Matua bromegrass hay for mares in gestation and lactation[1]

K. A. Guay*, H. A. Brady*[1], V. G. Allen†, K. R. Pond*, D. B. Wester‡, L. A. Janecka*, and N. L. Heninger*

Departments of *Animal and Food Sciences and †Plant and Soil Science, ‡Range, Wildlife, and Fisheries Management, Texas Tech University, Lubbock 79409

ABSTRACT: Matua bromegrass hay (*Bromus willdenowii* Kunth) is a high quality forage, but its value for mares during gestation and lactation is not well known. Intake, rate of passage, performance, and reproduction by gestating and lactating Quarter Horse mares fed the hay was investigated. In this experiment, 12, 2- to 12-yr-old gravid mares (mean BW = 553 kg; SD = 36) were fed Matua hay (CP = 11.5%) or alfalfa hay (*Medicago sativa* L.) (CP = 15.4%) for variable days prepartum (mean 59.9 d; SD = 23.5) and for 70 d postpartum. Matua and alfalfa hay were fed as the roughage portion of the diet with a grain supplement. Mares, blocked by age, expected date of foaling, and BW, were assigned randomly within blocks to treatments (six mares per treatment). Forage type did not affect intake, gestation length, birth weight, number of foals, foal weight gain, day of first postpartum ovulation, cycles per conception, or pregnancy rate at 70 d. On d 1, milk from mares fed alfalfa hay contained less ($P < 0.03$) CP than milk from mares fed Matua hay. Milk CP decreased ($P < 0.01$) in all mares over time. In a separate experiment, voluntary intake and rate of passage of Matua (CP = 15.5%), alfalfa (CP = 24.9%), and Timothy (*Phleum pratense* L.) (CP = 4.1%) hays were determined in nine 2-yr-old pregnant mares (mean BW = 447 kg; SD = 21). Diets were 100% forage. Timothy hay did not meet CP requirements for mares. Voluntary intake of alfalfa hay was higher ($P < 0.01$) than Matua hay. Intake of Timothy hay was lower ($P < 0.01$) than the mean of alfalfa and Matua hay. Rate of passage of forage was measured by passage of Cr-mordanted fiber. Passage rate and retention time did not differ between Matua and alfalfa hay; however, the retention times of Matua and alfalfa hays were shorter ($P < 0.01$) than for Timothy hay. Our results indicate that Matua hay is a forage that can be used safely for mares during gestation and early lactation and for their young foals.

Key Words: Forage, Hay, Lactation, Mares, Pregnancy

 J. Anim. Sci. 2002. 80:2960–2966

Introduction

Forage is an essential part of mare diets (Gibbs and Davison, 1992). Forages should be evaluated and safety for the mare and foal must be determined.

Matua bromegrass, a cool-season, short-lived perennial forage, was developed in New Zealand and released in 1973 (Rumball, 1974). Limited research demonstrated that apparent DM digestibility of Matua approached that of alfalfa hay when fed to yearling horses (LaCasha et al., 1999), or was equal to that of alfalfa hay in mature geldings (Sturgeon et al., 2000). A lack of difference in apparent DM digestibility but lower DM intake (LaCasha et al., 1999) suggests that rate of passage may differ between Matua and alfalfa hay. Effects of feeding Matua hay to gestating or lactating mares and their foals have not been investigated, to our knowledge. The inflorescence on Matua, with a prominent awn, raises concerns with respect to horses' sensitive mouths. Thus, two experiments were conducted to evaluate nutritional and reproductive effects of feeding Matua hay to gestating and lactating mares, and to young, growing foals. A second objective was to determine intake and rate of passage of Matua hay compared with alfalfa hay, and a low-quality, cool-season grass hay. In this rate of passage comparison, a low-quality grass hay and a high-quality legume were chosen to observe where Matua hay would rank.

Materials And Methods

Two experiments were conducted at the Texas Tech University Ranch Horse Center in New Deal, TX (lat

[1]This research was funded in part by a grant from the Center for Feed Industry Research and Education, Texas Tech University, Lubbock, TX, and by L. H. Rosevear and Company, Ashburton, New Zealand. Approved by the dean of the College of Agricultural Sciences and Natural Resources, Texas Tech Publ. No. T-5-418.

