, mg/kg	29.3 ± 4.3[a]	22.9 ± 4.7[bc]	26.5 ± 10[ac]
Cu, mg/kg	10.7 ± 1.0[a]	8.3 ± 1.3[bc]	8.5 ± 3.8[ac]
Mn, mg/kg	250 ± 75[a]	167 ± 109[ab]	98 ± 40[b]
Mo, mg/kg	0.3 ± 0.1	0.5 ± 0.2	0.4 ± 0.2
DE,[5] Mcal/kg	1.9 ± 0.1	1.8 ± 0.1	1.9 ± 0.1

[a–c]Within a row, means with different superscripts differ ($P < 0.05$).
[1]DM basis.
[2]Nonfiber carbohydrates: 100% − (% CP + % NDF + % fat + % ash).
[3]Water-soluble component: monosaccharides, disaccharides, and some polysaccharides (mainly fructans).
[4]Ethanol-soluble component: monosaccharides and disaccharides.
[5]DE = 2.118 + (0.01218 × CP) − (0.00937 × ADF) − [0.00383 × (NDF − ADF)] + (0.04718 × crude fat) + (0.02035 × NFC) − (0.0262 × ash) (NRC, 2007).

able differences in voluntary DMI between the boot and early-heading maturities overall or on any day of the study. The horses consumed more of the boot-cut hay than the late-heading hay on all days except d 3 and 5, and consumed more of the early-heading hay than the late-heading on d 7 through 9 ($P < 0.05$). The average voluntary DMI across all maturities was greatest on d 1 when compared with any of the other 8 d of the voluntary DMI phase ($P < 0.05$).

There were no detectable changes in BW for horses fed each of the teff hay maturities during the voluntary DMI phase (Table 3). We evaluated whether the horses were consuming sufficient nutrients and DE to be meeting their increased maintenance requirements, based on measured DMI and the nutrient composition of each maturity of hay (Figure 2). Digestible energy requirements were not met for any maturity of teff hay, although the estimate for boot maturity was 97%. The late-heading maturity did not meet the CP requirement, and none of the teff hay maturities met the Cu or Zn requirements.

Table 3. Voluntary DMI and BW of Quarter Horse mares fed 3 different maturities of teff hay[1]

	Teff hay maturity			
Item	Boot	Early	Late	SE
DMI, kg/d	9.7[a]	9.2[a]	8.1[b]	0.4
DMI, % of BW	1.8[a]	1.7[a]	1.5[b]	0.1
DMI, g/kg of BW$^{0.75}$	85.0[a]	81.0[a]	72.0[b]	4.7
Initial BW, kg	559.1	557.6	551.0	17.3
Final BW, kg	552.4	547.9	553.0	17.3

[a,b]Within a row, means with different superscripts differ ($P < 0.05$).
[1]Data are means for Quarter Horse mares fed boot (n = 6), early (n = 6), or late (n = 5) maturities of teff hay during the 9-d voluntary DMI period.

Digestibility

The DMI of the late-heading teff hay during the digestibility period (8.4 ± 0.9 kg/d) was less ($P < 0.05$) than that of either the boot (9.3 ± 1.0 kg/d) or early-heading (9.2 ± 1.0 kg/d) maturity (data not shown). These differences in DMI were reflective of what was measured during the voluntary DMI phase. Apparent nutrient DM digestibility values of boot, early-heading, and late-heading maturities of teff hay are shown in Table 4. Digestibility decreased ($P < 0.05$) from boot to early-heading to late-heading teff hay for CP (19% decrease from boot to late-heading maturity) and NDF (26% decrease from boot to late-heading maturity). Dry matter digestibility was 9 and 15% greater ($P < 0.05$) for the boot maturity when compared with the early- or late-heading stage, respectively. The ADF digestibility was 13 and 21% greater ($P < 0.05$) for the boot maturity when compared with the early- or late-heading stage, respectively. Digestibility increased ($P < 0.05$)

