Variation in Ruminants' Preference for Tall Fescue Hays Cut Either at Sundown or at Sunup[1]

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ABSTRACT: Plants vary diurnally in concentrations of nonstructural carbohydrates. If ruminants prefer forages with higher total nonstructural carbohydrates (TNC), then the preference for hays harvested within the same 24-h period may vary. An established field of tall fescue (*Festuca arundinacea* Schreb.) was harvested six times in the vegetative stage. Harvests were paired such that each cutting at sundown (PM) was followed by a cutting the next morning at sunup (AM). We harvested in this manner three times, resulting in six hays. The hays were field-dried, baled, and passed through a hydraulic bale processor prior to feeding. Experiments were conducted with sheep, goats, and cattle, using six animals in each case. During an adaptation phase, hays were offered alone as meals. In the experimental phase, every possible pair of hays (15 pairs) was presented for a meal. Data were analyzed by multidimensional scaling and by traditional analyses. Multidimensional scaling indicated that selection was based on a single criterion. Preference for PM hays was greater than for AM hays ($P < .01$) in all experiments. Increased preference was associated with increased TNC ($P < .01$) and in vitro true DM disappearance ($P < .01$) and decreased fiber concentration ($P < .01$; NDF, ADF, cellulose, and ADL). Mowing hay late in the day was effective in increasing forage preference.

Key Words: Feeding Preferences, Voluntary Intake, Sheep, Cattle, Goats

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Introduction

Plants vary diurnally in concentrations of nonstructural carbohydrates because export of photosynthate does not keep pace with the rate of carbon fixation during the photoperiod. Highest concentrations of nonstructural carbohydrates have been observed in the afternoon (Bowden et al., 1968; Lechtenberg et al., 1971; Gordon, 1996). Diurnal patterns in intake rates of sheep have been observed to coincide with increases in nonstructural carbohydrates (Orr et al., 1997). If ruminants generally prefer forages with higher nonstructural carbohydrate, then the preference for hays harvested within the same 24-h period may vary. Food preferences are affected by many factors (Forbes and Kyriazakis, 1995; Early and Provenza, 1998), but diurnal variation in nonstructural carbohydrate results in only a subtle change in forage composition. Forage composition is modified by diurnal variation without the use of supplements, which provides a rigorous test of the ruminant's ability to learn that the nutritive value or taste of one feed varies slightly from that of another (Provenza and Balph, 1987). The ruminant must either sample or remember the forage and be able to recognize it when it is paired with another feed, such as forage harvested from the same field after approximately 12 h. In the current study, we tested for variation in short-term preference for tall fescue (*Festuca arundinacea* Schreb.) hays harvested only 12 to 14 h apart.

Methods

Field Procedures

We harvested hay in 1996 from an established field of 'HiMag' tall fescue at the Northwest Irrigation and Soils Research Laboratory (Kimberly, ID) six times in the vegetative stage. Hay cuts were paired so that

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[1]Use of trade names does not imply endorsement by USDA, ARS, or by the North Carolina Agricultural Research Service of the products named or criticism of similar ones not mentioned.

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each harvest at sundown (**PM**), after a sunny day, was followed by another harvest the next morning (**AM**) at sunup. We harvested in this manner three times, resulting in six hays (Cut 1, August 20 PM; Cut 1, August 21 AM; Cut 2, August 21 PM; Cut 2, August 22 AM; Cut 3, September 20 PM; Cut 3, September 21 AM). Weather during the hay making was clear, and there was no precipitation. The maximum and minimum temperatures were 28 and 8°C on August 20, 26 and 10°C on August 21, 28 and 7°C on August 22, 21 and 3°C on September 20, and 20 and 12°C on September 21. The hays were field-dried 6 to 8 d and baled prior to shipping to Raleigh, NC, for the preference trials.