[2]Correspondence: Box 42141 (phone: 806-742-4455, fax: 806-742-0898, E-mail: heidi.brady@ttu.ed).

Received October 10, 2001.

Accepted June 25, 2002.

Table 1. Concentrate mixture fed to Quarter Horse mares and foals with Matua bromegrass or alfalfa hay

Ingredient	AF %
Oats	40.00
Cracked corn	40.00
Soybean meal	15.00
Molasses	3.00
Ground limestone	0.75
Dicalcium phosphate	0.75
Trace mineralized salt	0.50
Vitamin A premix[a]	0.8

[a]Vitamin A = 660,660 IU/kg of premix.

33°47′N, long 101°47′N); 993 m elevation). These experiments were designed to evaluate the value of Matua hay for pregnant and/or lactating mares. Both experiments were approved by the Texas Tech University Animal Care and Use Committee.

Gestation and Lactation

This experiment included eight 3-yr-old and four aged (7- to 12-yr-old) gravid Quarter Horse mares (mean initial BW = 553 kg; SD = 36), with expected foaling dates between March and May in 1998. Before the study began, mares were treated with Zimectrin (Farnam Companies Inc., Phoenix, AZ) and were vaccinated with Pneumabort-K (Fort Dodge Laboratories Inc., Fort Dodge, IA). The experiment began in mid-February, resulting in variable prepartum days among mares. Mean number of days on trial prepartum was 59.9 d (SD = 23.5). All mares and foals were on trial for 70 d postpartum. Mares were blocked by expected date of foaling, age, and BW, and assigned randomly to either Matua (n = 6) or alfalfa (n = 6) hay. Mares were housed at night in 3.3- × 4-m stalls with sand bedding and released into drylot pens during the day. Ad libitum access to water and white salt blocks were provided. Mares were fed in their stalls twice daily. Stalls were divided by solid partitions so that horses could not share feed. Mares were fed forage, using nonmesh, solid nylon hay bags (State Line Tack Co., Brockport, NY) to prevent waste. Hay bags and grain feeders were secured to the stall wall at a level that was accessible to both mare and foal. Feed was offered initially at 2% of BW before parturition (total feed offered) and increased to 3% of BW postpartum.

Table 2. Chemical composition of Matua bromegrass and alfalfa hay fed to gestating and lactating Quarter Horse mares and their foals[a]

Item	Matua	Alfalfa
CP	11.5	15.4
NDF	57.9	49.5
ADF	36.2	35.3

[a]Chemical composition measured as % DM.

Diets consisted of 1.5% of BW hay and 0.5% of BW concentrate prepartum, with hay at 1.55% of BW and concentrate at 1.45% of BW postpartum (Gibbs and Davison, 1992). Forage was available at all times with the exception of a 6-h midday turnout period. In the case of complete consumption of forage, the total quantity fed to the mare was increased an additional 0.1% of BW until refusals occurred.

The Matua hay used was grown in sandy loam soil in Friona, TX. The field was fertilized with N every 4 mo. Hay was harvested as round bales from the fourth cutting of the 1997 growing season. The alfalfa hay was grown in Lindsay, OK, and harvested as round bales from the fourth cutting of the 1997 growing season. Samples used to estimate nutritive value of the diet were taken from the round bales with a Pennsylvania Forage Sampler. Hay was chopped using a round bale chopper (Model BT25, Heston, KS) on the long-cut setting (approximately 15 cm). The concentrate contained 14.8% CP (Table 1) and was milled at the TTU Feed Mill. The diet was formulated using recommendations for gestating and lactating mares (NRC, 1989).

Hay was sampled at the time of feeding for further analyses. Daily samples were composited on an equal dry-weight basis prior to chemical analysis. Forage refusals were collected daily before the morning feeding. Refusals and hay samples were dried at 55°C in a forced-air oven and weighed. Refusals were composited for each mare separately as a percentage of the total dry weight of the daily refusal. Samples were ground to pass a 1-mm screen using a laboratory mill (Thomas-Wiley, Philadelphia, PA). All samples were analyzed for CP using the Kjeldahl method (AOAC, 1990). Additionally, hay samples were analyzed for percentage NDF and ADF (Goering and Van Soest, 1970). Results are reported on a DM basis (105°C; see Table 2).