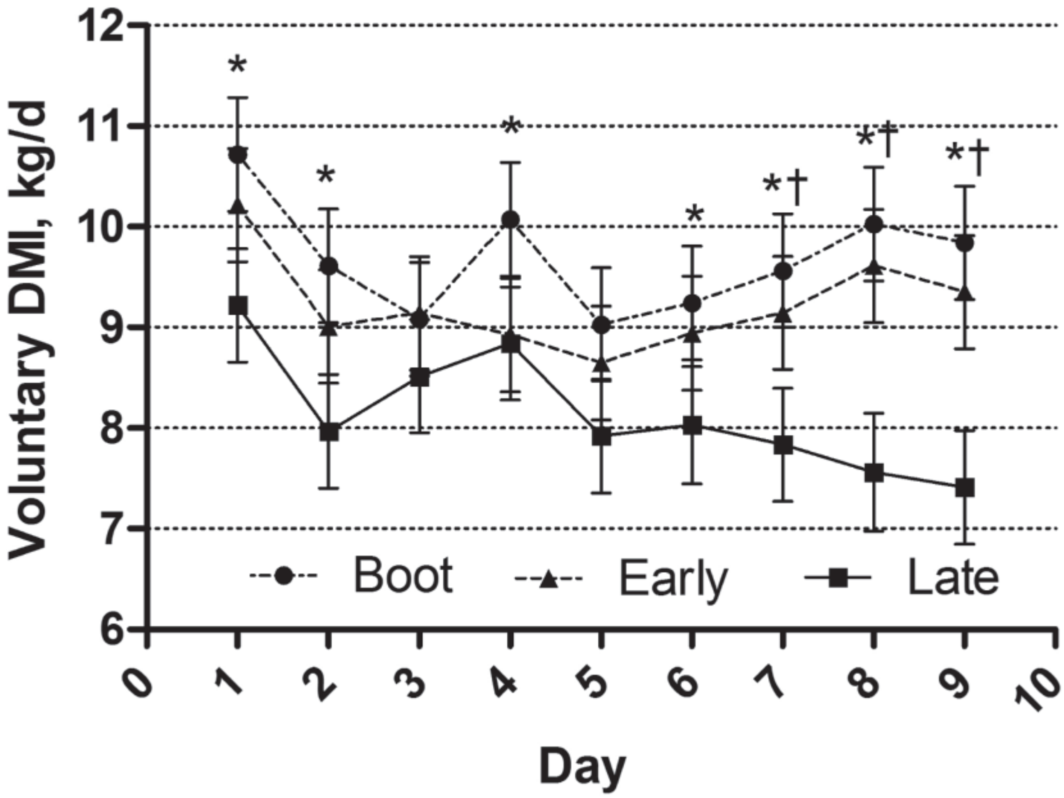

Figure 1. Average voluntary DMI (kg/d) by Quarter Horse mares fed teff hay at the boot (Boot; n = 6), early-heading (Early; n = 6), or late-heading (Late; n = 6) stage of maturity. There were main effects of stage of maturity and day ($P < 0.001$). Asterisks (*) denote differences in voluntary DMI between the boot and late-heading stages ($P < 0.05$), whereas daggers (†) denote differences in voluntary DMI between the early- and late-heading stages ($P < 0.05$).

from boot to early heading to late heading for nonfiber carbohydrates and WSC.

DISCUSSION

The results of this study demonstrate that the boot and early-heading maturities of teff hay were accepted by the horses in this study. Further, the nutrient profile was sufficient to meet the requirements of nutrients most commonly considered important for these horses at the intakes measured in this study. Based on our calculation of the DE content and the intakes measured, the maturities of teff hay met between 85 and 97% of the average DE requirement of the horses. The late-heading teff hay was not as well accepted and did not meet the DE or CP requirements based on the intakes measured. For all maturities of teff hay, the starch and WSC intakes were below 10% of the total intake, indicating that teff hay grown in central Pennsylvania under the conditions in this study would be appropriate for horses that may require low dietary NSC, such as those at risk for laminitis or other metabolic disorders.

