Quality Characteristics and In Situ Dry-Matter Disappearance Kinetics of Wheat Forages Harvested by Clipping or as Masticate

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Story in Brief

Much of the previous work evaluating forage quality characteristics and in situ DM disappearance kinetics of cereal-grain forages has not considered the effects of diet selection. Our objective was to evaluate the effects of harvest technique and sampling date on the in situ DM disappearance kinetics and nutritive value of wheat (*Triticum aestivum* L.). Forage was harvested on three dates (March 6, March 27, and April 11, 2000) using five techniques. Techniques included freeze- (FDM) or oven-dried (122°F; ODM) masticate and whole-plant, random-pluck, or top-half samples harvested with garden shears. There was an interaction ($P < 0.05$) of harvest date and sampling technique for CP, NDF, ADF, hemicellulose, cellulose, lignin, and whole-plant ash. There were greater ($P < 0.05$) concentrations of most fiber components in ODM than in FDM on all harvest dates. Experimental forages also were evaluated for ruminal disappearance of DM in situ. There was no interaction ($P = 0.092$) of harvest date and sampling technique for rate (k_d) of DM disappearance. The FDM exhibited the fastest k_d (0.088/h); ODM (0.070/h) and the top-half (0.076/h) clipping treatments were similar ($P > 0.05$), but slower ($P < 0.05$) than FDM. Disappearance from other clipped treatments was at the slowest rate (0.055/h). None of the clipping treatments did a good job of mimicking the diet selected by grazing cattle.

Introduction

Cereal grains, such as wheat, have been used routinely across the southern Great Plains to provide fall, winter, and spring grazing for a variety of livestock. Numerous studies have evaluated the nutritive value of wheat or mixtures containing wheat as affected by harvest date or growth stage. Recently, in situ disappearance kinetics of DM and NDF for wheat, oats (*Avena sativa* L.), and rye (*Secale cereale* L.) were related to growth stage by linear and polynomial regression techniques (Coblentz et al., 2000). While these efforts have provided a solid understanding of the relationships between the nutritive value or in situ disappearance kinetics of cereal grains and the associated harvest date or growth stage, they have not addressed the impact that diet selection may play in these relationships. Our objective in this study was to evaluate the effects of various sampling techniques and sampling date on the in situ DM disappearance kinetics and nutritive value of wheat forage.

Experimental Procedures

Establishment and Management of Experimental Forages. A 4-acre site located at the University of Arkansas Forage Research Area in Fayetteville was clean-tilled and fertilized to meet the soil test recommendations of the Arkansas Cooperative Extension Service; this included an application of 60 lb/acre of actual N as NH_4NO_3. The site was seeded with 'Delta King 9027' soft-red winter wheat on September 10, 1999 at a rate of 120 lb/acre with a 7-ft Marliss drill (Marliss Industries, Jonesboro, AR). An additional 50 lb/acre of N was applied as NH4NO3 on February 15, 2000. Throughout the late fall of 1999 the site was grazed lightly to control fall growth.

Collection of Experimental Forages. In the spring of 2000, three sampling dates were chosen to approximately coincide with the vegetative, mid-elongation, and boot stages of growth for the wheat forage (March 6, March 27, and April 11, respectively). On each date, five sampling techniques were used to gather samples of wheat forage. These included three clipping techniques: 1) whole plant (clipped to a 1-in stubble height); 2) random pluck (clipped to a 1-in stubble height); and 3) top half of standing forage. Masticate samples were also collected from ruminally cannulated steers following manual ruminal evacuation. These samples were either freeze-dried (FDM) or oven-dried (ODM) under forced air (122°F).

Laboratory Analyses. Dried forages were ground through a 1- or 2-mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, PA). Subsamples ground through a 1-mm screen were retained for standard assays of forage nutritive value that included NDF, ADF, cellulose, and acid detergent lignin; these were quantified by the batch procedures outlined by ANKOM Technology Corp. (Fairport, NY). Concentrations of hemicellulose were calculated as NDF - ADF. Concentrations of N in each forage were determined by rapid combustion (1562°F; LECO Model FP-428; LECO Corp., St. Joseph, MI); CP was calculated as the percentage of N in the sample x 6.25. Concentrations of whole-plant ash were determined by combusting 2-g samples of each forage at 932°F for 8 h in a muffle furnace. Subsamples ground through a 2-mm screen were retained for in situ analysis.