Mares were weighed initially at the beginning of the trial, every 2 wk throughout the trial, on the day of parturition, and at 70 d postpartum. Foals were weighed at birth and every 2 wk thereafter, until 70 d of age (final BW). Mucous membranes of mares and mouths of foals were monitored weekly throughout the study for irritation or sores. All mares were attended during parturition and monitored for signs of dystocia. Placentas were examined visually for abnormalities. Previous breeding dates and ovulations were known, and length of gestation was recorded on the day of parturition.

Milk samples were obtained by hand-milking beginning at parturition for 7 consecutive d and then once weekly until d 70 postpartum. Foals were muzzled for 1 h before milking to ensure sample collection. Milk was placed in acid-washed plastic bottles and frozen. Crude protein content of milk was determined using the Kjeldahl method (AOAC, 1990).

All mares were inseminated during the first postpartum estrus. Beginning 5 d postpartum, receptive

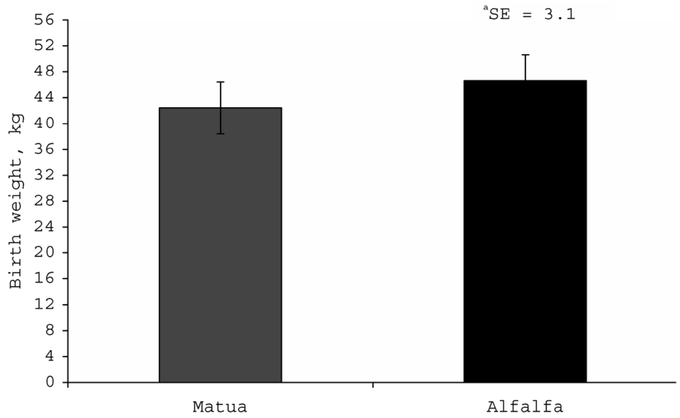

Figure 1. Birth weights of foals born to mares fed Matua bromegrass or alfalfa hay during gestation. [a]SE = standard error of the mean.

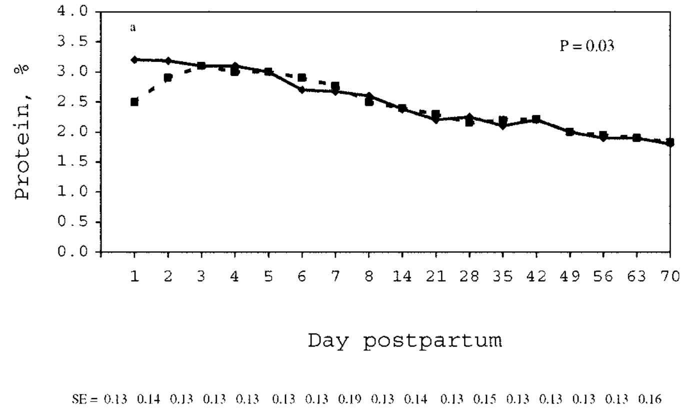

Figure 3. Percentage of crude protein in milk sampled from day of parturition (d 1) to d 70 postpartum from Quarter Horse mares fed Matua bromegrass (SOLID LINE) or alfalfa (DASHED LINE) hay. Milk protein was different on d 1 (P = 0.03). SE = standard error of the mean, n = 6.

breeding behavior was assessed by presenting each mare to a stallion across a solid partition for 3 min. Mares were also examined by transrectal palpation and transrectal ultrasonography to confirm ovarian status. Mares were artificially inseminated with a minimum of 500×10^6 progressively motile spermatozoa from one stallion after development of a 35-mm follicle and continuing every 48 h until confirmation of ovulation via ultrasonography. Mares were checked for pregnancy by ultrasound at 14, 45, and 70 d post-ovulation. If mares did not conceive during the first postpartum estrus, they were reinseminated on the following cycle.

Data were analyzed using a randomized block design of SAS (SAS Inst. Inc., Cary, NC) using a model that included effects of foaling date (random effect) and hay treatment (fixed effect). Data collected over the 70-d postpartum period were analyzed as repeated measures (Winer et al., 1991). When treatment and sampling day interacted, treatments were tested within a day by combining the main-plot error mean square and the residual error mean square (Milliken and Johnson, 1984). Assumptions for normality of main-plot and subplot error terms were tested with the Shapiro–Wilk (1965) test. Tukey's (1949) test was used to assess the block × treatment interaction in the main-plot analysis. Mauchly's (1940) test was used to test for sphericity in the repeated measures analysis.