'Triumph' tall fescue in a vegetative stage was harvested as hay at Raleigh, NC, and fed to the sheep and goats in Exp. 1 and 2 when animals were not being used to test the experimental forages. Carostan flaccidgrass (*Pennisetum flaccidum* Griseb.), a warm-season, perennial forage, was harvested in the late vegetative stage and fed to steers in Exp. 3 when they were not being used to test the experimental forages. All hays were stored undercover in the same metal building. Just prior to feeding, and to avoid leaf loss, all hays were passed through a hydraulic Van Dale 5600 Bale Processor (J. Star Industries, Fort Atkinson, WI) with stationary knives spaced 10 cm apart.

Design of Preference Trials

We conducted three experiments that differed in the animal species used for determining preference. In Exp. 1, six Katahdin ewes were used (mean BW = 56 kg), in Exp. 2, six Spanish doe goats were used (mean BW = 45 kg), and in Exp. 3, six Hereford steers were used (mean BW = 581 kg). The protocol for animal care and health was approved by the North Carolina State University Institutional Animal Care and Use Committee. During an adaptation or training period (Kyriazakis et al., 1990), single meals of each hay were offered to allow the animal to associate the hay with postingestive metabolic "feelings" and taste produced by the forage. This training period lasted 6 d, and we randomized the order in which the forages were offered to each animal. During the experimental phase, we presented each possible pair of the six hays (15 pairs) for a meal in the morning, but only one pair was offered each day. The experimental phase lasted 15 d. The order of presentation of the pairs and the left-right position of the hays in the pair were randomized. The weight of hay was determined before and after feeding. This permitted calculation of DM consumed after adjusting for the DM content of the hay. Animals were individually penned in all three experiments. Sheep and goat pens were approximately 1.5 × 2 m. Cattle pens were approximately 2.5 × 4 m. We presented the pair of forages side by side. Sheep and goats were offered approximately .75 kg of each hay and allowed approximately 2.5 h to feed. At approximately 30 min after offering the feed, an intermediate weight was collected for the sheep and goats. This was used to calculate an initial intake rate by dividing hay disappearance over the first 30 min by the time in minutes. The cattle were led into the pens, offered approximately 2 kg of each hay, and allowed approximately 30 min to feed. Only two pens were available for cattle, so approximately 2 h were required to finish each morning's pairs. Cattle were housed and fed in stalls for the remainder of the day. For the experiment with cattle, a video recorder was used to estimate the total time spent at each feeder in order to calculate intake rate by dividing hay disappearance by minutes at the feeder.

In all three experiments, we took care to prevent consumption of all of the preferred hay and, therefore, to always offer a choice between the two hays in the pair. Each day, after the preference trial, sheep and goats were given ad libitum access to 'Triumph' tall fescue, and cattle were given ad libitum access to flaccidgrass.

Collection of Masticated Forage

In order to test for possible differences in mastication of the forages, six esophageally cannulated steers (not part of the preference trial) were used to obtain a masticated (extrusa) sample of each of the forages. The steers were offered the hays one at a time in random order. Extrusa was quick-frozen in liquid nitrogen, stored frozen, and subsequently freeze-dried. Freeze-dried samples separated easily during sieving, and dried samples could be used for forage quality analysis without the losses of soluble material that may occur with wet sieving. For each hay from each animal, duplicate 15-g samples were dry-sieved into nine particle classes using a Fritsch vibrator system (Annalysette, The Tekman Co., Cincinatti, OH). Vibration was applied for 5 min, and any clusters of particles were gently separated. Then the screens were rotated 180°, and another 5 min of vibration was applied, after which the weight of particles on each screen was determined. The sieve sizes (U.S.A. Standard Testing Sieve, Fisher Scientific, Springfield, NJ) used were 5.6, 4.0, 2.8, 1.7, 1.0, .5, .25, and .125 mm. The weight that passed the .125-mm sieve was also recorded. These weights, expressed as cumulative percentage oversize, were used to estimate mean and median particle size (Fisher et al., 1988). The weights were also used to estimate percentages of large (> 1.7), medium, (≤ 1.7 mm but > .5), and small (≤ .5) particles. Samples of the three particle size classes were analyzed for NDF, CP, and an estimate of in vitro true DM disappearance (**IVTDMD**) as described below.