In Situ Procedures in Confinement. Five 739 ± 129-lb ruminally cannulated crossbred (Angus x Brangus x Angus) steers fitted with ruminal cannulae were housed in individual 11-ft by 16-ft pens with concrete floors that were cleaned regularly and offered a diet of alfalfa (*Medicago sativa* L.) hay (44.4% NDF, 32.9% ADF, and 17.7% CP) and a corn-based supplement (93.8% ground corn, 2.0% molasses, 4.0% trace mineral salt, and 0.2% vitamin A, D, and E premix). On a DM basis, the basal diet contained 87.3% alfalfa hay and 12.7% supplement, and was offered at 2.00% of BW daily in two equal portions (0700 and 1600 h). Water and a trace mineral block were provided for each steer for ad libitum intake. Steers were adapted to the basal diet for 9 d prior to initiating the trial. Other in situ procedures were consistent with the standardized in situ techniques described by Vanzant et al. (1998). Dacron bags containing 5-g samples of each experimental forage were incubated in the rumen for 0,

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3, 6, 9, 12, 24, 36, 48, 72, or 96 h, and subsequently washed in a top-loading washing machine (Coblentz et al., 1997).

Data were fitted to the nonlinear regression model of Mertens and Loften (1980) using PROC NLIN (SAS Inst., Inc., Cary, NC). Dry matter was partitioned into three fractions based on relative susceptibility to ruminal disappearance. The A fraction was defined as the immediately soluble portion; the B fraction was comprised of DM degraded at a measurable rate; and the C fraction was considered undegradable in the rumen. Fractions B and C, disappearance rate (k_d), and the lag time were determined directly from the nonlinear regression model. Fraction A was calculated for each forage as 100 - (B + C); similarly, the potential extent of disappearance was calculated as 100 - C. The effective degradability of DM for the wheat forages was calculated (Ørskov and McDonald, 1979) as A + B _ [k_d/(k_d + k_p)], where k_p = passage rate (0.035 + 0.009/h) that was determined experimentally in each steer using acid detergent insoluble ash as an internal marker.

Statistics. Growth characteristics (DM yield, plant height, and proportion of leaf) were analyzed as a randomized complete block design with harvest dates as treatments and four field replications as blocks. Nutritive value of the wheat forages was evaluated as a split-plot design with sampling techniques as whole plots, harvest dates as subplots, and field replications as the blocking term. Disappearance kinetics of DM were evaluated as a randomized complete block design with a factorial arrangement of five sampling techniques and three harvest dates; the five steers served as blocks. All analyses were conducted by PROC ANOVA (SAS Inst., Inc., Cary, NC).

Results and Discussion

Agronomic Characteristics of Wheat Forage. On March 6, tillers had not yet begun to elongate and plants remained vegetative. However, by the final sampling date, flag leaf sheaths were swollen, indicating that the reproductive head was ready to emerge. By this time, there was more than 7,395 lb DM/acre of available forage in the pasture, and about 3475 lbs DM/acre in the top half of the canopy (Table 1). All growth characteristics changed ($P < 0.05$) during each sampling interval. The proportion of leaf tissue in the forage canopy decreased ($P < 0.05$) from 47.0% on March 27 to 28.7% by April 11.

Nutritive Value of Wheat Forages. For CP, NDF, ADF, hemicellulose, cellulose, lignin, and whole-plant ash, there was an interaction ($P< 0.009$) of the main effects. Comparisons of subplot (sampling date) means within whole-plots (sampling technique) largely reflect changes in nutritive value associated with stem elongation; of greater interest are comparisons of sampling techniques within sampling date (Table 2).