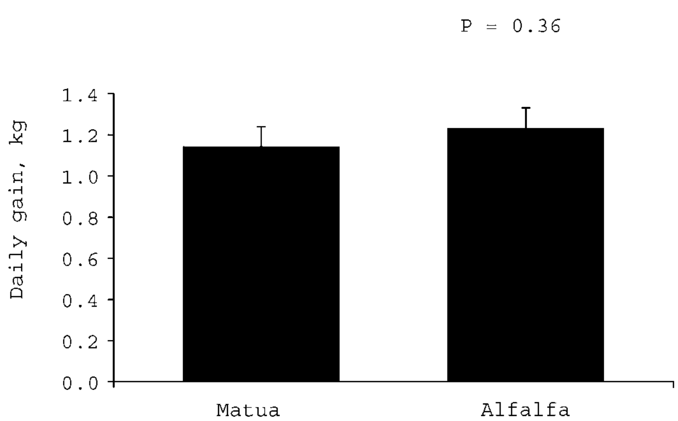

Figure 2. Daily gain by Quarter Horse foals from mares fed Matua bromegrass or alfalfa hay from birth to 70 d postpartum. SE = standard error of the mean, n = 6.

Rate of Passage

Nine 2-yr-old gravid mares (initial BW = 447 kg; SD = 21) in the first trimester of gestation were used in two trials during 1997 to compare voluntary intake and rate of passage of Matua, alfalfa, and Timothy hays (see Table 5). Mares were blocked by BW and assigned randomly within blocks to Matua, alfalfa, or Timothy hay treatments. For trial 2, mares were rerandomized with the restriction that no mare was to be placed on the same treatment as in trial 1. Mares were housed throughout the duration of the experiment in 3.3- × 4-m stalls with sand bedding. The mares were exercised daily. During each trial, mares were given ad libitum access to water, white salt, and their respective hays for a 15-d adjustment period, followed by a 4-d collection period.

At the beginning of the collection period, mares were fed 16 g of their respective hays mordanted with Cr (Uden et al., 1980) and coated with 5 mL of molasses. The Cr concentration was 2% of dry matter. Fecal grab samples were taken at 0 h, then at 4-h intervals for the next 48 h, and then at 8-h intervals until 96 h. Refusals were collected daily prior to the morning feeding. Refusals were oven-dried (55°C) and weighed. Intake was calculated as forage fed minus refused on a dry-weight (55°C) basis. Hay samples were collected daily at time of feeding (0900 and 2000) and composited by weight. Hay and fecal samples were oven-dried

Table 3. Dry matter intake of hay by Quarter Horse mares fed Matua bromegrass or alfalfa hay during late gestation (mean 59 d prepartum) and early lactation (70 d postpartum)

Item	Matua	Alfalfa	*P*-value	SE[a]
Prepartum				
kg/d	6.8	7.1		
% BW	1.21	1.24		
g/kgBW$^{0.75}$	59.98	61.73	0.45	2.07
Postpartum				
kg/d	7.8	8.3		
% BW	1.52	1.63		
g/kg BW$^{0.75}$	73.90	79.05	0.13	1.81

[a]SE = standard error of the mean, n = 6.

at 55°C and ground to pass through a 1-mm screen on a laboratory mill (Thomas-Wiley, Philadelphia, PA). Fecal samples were then digested in a 3:1 NO_3:$HClO_4$ acid solution, and Cr was determined by atomic emission with a Thermal Jarrell Ash Inductivity Coupled Plasma Spectrophotometer (Muchovej et al., 1986).

Crude protein (Kjehldahl method; AOAC, 1990), NDF, and ADF (Goering and Van Soest, 1970) were determined in hay samples. Hay samples were digested with 2:1 NO_3:$HClO_4$ and minerals were determined by atomic emission.