Forage Nutritive Value

In each experiment, forage samples that were composed of subsamples collected each time a hay was fed in a pair (n = 5) were analyzed. Samples were then composited for each animal and represented the forage offered to each animal. This included variation within the hay source as well as laboratory variation in our estimates of means (n = 6). The composite sample was dried at 75°C in a forced-draft oven, and composition values were reported on a DM basis. Samples were ground to pass a 1-mm screen in a cyclone mill.

In vitro true DM disappearance was estimated for hay and masticate samples. Ruminal inoculum was collected from a cannulated, mature Hereford steer fed a mixed alfalfa and orchardgrass hay. After a 48-h incubation in a batch processor (Ankom Technology Corp., Fairport, NY), samples were extracted with neutral detergent solution prior to drying and weighing to estimate disappearance. Near-infrared reflectance (**NIR**) was also a part of this analysis. Samples (as-fed) of hays and orts (data not shown) for all three experiments reported here (n = 216) were scanned and used as the initial base population. In addition, fescue hays were selected for scanning and inclusion in the base population from two experiments in Idaho (n = 384). This resulted in a selected set of 331 scans and IVTDMD observations, from which 22 lab outliers were dropped. The final equation used to predict hay IVTDMD was based on 309 samples with a range of 75 to 90% IVTDMD, a SE of calibration of 1.97, and a SE of cross-validation of 2.14. In the case of the masticate, samples of all masticate particle size classes and representative whole samples were scanned for the three experiments reported here and for the two additional fescue experiments. The total number of masticate samples scanned was 527, and a subset of 117 samples was used to develop a prediction equation, with a range of 82 to 92% IVTDMD, a SE of calibration of .96, and a SE of cross-validation of 1.12.

Fiber fractions were estimated (NDF, ADF, cellulose, ADL, and AIA) according to Van Soest and Robertson (1980) in a batch processor (Ankom Technology Corp.) for samples of the hays. The only fiber fraction estimated for the masticated samples was NDF. Crude protein was estimated as 6.25 times the percentage of N determined with an AutoAnalyzer (Technicon Industrial Systems, Tarrytown, NY) for the masticate and hay samples (AOAC, 1990). Near-infrared reflectance was also used in the analysis of NDF and CP concentrations in masticate samples. As in the case of masticate IVTDMD, we scanned 527 samples. A subset of 117 samples was selected for NDF, and a subset of 100 samples was selected for CP. The NDF prediction equation resulted in a range of 40 to 54% NDF, with a SE of calibration of .96 and a SE of cross-validation of 1.15. The CP prediction equation resulted in a range of 12 to 24% CP, with a SE of calibration of .34 and a SE of cross-validation of .49.

The total nonstructural carbohydrates of the forage samples (**TNC**) were analyzed with an adaptation (Fisher and Burns, 1987) of the method described by Smith (1969). The TNC were fractionated by differential solubility into monosaccharides, disaccharides, fructans, and starch. Starch was determined by digesting to glucose with amyloglucosidase and measuring the monomer concentration with a YSI Model 27 Industrial Analyzer (Yellow Springs Instrument Co., Yellow Springs, OH).

Statistical Analysis

The experimental design allowed statistical analysis by multidimensional scaling (Buntinx et al., 1997) as well as by traditional analyses. Multidimensional scaling is used to develop a spatial arrangement representing the differences expressed as selective forage intake by the animals. For multidimensional scaling, the difference in preference between a pair of hays was expressed by subtracting the amount of the least preferred hay from the most preferred hay and dividing by the sum of the two intakes. In this way, preference was expressed numerically. If an animal consumes equal quantities of the hays in the pair, then the difference ratio is equal to zero and no preference is expressed. If only one of the pair is consumed, then the difference ratio is equal to one, and the maximum difference in preference between hays is expressed (Buntinx et al., 1997).