The concentration of whole-plant ash in clipped samples did not differ ($P > 0.05$) within any sampling date; however, concentrations of ash in masticate ranged from 10.1 to 17.3 percentage units greater ($P < 0.05$) than those of associated clipped samples. Within sampling date, drying method did not affect ($P > 0.05$) concentrations of CP in masticate samples on March 6 and April 11, but CP was 2.3 percentage units greater ($P < 0.05$) in ODM on March 27. Although non-significant, this pattern was also observed on the other sampling dates. Concentrations of CP in samples clipped from the top half of the canopy were greatest ($P < 0.05$) on all sampling dates; these concentrations were 9.5 and 7.8 percentage units greater ($P < 0.05$) than FDM masticate collected on March 6 and 27, but both masticate treatments and forage clipped from the top half of the canopy did not differ ($P > 0.05$) on April 11. Clipped whole-plant forage had the lowest concentration of CP on all dates, but this differed ($P < 0.05$) from FDM and ODM on the final sampling date only.

The drying techniques that were used to dehydrate masticate samples had clear effects on the associated concentrations of fibrous components. On the March 6 sampling date, the concentration of NDF in masticate samples increased ($P < 0.05$) by 7.7 percentage units in response to oven drying compared to freeze drying; similar responses were observed on subsequent harvest dates. With relatively few exceptions, samples clipped from the top half of the canopy had lower ($P < 0.05$) concentrations of fibrous components than did random-pluck and whole-plant samples. Random-pluck and whole-plant samples had higher ($P < 0.05$) concentrations of NDF, cellulose, and hemicellulose than FDM on all sampling dates. However, this was not true for ODM; concentrations of NDF and hemicellulose for ODM did not differ ($P > 0.05$) from those of random-pluck or whole-plant treatments on at least one sampling date. Concentrations of ADF were lower ($P < 0.05$) for random-pluck and whole-plant samples than for FDM on March 6; however, concentrations did not differ ($P > 0.05$) on March 27, and ADF was greater in random-plucked and whole-plant samples than in FDM on April 11. Generally, lignin varied over treatments, but the concentration of lignin in FDM was lowest ($P < 0.05$) on all sampling dates. The ODM had greater ($P < 0.05$) concentrations of lignin than FDM on the initial two sampling dates and was numerically ($P > 0.05$) greater on the final sampling date.

Disappearance Kinetics. For the evaluation of in situ DM disappearance kinetics, the interaction of harvest date and sampling technique effects was significant ($P < 0.0001$) for fractions A, B, C, and the potential extent of disappearance; therefore, only interaction means are presented (Table 3). Overall, the large proportions of DM partitioned into fraction A (37.6 to 55.5% of DM) were indicative of high-quality forage. The FDM had greater ($P < 0.05$) proportions of soluble DM than did clipped samples on all sampling dates; this was also true ($P < 0.05$) for ODM on the March 6 and 27 sampling dates, but not ($P > 0.05$) on April 11. The smallest ($P < 0.05$) proportion of DM partitioned into fraction B was observed in FDM on all sampling dates. There were large differences between FDM and clipped treatments (10.3 to 15.5 percentage units) on the first two sampling dates, but these were relatively small (2.0 to 6.0 percentage units) on the final date. Oven-drying greatly increased ($P < 0.05$; 8.4 to 12.5 percentage units) fraction B relative to FDM on all harvest dates, but did not affect ($P > 0.05$) the portion of DM that was unavailable in the rumen. Fraction C for ODM and FDM varied by a maximum of only 0.6 percentage units within any given sampling date. Over all treatments, the potential extent of disappearance ranged from 83.3 to 96.3% of DM (Table 3), which is generally indicative of excellent forage nutritive value.

Sampling technique affected ($P = 0.027$) our estimates of lag time, but sampling date ($P = 0.139$) and the interaction of main effects ($P = 0.534$) did not (Table 4). Averaged over three sampling dates, FDM exhibited a shorter ($P < 0.05$) lag time (0.88 h) than did all other treatments (range = 1.58 to 1.68 h; Table 4). Sampling date and technique both affected our estimates of k_d ($P < 0.0001$), but their associated interaction did not ($P = 0.092$; Table 4). Averaged over three sampling dates, FDM exhibited the most rapid ($P < 0.05$) estimate of k_d (0.088/h). The ODM (0.070/h) and forage clipped from the top half of the canopy (0.076/h) did not differ from each other ($P > 0.05$), but both were slower ($P < 0.05$) than observed for FDM. Whole-plant (0.055/h) and random-pluck (0.055/h) forages had identical ($P > 0.05$) estimates of k_d that were slower ($P < 0.05$) than all other treatments.