The Cr concentration at each collection time was fitted to age-dependent two-compartment models with gamma 2, 3, and 4 age depending as described by Moore et al. (1992). Passage parameters were determined for lambda 1 (fast rate), lambda 2 (slow rate), and tau (time delay or lag from dosing to first appearance in the feces), and mean retention time was calculated. In calculating rate of passage, a gamma 2 age-dependent model (Moore et al., 1992) was effective for only four of the 18 horses. Convergence criteria were not met and lambda 1 was equal to lambda 2. Thus, a gamma 3 age-dependent model was used. Two of the 18 horses were removed from the data set because of marker excretion curve irregularities and because of failure of convergence. The excretion of Cr did not follow a normal pattern in these animals. High levels of Cr were followed by samples with no Cr, followed by low levels of Cr, representing a pattern which was not normal. The gamma 3 age-dependent, two-compartment model estimates three parameters: lambda 1, lambda 2, and tau. With these parameters, the kinetics of passage can be further described.

The experiment was analyzed as a randomized block design using a model that tested effects of treatment, block, trial, and their interactions. Differences among treatments were tested by orthogonal contrasts that compared 1) the low-quality Timothy hay vs the mean of the two high-quality forages (alfalfa and Matua hays), and 2) the legume hay vs the grass hay, Matua.

Results and Discussion

Gestation and Lactation

Chemical composition of Matua and alfalfa hays is shown in Table 2. Values for CP in Matua hay were in the range of those reported by LaCasha et al. (1999) and Sturgeon et al. (2000; 13.5 and 10.9% CP, respectively). Box et al. (2001) reported values in a range of 8.59% to 18.54% CP in Matua hays. Neutral detergent fiber in Matua hay was lower but ADF was similar to values reported in previous studies. LaCasha et al. (1999) reported values of 62.4% NDF and 36.1% ADF, whereas Sturgeon et al. (2000) recorded values of 76.46% and 39.96%, respectively, for Matua hay. Crude protein, NDF, and ADF in alfalfa hay were similar to values reported by NRC (1989) for full-bloom alfalfa (17.0, 48.8, and 38.7%, respectively).

Mares readily accepted each forage. Intake of Matua hay by mares was not different ($P = 0.42$) from intake of alfalfa hay (Table 3). Although forage intake was intended to be 1.5% and 1.55% of the diet prepartum and postpartum, respectively, mares were fed until a refusal was measured. Therefore, differences in intake between the two forages should have been detected.

Table 4. Mean reproductive measurements of Quarter Horse mares fed Matua bromegrass or alfalfa hay

Item	Matua	Alfalfa	*P*-value	SE[a]
Gestation length, d	342.4	340.7	0.73	3.03
Days to first postpartum ovulation	15.2	14.2	0.33	0.98
Cycles per conception	1.5	1.2	0.17	0.20

[a]SE = standard error of the mean, n = 6.

Table 5. Chemical composition of Matua bromegrass, alfalfa, and Timothy hays fed to 2-yr-old Quarter Horse mares during their first trimester of pregnancy[a]

Item	Matua	Alfalfa	Timothy
CP, %	15.5	24.9	4.1
NDF, %	61.4	34.1	74.4
ADF, %	36.7	25.2	47.6
Ca, %	0.61	1.30	0.33
P, %	0.28	0.40	0.16
Mg, %	0.33	0.33	0.11
K, %	2.3	1.9	1.6
S, %	0.5	0.4	0.1
Fe, ppm	110	250	77
Zn, ppm	29	30	16
Cu, ppm	20	18	9
Mn, ppm	88	43	43
Al, ppm	63	251	45

[a]Chemical composition measured as % DM.

The lack of difference between the grass and legume is of interest. Voluntary intake of legumes has generally been reported to be higher than grasses in ruminants (Minson, 1982). Fonnesbeck et al. (1967) found a greater intake of legumes than grasses by geldings offered a choice of six different hays. LaCasha et al. (1999) reported that yearling horses preferred alfalfa hay over Matua bromegrass hay when given a choice and when horses were restricted to a single forage, voluntary intake of alfalfa hay was slightly higher than that of Matua hay (10.9 vs 10.0 kg/d, respectively). Birth weights of foals did not differ ($P = 0.49$) between mares fed Matua or alfalfa hays (Figure 1). No differences ($P = 0.36$) were noted in daily weight gain of foals from mares fed Matua or alfalfa hay (Figure 2).