Each experiment was also tested by analysis of variance after averaging intake of each hay (averaged across each combination, n = 5) by each animal. The analysis of variance only included terms for animal and hay. Within the hay treatments, means were separated using the minimum significant difference (**MSD**) from the Waller-Duncan k-ratio *t*-test (K = 100). In addition, a contrast statement was used to test for the PM vs the AM harvest effect. Simple linear correlation was used to examine the relationship of DM intake to nutritive value.

Results and Discussion

Multidimensional scaling indicated that all three animal species based selection on a single dimension (criterion), with correlation coefficients ranging from .97 to .99. Consequently, to simplify presentation, only the results of the traditional analysis of variance will be reported.

All three animal species preferred (as measured by DMI and tested by orthogonal contrast) PM hays over AM hays, and their preference for the third cut was greater than for the first two cuts (Tables 1, 2, and 3). The effect of PM and AM cutting varied among animal species for the third cut. With goats and cattle, no significant difference in preference was found between the third-cut hays according to MSD, although the contrast for the overall PM and AM effect was significant for all three animal species. These results are consistent with the work of Kim (1995), in which

Table 1. Intake and composition of hays from three cuts harvested either in the afternoon (PM) or morning (AM) of the following day in an experiment with sheep

Variable	Cut 1		Cut 2		Cut 3		MSD[a]	Mean effect of time		
	PM	AM	PM	AM	PM	AM		PM	AM	P > F
DMI, g/meal[b]	335	216	310	171	598	490	60	414	292	<.01
DMI rate, g/min	3.97	2.78	4.26	1.98	11.48	8.75	1.22	6.57	4.50	<.01
NDF, % DM	50.6	53.2	51.7	53.9	42.2	48.4	1.7	48.2	51.8	<.01
ADF, % DM	25.6	26.6	26.1	27.5	22.2	24.0	.4	24.6	26.0	<.01
Cellulose, % DM	22.8	23.7	23.3	24.5	19.5	21.3	1.6	21.9	23.2	<.01
ADL, % DM	1.29	1.45	1.36	1.44	1.06	1.14	.11	1.24	1.34	<.01
AIA, % DM	1.29	1.24	1.26	1.37	1.44	1.43	—	1.33	1.35	.73
MonoSac, % DM[c]	2.48	1.56	2.04	1.82	2.54	2.01	.42	2.35	1.80	<.01
DiSac, % DM[d]	4.03	2.91	3.19	3.02	6.71	4.65	.61	4.64	3.53	<.01
Fructans, % DM	.96	.86	.94	1.13	2.35	2.08	.29	1.42	1.36	.50
Starch, % DM	1.12	1.16	1.21	1.19	1.04	1.18	.09	1.12	1.18	.05
TNC, % DM[e]	8.59	6.49	7.38	7.15	12.65	9.92	.78	9.54	7.85	<.01
CP, % DM	22.8	22.4	22.2	20.9	20.3	19.9	.6	21.8	21.1	<.01
IVTDMD, % DM[f]	84.3	81.7	83.0	81.6	88.5	86.9	.7	85.3	83.4	<.01

[a]MSD = minimum significant difference (Waller-Duncan, k-ratio = 100).
[b]Intake values are means for six animals (n = 6), and composition values are means for samples collected each time a feed was offered and composited by feed and animal (n = 6).
[c]MonoSac = monosaccharides.
[d]DiSac = disaccharides.
[e]TNC = total nonstructural carbohydrates.
[f]IVTDMD = in vitro true dry matter disappearance.

greater DMI and fat-corrected milk yields were found with dairy cows fed 40% PM-harvested vs 40% AM-harvested alfalfa hay in a total mixed ration.

Intake rates calculated over the first 30 min for sheep (Table 1) and goats (Table 2) were higher for the PM hays than for the AM hays. Intake rates for cattle (Table 3), calculated from video observations of time spent feeding at each manger, did not differ significantly overall between PM and AM hays. However, as indicated above, DMI by cattle was higher for the PM hays than for the AM hays. This was associated with the increased time ($P < .01$) spent feeding from mangers containing the PM hays (11 min) compared with mangers containing AM hays (8 min).