Effective Degradability. For the effective ruminal degradability of DM, the interaction of main effects was significant ($P < 0.0001$). Within each sampling date, the effects of oven-drying reduced ($P < 0.05$) the effective degradability of DM relative to FDM. The effective ruminal degradability of DM for forage clipped from the top half of the canopy did not differ ($P > 0.05$) from that of FDM, and was greater (P < 0.05) than ODM on the March 6 sampling date; however, both masticate treatments had greater (P < 0.05) estimates of effective degradability on subsequent sampling dates than other forage sampling techniques. On all sampling dates, forage clipped from the top half of the canopy exhibited a greater (P < 0.05) effective degradability than all other clipped treatments.

Implications

No clipping technique was successful at mimicking the diet selected by cattle grazing wheat pasture. Although oven-drying is a simpler method of processing masticate samples, quality characteristics and digestion kinetics are altered relative to freeze-drying.

Literature Cited

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Table 1. Agronomic characteristics of experimental wheat forages harvested in Fayetteville during 2000

Harvest date	Whole-plant yield	Top-half yield	Plant height	Leaf proportion[1]
	------------ lb/acre ------------		inches	%
6 March	2,940[c]	1,158[c]	12.8[c]	ND[2]
27 March	5,079[b]	2,317[b]	20.7[b]	47.0[a]
11 April	7,395[a]	3,475[a]	26.0[a]	28.7[b]
SEM	178	116	0.4	0.9

[a,b,c] Means within a column with no superscript in common differ (P < 0.05).
[1] Leaf blade only.
[2] Not determined. Stem elongation had not begun.

Table 2. Nutritive value of wheat forage harvested by five sampling techniques on three dates

Harvest date/technique	Whole-plant ash	CP	NDF	ADF	Cellulose	Hemicellulose	Lignin
	------------------------- (% of DM) -------------------------						
6 March							
Freeze-dried masticate	25.4[a]	23.0[c]	39.3[c]	29.0[a]	7.4[b]	10.3[d]	2.4[c]
Oven-dried masticate	24.8[a]	24.1[c]	47.0[a]	30.0[a]	7.6[b]	17.0[c]	3.6[a]
Random pluck	9.7[b]	28.9[b]	44.1[b]	21.5[bc]	16.2[a]	22.7[a]	3.0[abc]
Top half	9.2[b]	32.5[a]	40.1[c]	20.4[c]	15.1[a]	19.7[b]	2.7[bc]
Whole plant	10.7[b]	23.5[c]	45.9[ab]	23.1[b]	15.8[a]	22.8[a]	3.1[ab]
27 March							
Freeze-dried masticate	22.5[a]	16.9[c]	43.8[d]	29.5[b]	10.7[c]	14.3[d]	2.7[c]
Oven-dried masticate	24.8	19.2[b]	52.7[b]	35.4[a]	9.8[c]	17.3[c]	5.6[a]
Random pluck	8.4[b]	16.8[c]	57.0[a]	30.3[b]	21.6[a]	26.7[a]	4.2[b]
Top half	7.5[b]	24.7[a]	49.0[c]	24.8[c]	18.1[b]	24.2[b]	3.9[b]
Whole plant	8.6[b]	18.1b[c]	56.5[a]	29.9[b]	20.8[a]	26.7[a]	4.2[b]
11 April							
Freeze-dried masticate	17.9[a]	18.0[a]	40.5[c]	24.8[b]	13.5[c]	15.7[c]	2.6[c]
Oven-dried masticate	16.7[a]	18.7[a]	54.3[ab]	30.1[a]	17.3[b]	24.2[b]	3.0[c]
Random pluck	6.6[b]	13.4[b]	55.4[a]	29.7[a]	20.9[a]	25.7[ab]	4.0[b]
Top half	7.0[b]	18.7[a]	52.4[b]	25.2[b]	18.4[b]	27.2[a]	3.2[c]
Whole plant	6.5[b]	13.0[b]	55.1[ab]	29.9[a]	20.8[a]	25.2[ab]	5.7[a]
SEM[1,2]	0.1	0.6	0.1	0.6	0.8	0.7	0.2

[a,b,c,d] Means in a column for a given harvest date without common superscripts differ (P < 0.05).