The nutrient composition of the 3 maturities differed from each other in a predictable fashion for a grass hay, with carbohydrates increasing and other nutrients decreasing as the plant matured (Darlington and Hershberger, 1968; Kilcher, 1981). We evaluated whether nutrient requirements were being met, based on the nutrient composition of each teff maturity and the measured voluntary DMI (NRC, 2007). All maturities of teff hay met the requirements for Ca, P, Mg,

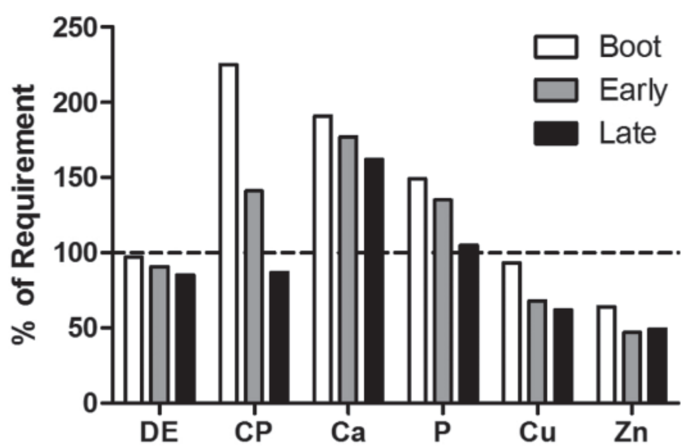

Figure 2. Depiction of the percentage of the recommended DE or nutrient requirement met by teff hay at the boot (Boot), early-heading (Early), or late-heading (Late) stage of maturity based on the average intake of each and the initial BW during the voluntary DMI period of the study. The requirement used was the high maintenance requirement.

Table 4. Apparent nutrient digestibility values[1] of 3 different maturities of teff hay fed to Quarter Horse mares

Digestibility,[2] %	Teff hay maturity			
	Boot	Early	Late	SE
DM	60.6[a]	55.3[b]	51.5[b]	1.5
CP	69.1[a]	63.8[b]	56.2[c]	1.7
ADF	63.2[a]	55.3[b]	49.7[b]	2.4
NDF	64.3[a]	55.7[b]	47.9[c]	1.8
NFC	55.6[a]	64.7[b]	71.7[c]	1.5
Starch	64.8	68.1	50.2	9.8
WSC	72.7[a]	82.7[b]	87.8[c]	1.5
ESC	72.7	81.4	90.6	4.9
Crude fat	44.9[a]	35.4[a]	63.8[b]	2.7
Ca	40.3	50.9	43.3	3.4
P	−4.3	5.6	0.0	3.8
Mg	26.2	35.6	23.4	3.5
K	72.7	67.3	68.0	2.6
Fe	19.8	−16.1	−34.7	14.0
Zn	1.6	5.5	20.1	5.3
Cu	47.3[ab]	46.7[a]	61.6[b]	3.4
Mn	−2.5	10.4	15.0	7.6

[a–c]Within a row, means with different superscripts differ ($P < 0.05$).

[1]Data are means for Quarter Horse mares fed boot (n = 6), early (n = 6), or late (n = 6) maturities of teff hay during the 3-d digestibility period.

[2]NFC = nonfiber carbohydrates; WSC = water-soluble carbohydrates; ESC = ethanol-soluble carbohydrates.

K, Fe, and Mn and fell short of meeting the DE, Cu, and Zn requirements. The nutrient concentrations of Cu and Zn in this teff hay were similar to those for timothy, reed canarygrass, tall fescue, and alfalfa measured in other studies (Crozier et al., 1997; LaCasha et al., 1999; Ordakowski-Burk et al., 2006). The boot and early-heading stages exceeded the CP requirement. One reason that none of the measured intakes of these maturities of teff hay met the DE requirement may be the reduced NSC content. It is this reduced NSC content that makes teff hay relatively less in DE and such an attractive option for owners seeking a hay to feed to horses with insulin resistance, metabolic syndrome, or an increased risk of laminitis.

The mean voluntary DMI for teff hay ranged from 1.8 to 1.5% of BW in this study. This range is within the expected range of DMI for horses and corresponds with other studies of hay intake in mature horses (Ordakowski-Burk et al., 2006; NRC, 2007; Miyaji et al., 2008). However, the intakes measured were less than those recorded in other similar studies for alfalfa (3.1 to 2.8%), matua bromegrass (2.8%), coastal bermudagrass (2.1%), tall fescue (2.5%), and caucasian bluestem (2.3%; Crozier et al., 1997; LaCasha et al., 1999). It is likely that a portion of the differences in intake were associated with differences in forage preference, although this was confounded by the possible effect of breed and age. Future studies should directly compare teff hay with other common equine forages. Although the majority of mares were perceived to be healthy and in good condition throughout the trial, the authors feel it is important to note that 1 mare fed the late-heading teff hay had a minor impaction colic during the voluntary DMI period of the study. She was placed on limited intake for a period of 4 d and subsequently returned to the study based on veterinary evaluation and approval. The DMI data from this mare for the late-heading teff hay were not included in the final analysis.