In all three experiments, NDF, ADF, and cellulose were lower in the PM hays (Tables 1, 2, and 3). No significant effect was found for ADL in hay fed to

Table 2. Intake and composition of hays from three cuts harvested either in the afternoon (PM) or morning (AM) of the following day in an experiment with goats

Variable	Cut 1		Cut 2		Cut 3		MSD[a]	Mean effect of time		
	PM	AM	PM	AM	PM	AM		PM	AM	P > F
DMI, g/meal[b]	316	177	276	155	486	522	81	359	285	<.01
DMI rate, g/min	4.3	1.8	4.1	1.9	9.2	9.3	1.2	5.9	4.3	<.01
NDF, % DM	50.7	53.6	53.0	54.1	45.4	47.3	2.1	49.7	51.7	<.01
ADF, % DM	25.3	26.8	26.7	27.4	22.8	23.9	.9	24.9	26.0	<.01
Cellulose, % DM	22.7	23.9	23.8	24.5	20.1	21.3	.9	22.2	23.2	<.01
ADL, % DM	1.29	1.54	1.47	1.46	1.13	1.15	.14	1.30	1.38	.05
AIA, % DM	1.14	1.26	1.20	1.23	1.38	1.33	—	1.24	1.27	.57
MonoSac, % DM[c]	2.48	1.85	2.00	1.61	2.35	2.11	.49	2.28	1.86	<.01
DiSac, % DM[d]	4.13	3.12	3.82	3.82	5.84	4.93	.76	4.60	3.96	<.01
Fructans, % DM	1.58	1.39	1.54	1.70	2.83	2.90	.42	1.98	2.00	.92
Starch, % DM	1.00	1.00	1.07	1.06	.98	1.00	—	1.02	1.02	.92
TNC, % DM[e]	9.20	7.36	8.42	8.18	12.01	10.94	1.09	9.88	8.83	<.01
CP, % DM	22.8	22.3	22.3	20.2	20.8	20.0	.9	22.0	20.8	<.01
IVTDMD, % DM[f]	84.6	81.5	82.5	81.7	88.1	87.1	1.1	85.1	83.4	<.01

[a]MSD = minimum significant difference (Waller-Duncan, k-ratio = 100).
[b]Intake values are means for six animals (n = 6), and composition values are means for samples collected each time a feed was offered and composited by feed and animal (n = 6).
[c]MonoSac = monosaccharides.
[d]DiSac = disaccharides.
[e]TNC = total nonstructural carbohydrates.
[f]IVTDMD = in vitro true dry matter disappearance.

Table 3. Intake and composition of hays from three cuts harvested either in the afternoon (PM) or morning (AM) of the following day in an experiment with cattle

Variable	Cut 1		Cut 2		Cut 3		MSD[a]	Mean effect of time		
	PM	AM	PM	AM	PM	AM		PM	AM	$P > F$
DMI, g/meal[b]	987	544	788	427	1460	1310	154	1078	760	<.01
DMI rate, g/min	98	74	124	173	115	104	39	112	117	.68
NDF, % DM	49.6	52.0	51.5	53.5	43.5	47.0	1.3	48.2	50.8	<.01
ADF, % DM	26.0	27.1	26.8	28.2	22.4	24.3	.6	25.1	26.5	<.01
Cellulose, % DM	23.2	24.3	24.0	25.3	19.7	21.8	.6	22.3	23.8	<.01
ADL, % DM	1.60	1.65	1.66	1.67	1.22	1.23	.19	1.49	1.52	.64
AIA, % DM	.98	.98	1.01	1.03	1.30	1.13	.19	1.10	1.05	.33
MonoSac, % DM[c]	2.45	1.67	2.12	1.71	2.83	2.42	.39	2.47	1.93	<.01
DiSac, % DM[d]	3.45	2.65	3.28	2.72	5.76	3.49	.67	4.16	2.95	<.01
Fructans, % DM	1.25	.89	1.18	1.23	2.30	2.40	.29	1.58	1.51	<.01
Starch, % DM	1.00	1.00	1.04	1.06	.93	1.02	.07	.99	1.03	.08
TNC, % DM[e]	8.15	6.21	7.73	6.71	11.82	9.33	.78	9.23	7.42	<.01
CP, % DM	22.2	21.7	21.7	19.9	20.6	19.9	.8	21.5	20.5	<.01
IVTDMD, % DM[f]	84.7	82.4	83.1	82.1	88.8	87.5	.6	85.5	84.0	<.01