[1] Standard error of whole plot (sampling techniques) within subplot (sampling date) interaction means.

[2] Appropriate LSDs (0.05) for comparing interaction means of subplot (sampling date) within whole plot (sampling techniques) were 2.7, 1.8, 2.2, 1.7, 2.2, 1.9, and 0.5 percentage units for concentrations of ash, CP, NDF, ADF, cellulose, hemicellulose, and lignin, respectively. These differences can largely be explained on the basis of plant maturity. Mean separation is not shown.

Table 3. In situ DM disappearance characteristics for wheat forage harvested on three dates by various techniques. In situ evaluation of disappearance kinetics was performed in confinement. For clarity, only mean separation within an individual harvest date is shown

Harvest date/technique	A[1]	B	C	Extent[2]	Effective Degradability[3]
	--------------- (% of DM)	----------------			% of DM
6 March					
Freeze-dried masticate	55.5[a]	37.3[c]	7.2[a]	92.8[c]	82.3[a]
Oven-dried masticate	47.0[b]	45.7[b]	7.3[a]	92.7[c]	76.3[bc]
Random pluck	44.1[c]	52.2[a]	3.7[c]	96.3[a]	77.6[b]
Top half	43.6[c]	52.4[a]	4.0[bc]	96.0[ab]	80.6[a]
Whole plant	42.2[d]	52.8[a]	5.0[b]	95.0[b]	75.3[c]
27 March					
Freeze-dried masticate	53.7[a]	39.2[c]	7.1[b]	92.9[a]	80.2[a]
Oven-dried masticate	43.6[b]	48.7[b]	7.7[b]	92.3[a]	75.8[b]
Random pluck	37.6[d]	50.3[b]	12.1[a]	87.9[b]	65.3[d]
Top half	38.8[c]	53.6[a]	7.6[b]	92.4[a]	73.5[c]
Whole plant	38.7[c]	49.5[b]	11.8[a]	88.2[b]	66.5[d]
11 April					
Freeze-dried masticate	52.7[a]	42.3[d]	5.0[d]	95.0[a]	80.3[a]
Oven-dried masticate	39.7[c]	54.8[a]	5.5[d]	94.5[a]	72.5[b]
Random pluck	39.0[c]	44.3[c]	16.7[a]	83.3[d]	61.6[e]
Top half	41.1[b]	48.3[b]	10.6[c]	89.4[b]	68.2[c]
Whole plant	40.8[b]	44.4[c]	14.8[b]	85.2[c]	63.8[d]
SEM[4]	0.4	0.6	0.5	0.5	0.7

[a,b,c,d] Means in a column and within a given harvest date that are without common superscripts differ ($P < 0.05$).

[1] Abbreviations: A = Immediately soluble fraction, B = fraction disappearing at a measurable rate, and C = undegraded fraction.

[2] Potential extent of disappearance in the rumen.

[3] Calculated as A + B(k_d/k_d + passage rate), where k_d = disappearance rate and the mean passage rate for five steers was 0.035 ± 0.009/h.

[4] Standard error of sampling date by sampling technique interaction means (n = 5 steers).

Table 4. Summary of main effects for lag time and disappearance rate (k_d) determined in confined steers for experimental wheat forages. Sampling technique (P = 0.027) affected lag times, but sampling date did not (P = 0.139). For k_d, both sampling technique and sampling date were significant (P < 0.0001), but the interaction of these effects was not (P = 0.092).

Main effect/treatment	Lag time	k_d
	h	/h
Sampling Technique		
Freeze-dried masticate	0.88^b	0.088^a
Oven-dried masticate	1.68^a	0.070^b
Random pluck	1.67^a	0.055^c
Top half	1.58^a	0.076^b
Whole plant	1.67^a	0.055^c
SEM[1]	0.20	0.003
Sampling Date		
6 March	- - -	0.083^a
27 March	- - -	0.069^b
11 April	- - -	0.055^c
SEM[1]	- - -	0.003

[a,b,c] Means in a column and within a given main effect that are without common superscripts differ (P < 0.05).

[1] Standard error of main effect mean.