Casler and Carlson (1995) stated that the presence of awns on matured seeds of some annual grasses such as soft chess (*Bromus mollis* L.) and ripgutgrass (*B. rigidus* Roth) can be harmful to grazing animals. Matua has awns up to 5 mm. Because Matua bromegrass flowers continuously, most hay harvested is likely to contain some inflorescences. Inflorescences were abundant in Matua hay used in this experiment. However, no sores or abscesses were observed in the mouths of mares. LaCasha et al. (1999) also observed no mouth problems in yearling horses consuming Matua hay. Similarly, Wilson (1977) stated that inflorescences of Matua bromegrass did not adversely affect mouths of cattle. Foals were observed to eat both forage and concentrate, although this was not quantified in this experiment.

Mean milk CP for the entire 70 d was 2.53 for Matua hay and 2.47 for alfalfa hay (SE = 0.07). Gibbs et al. (1982) reported 2.1% CP in mares milk over 150 d of lactation, with a range of 1.6% to 3.3% CP. The highest milk CP (3.3% CP) occurred 10 d postpartum (Gibbs et al., 1982). In the present study, differences in percentage CP between treatments varied by day of sampling (Figure 3). Milk CP from mares fed alfalfa hay was lower ($P < 0.05$) on the day of parturition (d 1) than milk from mares fed Matua hay. Throughout the remainder of this experiment, milk CP did not differ ($P = 0.58$) between treatments.

Milk CP declined ($P < 0.01$) throughout the 70-d postpartum period (Figure 3) but there were no differences between treatments in rate of decline. Schryver et al. (1986) reported that concentrations of all mare's milk components, with the exception of Na and K, decreased throughout lactation. Gibbs et al. (1982) also reported that constituents of mare's milk decreased with advancing lactation.

We found no adverse reproductive effects as a result of feeding Matua bromegrass hay to gravid mares (Ta-

Table 6. Voluntary intake and change in body weight of 2-yr-old pregnant Quarter Horse mares fed Matua bromegrass, alfalfa, or Timothy hay

Item	Matua	Alfalfa	Timothy	SE[a]
Voluntary intake				
kg/d[bc]	11.5	13.7	10.0	0.15
% of BW[bc]	2.6	3.0	2.2	0.08
g/kg $BW^{0.75}$ [bc]	117.6	138.4	101.8	3.3
Body weight change, kg[c]	16.3	25.7	–10.0	23.7

[a]SE = standard error of the mean, n = 6.
[b]Alfalfa hay differed from Matua hay ($P < 0.01$).
[c]Timothy hay differed from mean of Matua and alfalfa hays ($P < 0.01$).

Table 7. Passage rate measurements for Cr-mordanted fiber of Matua bromegrass, alfalfa, or Timothy hay

Item	Matua	Alfalfa	Timothy	SE[a]
Lambda 1, h^{-1} (fast rate)	1.86	0.9976	0.5614	0.8416
Lambda 2, h^{-1} (slow rate)	0.0642	0.0771	0.0406	0.0061
Tau, h	9.8	10.1	12.4	1.9
Mean retention time, h[b]	26.8	26.1	42.4	8.6

[a]SE = standard error of the mean, n = 6.
[b]Timothy hay differed from the mean of Matua and alfalfa hays ($P < 0.01$).

ble 4). Mean gestation length of mares fed Matua hay did not differ ($P = 0.73$) from mares fed alfalfa hay. Moreover, there were no differences ($P = 0.67$) in gestation length of aged mares (344.5 d ± 3.05 d) and of 3-yr-old mares (339.7 d ± 3.05 d). These values for gestational length are within normal ranges reported for light mares (Evans et al., 1997) and Thoroughbred mares (Hintz et al., 1979).

Live foal births were 100% for each treatment, and no dystocia was observed. No agalatia was observed in mares on either diet or age group. The day of first postpartum ovulation did not differ ($P = 0.33$) between mares fed Matua or alfalfa hay (Table 4). No treatment differences ($P = 0.20$) were found in mean cycles per conception. Pregnancy rates measured at 45 and 70 d postovulation were 100% for each treatment.

Rate of Passage

Chemical composition of Matua bromegrass, alfalfa, and Timothy hays used are presented in Table 6. The hay CP concentration was higher but NDF and ADF were similar to Matua hay used in the gestation and lactation experiment. However, the alfalfa hay contained more CP and less NDF and ADF than alfalfa hay fed during the gestation and lactation experiment. These values are consistent with alfalfa hay that would have met high quality standards (Linn and Martin, 1989), and were consistent with a late vegetative growth stage (NRC, 1989). The Timothy hay fed in this experiment was low quality and CP concentrations did not meet the protein requirements for gestating mares (NRC, 1989).