[a]MSD = minimum significant difference (Waller-Duncan, k-ratio = 100).
[b]Intake values are means for six animals (n = 6), and composition values are means for samples collected each time a feed was offered and composited by feed and animal (n = 6).
[c]MonoSac = monosaccharides.
[d]DiSac = disaccharides.
[e]TNC = total nonstructural carbohydrates.
[f]IVTDMD = in vitro true dry matter disappearance.

cattle (Table 3), but ADL was significantly lower in the PM hays fed to sheep (Table 1) and goats (Table 2). We found no effect of time of day (PM vs AM) on the concentration of AIA. The decreased fiber fractions in the PM hays are assumed to be a result of dilution with TNC produced by photosynthesis.

Monosaccharides, disaccharides, and TNC were higher in the PM hays than in the AM hays (Tables 1, 2, and 3). Fructans and starch were inconsistent from experiment to experiment. This is in contrast to previous work with alfalfa (Lechtenberg et al., 1971; Kim, 1995), in which starch increased during daylight hours. However, Gordon (1996) reported that temperate grasses accumulated sucrose more rapidly than starch. In further contrast to previous work, CP increased rather than decreased, as was found in alfalfa (Youngberg et al., 1972). This was despite a dilution effect that could be attributed to increased TNC.

Small but significant increases in IVTDMD were found in the three experiments for the PM vs AM hays (Tables 1, 2, and 3). The two hays from the third cut

Table 4. Correlations between composition of hays from three cuts harvested either in the afternoon (PM) or morning (AM) of the following day and DMI of sheep, goats, and cattle

Variable	Sheep		Goats		Cattle	
	r	P[a]	r	P	r	P
NDF[a]	−.961	<.01	−.955	<.01	−.968	<.01
ADF	−.991	<.01	−.944	<.01	−.967	<.01
Cellulose	−.988	<.01	−.938	.01	−.960	<.01
ADL	−.989	<.01	−.943	<.01	−.914	.01
AIA	.696	.12	.629	.18	.789	.06
MonoSac[b]	.701	.12	.664	.15	.953	<.01
DiSac[c]	.943	<.01	.882	.02	.830	.04
Fructans	.895	.02	.909	.01	.887	.02
Starch	−.664	.15	−.580	.23	−.700	.12
TNC[d]	.954	<.01	.938	.01	.939	.01
CP	−.589	.22	−.385	.45	−.183	.73
IVTDMD[e]	.991	<.01	.966	<.01	.981	<.01

[a]Probabilities of r based on n of 6.
[b]MonoSac = monosaccharides.
[c]DiSac = disaccharides.
[d]TNC = total nonstructural carbohydrates.
[e]IVTDMD = in vitro true dry matter disappearance.

Table 5. Nutritive value of whole masticate and three particle size classes collected from six esophageally fistulated cattle (n = 6) offered hays from three cuts harvested either in the afternoon (PM) or morning (AM) of the following day