It has been documented that stage of maturity at cutting is the single most important determinant of digestibility of preserved forages fed to livestock (Van Soest, 1965). Therefore, it was expected and observed that digestibility of teff hay would decrease as the stage of maturity at cutting increased. When fed to mares at maintenance, we measured a 9% reduction in total DM digestibility from boot to early-heading teff hay and a 15% reduction from boot to late-heading teff hay. This pattern is consistent with previous studies in which cool season preserved forages of increasing maturities were fed to horses (Darlington and Hershberger, 1968; Ragnarsson and Lindberg, 2008). Apparent digestibility values of some nutrients were either negative or highly variable, both of which are likely due to error associated with not taking endogenous losses into account.

When comparing the DM digestibility values observed in this study with cool-season grass hays fed to mature horses, we found the teff hays to be comparable (Fonnesbeck et al., 1967; Crozier et al., 1997; Ordakowski-Burk et al., 2006). Although this study did not specifically compare teff hay with hays commonly fed to horses, such as timothy or orchardgrass, the digestibility and DMI values measured in this study were similar to those measured for these more common equine forages. Others found total DM digestibility values of timothy and orchardgrass hays fed to mature horses to range from 45.7 to 65.9% and 54.7 to 63.1%, respectively (Darlington and Hershberger, 1968; Takagi et al., 2002; Ordakowski-Burk et al., 2006), which is similar to the 51.5 to 60.6% measured in this study. Therefore, teff hay appears to have a digestibility similar to popular cool-season hay species fed to horses. The DM and nutrient digestibility values of teff hay fed in this study were similar to that measured for bermudagrass, another warm-season grass fed to horses (Sturgeon et al., 2000).

Estimating forage digestibility based on individual nutrient percentages is unreliable because of interactions between nutrients and a lack of information on cause-effect relationships (Van Soest, 1982). The NDF and ADF percentages in the teff hay and the digestibility values measured in this study are similar to values measured for other forages fed to horses (LaCasha et al., 1999; Ordakowski-Burk et al., 2006). There are potentially numerous other factors not measured in this study that may have resulted in the reduced digestibility and intake values for the late-heading teff hay. These could include interactions between dietary nutrient composition and hindgut microbes, the differences in stem-to-leaf ratio of the 3 hay maturities, or palatability differences. We assume that the reduced digestibility of the late-heading maturity may have contributed to the minor impaction colic in the 1 mare. Based on the reduced digestibility, intake, and potential risk of impaction colic, late-heading teff hay should be avoided for most horses.

Several recent reviews that focus on the topics of equine metabolic syndrome and laminitis suggest that best practices for avoiding these disorders should include feeding a diet containing an NSC content below 10% (Frank, 2009; Geor, 2009). Based on the intakes and dietary NSC contents measured in this study, the maximum intake of NSC was approximately 680 g/d, which is less than dietary intakes of NSC thought to cause digestive disturbances and laminitis. The relatively less DE of all maturities of teff hay in this study may also make it an excellent forage choice for obese horses. Equine obesity is a growing health concern to the equine industry and has been associated with equine metabolic syndrome and laminitis (Carter et al., 2009). Feeding teff hay may offer an effective strategy to decrease dietary DE and help to reduce BW.

Finally, although there were few differences between the boot and early-heading maturities with regard to digestibility and DMI, harvesting at the early-heading stage is more economical for the forage producer. In previous research, harvesting teff at early heading resulted in 1 less harvest during the growing season than when harvesting at boot, but total season yields were similar for both harvesting schedules (M. H. Hall, unpublished data). The practical implication for the forage producer is that harvesting teff at early heading is more economical because it has no negative impact on yield or quality but requires 1 less harvest per year than harvesting at the boot stage.

Teff hay is a novel forage choice for horses, with a fiber and nutrient content similar to other commonly fed hays. Its relatively small NSC and DE content make it a potentially beneficial forage choice for overweight horses, those with equine metabolic syndrome, or those prone to laminitis. Finally, the results of this study indicate that the early-heading maturity of teff hay offers the best balance between providing a palatable and digestible nutrient source for the horse and a productive forage crop.

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