Dry matter intake of alfalfa hay was greater ($P < 0.01$) than intake of Matua hay (Table 6). Intake of Timothy hay was different than Matua and alfalfa hay ($P < 0.01$). Differences were observed whether intake was expressed as kilograms per day or relative to BW, or metabolic body size. LaCasha et al.(1999) also reported that DM intake of alfalfa hay was higher than intake of Matua hay. The low quality of the Timothy hay resulted in a weight loss while mares fed alfalfa and Matua hay gained weight during the trial (Table 6). Lamba 2 values and mean retention time (**MRT**) did not differ between Matua and alfalfa hay. However, MRT of Matua and alfalfa hays were lower ($P < 0.01$) than the MRT of Timothy hay (Table 7).

The rate of passage of forage in the horse is more rapid than in cattle (Uden et al., 1982). Unlike the ruminant digestive tract, the digestive tract of the horse lacks the ability to selectively filter large particles. Thus the fibrous particles in the diet of a horse pass at a more rapid rate than in ruminants (Van Soest, 1994). Therefore, for efficient absorption of nutrients from a system with a relatively high rate of passage, it is recommended that forages in horse diets have relatively high rates and extent of digestion (Buxton and Mertens, 1995).

Many factors can affect rate of passage, including particle size, ingredient, nutrient composition, and intake (Merchen, 1988). In cattle and sheep, increased intake is usually associated with increased rate of passage (Colluci et al., 1984, 1990). The lower intake and higher cell wall of Timothy hay in our experiment probably contributed to the longer retention time. It is interesting that rates of passage for Matua hay and alfalfa hay were not different despite differences in intake. The fact that rate of passage was not different between Matua and alfalfa hay is also interesting because in other species, grasses generally have a slower rate of passage in comparison with legumes.

Implications

The present study demonstrated that Matua bromegrass hay is an acceptable forage for mares in early and late gestation and early lactation. Based on these studies, Matua hay can be recommended as a safe, acceptable hay for mares in production giving producers a viable alternative to traditional horse forages.

Literature Cited

AOAC. 1990. Official Methods of Analysis, 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.

Box, A. C., L. A. Baker, J. L. Pipkin, and J. C. Halliburton. 2001. The digestibility and mineral availability of Matua grass hay in mature horses. Pages 53–54 in Proc. Equine Nutr. and Phys. Symp., Lexington, KY.

Buxton, D. R., D. and R. Mertens. 1995. Quality-related characteristics of forages. Pages 83–93 in Forages: Vol II: The Science of

Grassland Agriculture. R. F. Barnes, D. A. Miller, and C. J. Nelson, ed. Iowa State Univ. Press, Ames.

Casler, M. D., and I. T. Carlson. 1995. Smooth bromegrass. Pages 313–324 in Forages: Vol I: An Introduction to Grassland Agriculture. R. F. Barnes, D. A. Miller, and C. J. Nelson, ed. Iowa State Univ. Press, Ames.

Colluci, P. E., G. K. McLeod, W. L. Grovum, I. McMillan and D. J. Barney. 1990. Digesta kinetics in sheep and cattle fed diets with different intakes. J. Dairy Sci. 73:2143–2156.

Colluci, P. E., G. K. McLeod, W. L. Grovum, and I. McMillan. 1984. Comparative digestion and digesta kinetics in sheep and cattle. Can. J. Anim. Sci. 64(Suppl.):173–174.

Evans, J. W., A. Borton, H. F. Hintz, and L. D. Van Vleck. 1997. The Horse. Freeman, San Francisco, CA.

Fonnesbeck, P. V., R. K. Lydman, G. W. Vander Noot, and L. D. Symons. 1967. Digestion of the proximate nutrients of forages by horses. J. Anim. Sci. 26:1039–1045.

Gibbs, P. G., and K. E. Davison. 1992. Nutritional management of pregnant and lactating mares. Texas Agricultural Extension Service. Bull. No. 5025. Texas A&M University, College Station.

Gibbs, P. G., G. D. Potter, R. W. Blake, and W. C. McMullan. 1982. Milk production of quarter horse mares during 150 days of lactation. J. Anim. Sci. 54:496–499.