	Cut 1		Cut 2		Cut 3			Mean effect of time		
Variable	PM	AM	PM	AM	PM	AM	MSD[a]	PM	AM	$P > F$
Whole Masticate										
NDF, % DM	48.7	51.6	48.8	50.9	42.5	46.4	.8	46.7	49.6	<.01
CP, % DM	22.7	22.3	21.8	18.9	20.1	19.6	.6	21.5	20.3	<.01
IVTDMD, % DM[b]	89.1	88.5	87.8	85.2	91.6	90.5	.4	89.5	88.1	<.01
Large particles (> 1.7 mm)										
NDF, % DM	49.0	52.1	49.3	51.4	42.6	46.4	.9	47.0	50.0	<.01
CP, % DM	22.4	21.8	21.4	18.6	19.7	19.2	.6	21.2	19.9	<.01
IVTDMD, % DM	89.2	88.4	87.8	85.3	91.7	90.5	.4	89.6	88.1	<.01
Medium particles (≤ 1.7 mm and > .5 mm)										
NDF, % DM	48.5	51.3	48.5	50.8	42.5	46.4	.9	46.5	49.5	<.01
CP, % DM	23.1	23.0	22.4	19.3	20.9	20.3	.7	22.1	20.9	<.01
IVTDMD, % DM	89.1	88.6	88.0	85.1	91.7	90.6	.5	89.6	88.1	<.01
Small particles (≤ .5 mm)										
NDF, % DM	46.6	49.0	45.6	48.0	42.2	45.6	1.2	44.8	47.5	<.01
CP, % DM	21.7	21.6	21.6	18.5	19.1	19.0	.6	20.8	19.7	<.01
IVTDMD, % DM	88.7	88.0	87.8	85.2	90.4	89.4	.7	89.0	87.5	<.01

[a]MSD = minimum significant difference (Waller-Duncan, k-ratio = 100).
[b]IVTDMD = in vitro true dry matter disappearance.

had higher IVTDMD than hays from the first two cuts, probably as a result of cooler temperatures during the growth of the September-harvested hays.

Negative correlations were found between preference (expressed as DMI) and NDF, ADF, cellulose, and ADL in all three animal species (Table 4). Disaccharides, fructans, TNC, and IVTDMD were positively correlated with preference in all three animal species. Monosaccharides were only correlated with DMI in cattle. Acid insoluble ash, starch, and CP were not correlated with DMI. This is not surprising for AIA, because we only detected a significant treatment effect for this variable in Exp. 3 (Cut 3 PM greater than either PM or AM in Cuts 1 and 2). Fescue accumulates fructans rather than starch as a storage carbohydrate, and a significant PM vs AM effect for starch was noted only in the experiment with sheep (Table 1). No significant correlations with intake were detected for starch (Table 4). An absence of correlation with CP is more surprising, because we observed significant treatment effects in all three experiments. However, the treatment effects were small and CP was high in all hays.

The experimental treatments did not affect the particle size of the masticate samples. Although it is not intuitive, a positive correlation between forage quality and particle size have been noted previously (Fisher et al., 1991). Averaged over all observations, 53% (SE = 5) of the particles were classified as large (> 1.7 mm), 41% (SE = 4) as medium (≤ 1.7 mm but > .5 mm), and 6% (SE = 1) as small (< .5 mm) particles. Mean particle size was 2.1 mm (SE = .2), and the median particle size was 1.8 mm (SE = .2). These particle sizes are larger than observations for fescue hay estimated by Pond et al. (1990) or Buntinx et al. (1997) using similar techniques. This may be because the hays tested in these experiments were of very high quality and dried under good conditions.

The NDF, CP, and IVTDMD of the whole masticate and the large, medium, and small masticate particles were all affected by time of harvest (Table 5). In every case, the contrasts for the effect of PM vs AM harvest indicated lower NDF, higher CP, and higher IVTDMD for hays harvested in the afternoon ($P < .01$). Use of the Waller-Duncan k-ratio MSD also indicated differences at each individual cut for NDF and IVTDMD. Differences between CP concentrations of the PM and AM hays of the first and third cuts were small and generally not significant according to the MSD test. The statistical power of the contrast and the larger effect in the second harvest resulted in a significant effect.

Implications

Sheep, goats, and cattle can detect subtle differences between tall fescue hays cut within the same 14-h period. These differences seemed to be related to nonstructural carbohydrate that accumulated during the day as a result of photosynthesis. Dilution by accumulated carbohydrate reduced the concentrations of fiber fractions in hays cut near sundown. Ruminants can also identify and select the preferred hays when hays are offered in pairs on days after the initial meal. Hays cut in the afternoon are of higher nutritive value and are preferred by sheep, goats, and cattle. Thus, mowing tall fescue hays near sundown can improve the forage nutritive value and increase animals' preference for the hays.

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