Goering, H. K., and P. J. Van Soest. 1970. Forage Fiber Analyses (Apparatus, Reagents, Procedures and Some Applications). Agric. Handbook No. 379. ARS–USDA, Washington, DC.

Hintz, H. F., H. F. Schryver, and C. E. Stevens. 1979. Digestion and absorption in the hindgut of nonruminant herbivores. J. Anim. Sci. 46:1803–1807.

LaCasha, P. A., H. A. Brady, V. G. Allen, C. R. Richardson, and K. R. Pond. 1999. Voluntary intake, digestibility and subsequent selection of Matua bromegrass, Coastal bermuda grass and alfalfa hays by yearling horses. J. Anim. Sci. 77:2766–2773.

Linn, J. G., and N. P. Martin. 1989. Forage quality tests and interpretations. Minnesota Ext. Ser. AG-F0-2637. Univ. of Minnesota, St. Paul.

Mauchly, J. W., 1940. Significance test for sphericity of a normal n-variate distribution. Ann. Math. Stat. 11:204–209.

Merchen, N. R. 1988. Digestion, absorption and excretion in ruminants. Pages 99–114 in The Ruminant Animal. Digestive Physiology and Nutrition. D. C. Church, ed. Prentice Hall, Engelwood Cliffs, NJ.

Milliken, G. A., and D. E. Johnson. 1984. Page 473 in Analysis of Messy Data. Van Nostrand Reinhold Co., New York.

Minson, D. J. 1982. Effects of chemical and physical compostion of herbage eaten upon intake. Pages 167–182 in Nutritional Limits to Animal Production for Pastures. J. B. Hacker, ed. Commonwealth Agric. Bureaux, Farnham Royal, UK.

Moore, J. A., K. R. Pond, M. H. Poore, and T. G. Goodwin. 1992. Influence of model and marker on digesta kinetic estimates for sheep. J. Anim. Sci. 70:3528–3540.

Muchovej, R. M. C., V. G. Allen, D. C. Martens, L. W. Zelazny, and D. R. Notter. 1986. Aluminum, citric acid, nitriotriacetic acid and soil moisture effects on aluminum and iron concentrations in ryegrass. Agron. J. 78:138–145.

NRC. 1989. Nutrient Requirements of Horses. 5th rev. ed. Natl. Acad. Press, Washington D.C.

Rumball, W. 1974. 'Grasslands Matua' prairie grass (*Bromus catharticus* Vahl). N. Z. J. Exp. Agric. 2:1–5.

Schryver, H. F., O. T. Oftedal, J. Williams, L. V. Soderholm, and H. F. Hintz. 1986. Lactation in the horse: the mineral composition of mare milk. J. Nutr. 116:2142–2147.

Shapiro, S. S., and M. B. Wilk. 1965. An analysis of variance test for normality (complete samples). Biometrika 52:591–611.

Sturgeon, L. S., L. A. Baker, J. L. Pipkin, J. C. Haliburton, and N. K. Chirase. 2000. Digestibility and mineral availability of Matua, bermuda grass and alfalfa hay in mature horses. J. Equine Vet. Sci. 20:45–48.

Tukey, J. W. 1949. One degree of freedom for non-additivity. Biometrics 5:232–242.

Uden, P., E. Colucci, and P. J. Van Soest. 1980. Investigation of chromium, cerium and cobalt as markers in digesta. Rate of passage studies. J. Sci. Food Agric. 31:625–632.

Uden, P., Rounsaville, T. R., G. R. Wiggans, and P. J. Van Soest. 1982. The measurement of liquid and solid digesta retention in ruminants, equines and rabbits given timothy (*Phleum pratense*) hay. Br. J. Nutr. 48:329–339.

Van Soest, P. J. 1994. Body size and limitations of ruminants and non-ruminant herbivores. Pages 40–56 in Nutritional Ecology of the Ruminant. Cornell Univ. Press, Ithaca, NY.

Wilson, G. F. 1977. Grasslands Matua Prairie grass. N. Z. Agric. Sci. 11:47–48.

Winer, B. J., D. R. Brown, and K. M. Michels. 1991. Pages 497–580 in Statistical Principles in Experimental Design. 3rd ed. McGraw-Hill Book Co., Boston, MA.